# IEC 61158-2

Edition 7.0 2023-03

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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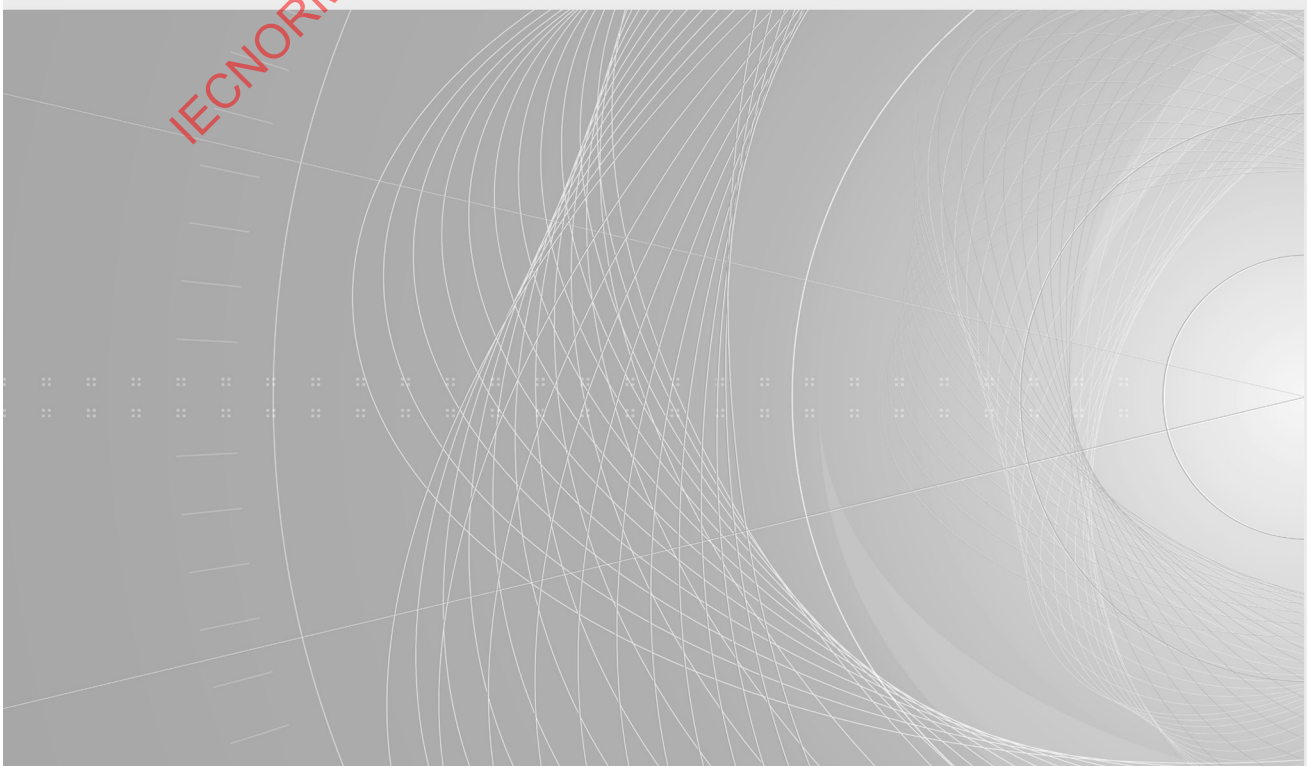
## Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition

## Réseaux de communication industriels – Spécifications des bus de terrain – Partie 2: Spécification et définition des services de la couche physique



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## Réseaux de communication industriels – Spécifications des bus de terrain – Partie 2: Spécification et définition des services de la couche physique

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

## Part 2: Physical layer specification and service definition

## FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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Attention is drawn to the fact that the use of some of the associated protocol types is restricted by their intellectual-property-right holders. In all cases, the commitment to limited release of intellectual-property-rights made by the holders of those rights permits a layer protocol type to be used with other layer protocols of the same type, or in other type combinations explicitly authorized by their respective intellectual property right holders.

NOTE 1 Combinations of protocol types are specified in the IEC 61784-1 series and the IEC 61784-2 series.

IEC 61158-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This seventh edition cancels and replaces the sixth edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Type 12 added power option to 100BASE-TX in Clause 29;
b) enhanced Type 24 specification in Clause 33, Annex S and Annex U;
c) new Type 28 specification;
d) LVDS wire medium up to 100 Mbit/s of Type 12 is removed.

The text of this International Standard is based on the following documents:

| Draft | Report on voting |
|---|---|
| 65C/1200/FDIS | 65C/1241/RVD |

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

NOTE 2 Slight variances from the directives have been allowed by the IEC Central Office to provide continuity of subclause numbering with prior editions.

A list of all the parts of the IEC 61158 series, under the general title *Industrial communication networks – Fieldbus specifications*, can be found on the IEC web site.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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# 0 INTRODUCTION

## 0.1 General

This part of IEC 61158 is one of a series produced to facilitate the interconnection of automation system components. It is related to other standards in the set as defined by the "three-layer" fieldbus reference model described in IEC 61158-1.

## 0.2 Physical layer overview

The primary aim of this document is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer Ph-entities at the time of communication.

The physical layer receives data units from the data-link Layer, encodes them, if necessary by adding communications framing information, and transmits the resulting physical signals to the transmission medium at one node. Signals are then received at one or more other node(s), decoded, if necessary by removing the communications framing information, before the data units are passed to the data-link Layer of the receiving device.

## 0.3 Document overview

This document comprises physical layer specifications corresponding to many of the different DL-Layer protocol Types specified in IEC 61158 series.

NOTE 1 The protocol Type numbers used are consistent throughout the IEC 61158 series.

NOTE 2 Specifications for Types 1, 2, 3, 4, 8, 12, 16, 18, 20, 24 and 28 are included. Type 7 uses Type 1 specifications. The other Types do not use any of the specifications given in this document.

NOTE 3 For ease of reference, Type numbers are given in clause names. This means that the specification given therein applies to this Type, but does not exclude its use for other Types.

NOTE 4 It is up to the user of this document to select interoperating sets of provisions. Refer to the IEC 61784-1 series or the IEC 61784-2 series for standardized communication profiles based on the IEC 61158 series.

A general model of the physical layer is shown in Figure 1.

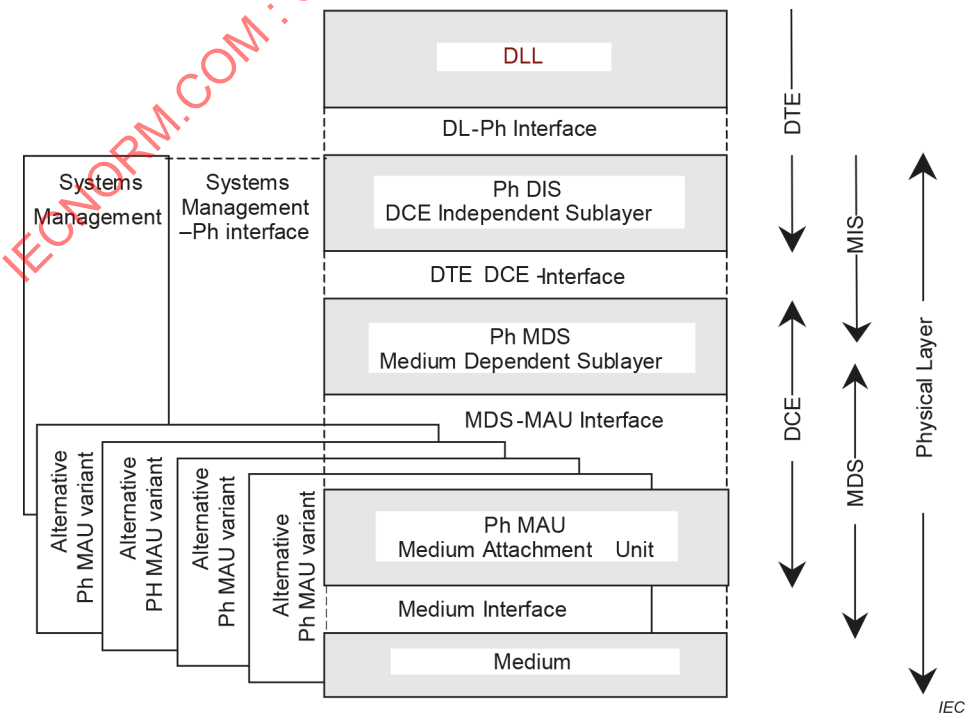


**Figure 1 – General model of physical layer**

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NOTE 5 The protocol types use a subset of the structure elements.

NOTE 6 Since Type 8 uses a more complex DIS than the other types, it uses the term MIS to differentiate.

The common characteristics for all variants and types are as follows:

– digital data transmission;
– no separate clock transmission;
– either half-duplex communication (bi-directional but in only one direction at a time) or full-duplex communication.

## 0.4 Major physical layer variations specified in this document

### 0.4.1 Type 1 media

#### 0.4.1.1 Type 1: Wire media

For twisted-pair wire media, Type 1 specifies two modes of coupling and different signaling speeds as follows:

a) voltage mode (parallel coupling), 150 Ω, data rates from 31,25 kbit/s to 25 Mbit/s;
b) voltage mode (parallel coupling), 100 Ω, 31,25 kbit/s;
c) current mode (serial coupling), 1,0 Mbit/s including two current options.

The voltage mode variations may be implemented with inductive coupling using transformers. This is not mandatory if the isolation requirements of this document are met by other means.

The Type 1 twisted-pair (or untwisted-pair) wire medium physical layer provides the options:

– no power via the bus conductors; not intrinsically safe;
– power via the bus conductors; not intrinsically safe;
– no power via the bus conductors; intrinsically safe;
– power via the bus conductors; intrinsically safe.

#### 0.4.1.2 Type 1: Optical media

The major variations of the Type 1 optic fiber media are as follows:

– dual fiber mode, data rates from 31,25 kbit/s to 25 Mbit/s;
– single fiber mode, 31,25 kbit/s.

### 0.4.2 Type 2: Coaxial wire and optical media

Type 2 specifies the following variants:

– coaxial copper wire medium, 5 Mbit/s;
– optical fiber medium, 5 Mbit/s;
– network access port (NAP), a point-to-point temporary attachment mechanism that can be used for programming, configuration, diagnostics or other purposes;
– repeater machine sublayers (RM, RRM) and redundant physical layers.

### 0.4.3 Type 3: Twisted-pair wire and optical media

Type 3 specifies the following synchronous transmission:

a) twisted-pair wire medium, 31,25 kbit/s, voltage mode (parallel coupling) with the options:
   – power via the bus conductors: not intrinsically safe;
   – power via the bus conductors: intrinsically safe;

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and the following asynchronous transmission variants:

b) twisted-pair wire medium, up to 12 Mbit/s, TIA-485-A;

c) optical fiber medium, up to 12 Mbit/s, with fiber type A4a of IEC 60793-2-40 and fiber type A3c of IEC 60793-2-30.

#### 0.4.4 Type 4: Wire medium

Type 4 specifies wire media with the following characteristics:

– RS-485 wire medium up to 76,8 kbit/s;

#### 0.4.5 Type 8: Twisted-pair wire and optical media

The physical layer also allows transmitting data units that have been received through a medium access by the transmission medium directly through another medium access and its transmission protocol to another device.

Type 8 specifies the following variants:

– twisted-pair wire medium, up to 16 Mbit/s;

– optical fiber medium, up to 16 Mbit/s.

The general characteristics of these transmission media are as follows:

– full-duplex transmission;

– non-return-to-zero (NRZ) coding.

The wire media type provides the following options:

– no power supply via the bus cable, not intrinsically safe;

– power supply via the bus cable and on additional conductors, not intrinsically safe.

#### 0.4.6 Type 12: Wire medium

Type 12 specifies wire media with the following characteristics:

– two pair of wires carrying two separate power supply channels combined with signal transmission.

#### 0.4.7 Type 16: optical media

Type 16 specifies a synchronous transmission using optical fiber medium, at 2 Mbit/s, 4 Mbit/s, 8 Mbit/s and 16 Mbit/s.

#### 0.4.8 Type 18: Media

##### 0.4.8.1 Type 18: Basic media

The Type 18-PhL-B specifies a balanced transmission signal over a shielded 3-core twisted cable. Communication data rates as high as 10 Mbit/s and transmission distances as great as 1,2 km are specified.

##### 0.4.8.2 Type 18: Powered media

The Type 18-PhL-P specifies a balanced transmission signal over a 4-core unshielded cable in both flat and round configurations with conductors specified for communications signal and network-embedded power distribution. Communication data rates as high as 2,5 Mbit/s and transmission distances as great as 500 m are specified.

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### 0.4.9 Type 20: Media

Type 20 uses binary phase continuous Frequency Shift Keying (FSK). A relatively high frequency current is superimposed on a low-frequency analog current, which is usually in 4 mA to 20 mA range. The digital signal and analog signal share the same medium, but differ in frequency contents. The communicating devices signal with either current or voltage, and all signaling appear as voltage when sensed across low impedance. Thus, digital signaling is an extension of conventional analog signaling.

The physical layer commonly uses twisted pair copper cable as its medium and provides solely digital or simultaneous digital and analog communication to distances of at least 1 500 m (ca. 5 000 feet). Maximum communication distances vary depending on network construction and environmental conditions.

### 0.4.10 Type 24: Media

#### 0.4.10.1 Type 24: Basic media

Type 24 specifies twisted-pair wire medium. The general characteristics of this transmission medium are as follows:

– TIA-485-A bus interface with galvanic isolation using transformer;
– up to 10 Mbit/s;
– half-duplex transmission;
– Manchester coding.

#### 0.4.10.2 Type 24: Powered media

The powered media type provides the following options:

– TIA-485-A bus interface without galvanic isolation using transformer;
– up to 32 Mbit/s;
– half-duplex transmission;
– Manchester coding or NRZI coding;
– power via the bus conductors.

### 0.4.11 Type 28: Media

Type 28 uses Orthogonal Frequency Division Multiplexing (OFDM) technology. The frequency subcarrier ranges from 1,536 MHz to 32,256 MHz. The transmission distances are up to 500 m on a single bus. The analog signal shall be delivered on the medium that connected to each device in network.

Type 28 specifies the following synchronous transmission:

a) twisted-pair wire medium, up to 100 Mbit/s;
b) coaxial wire medium, up to 100 Mbit/s.

The general characteristics of these transmission media are as follows:

a) full-duplex transmission;
b) OFDM coding.

**0.5**

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**Patent declaration**

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent. IEC takes no position concerning the evidence, validity, and scope of this patent right.

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# INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

## Part 2: Physical layer specification and service definition

## 1 Scope

This part of IEC 61158 specifies the requirements for fieldbus component parts. It also specifies the media and network configuration requirements necessary to ensure agreed levels of

a) data integrity before data-link layer error checking;

b) interoperability between devices at the physical layer.

The fieldbus physical layer conforms to layer 1 of the OSI 7-layer model as defined by ISO/IEC 7498 with the exception that, for some types, frame delimiters are in the physical layer while for other types they are in the data-link layer.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE All parts of the IEC 61158 series, as well as the IEC 61784-1 series and the IEC 61784-2 series are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

IEC 60079-11, *Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"*

IEC 60079-14:2007[1], *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 60079-25, *Explosive atmospheres – Part 25: Intrinsically safe electrical systems*

IEC 60169-17, *Radio-frequency connectors – Part 17: R.F. coaxial connectors with inner diameter of outer conductor 6,5 mm (0,256 in) with screw coupling – Characteristic impedance 50 ohms (Type TNC)*

IEC 60189-1:2018, *Low-frequency cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods*

IEC 60255-22-1:1988[2], *Electrical relays – Part 22-1: Electrical disturbance tests for measuring relays and protection equipment – Section 1: 1 MHz burst disturbance tests*

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1 A 2013 edition exists but the listed edition applies.

2 This publication was withdrawn.

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-5-54, *Low voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60603-7-4, *Connectors for electronic equipment – Part 7-4: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz*

IEC 60754-2, *Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement) and conductivity*

IEC 60793 (all parts), *Optical fibres*

IEC 60793-2:2019, *Optical fibres – Part 2: Product specifications – General*

IEC 60793-2-30:2015, *Optical fibres – Part 2-30: Product specifications – Sectional specification for category A3 multimode fibres*

IEC 60793-2-40:2021, *Optical fibres – Part 2-40: Product specifications – Sectional specification for category A4 multimode fibres*

IEC 60794-1-2:2003[3], *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures*

IEC 60807-3, *Rectangular connectors for frequencies below 3 MHz – Part 3: Detail specification for a range of connectors with trapezoidal shaped metal shells and round contacts – Removable crimp contact types with closed crimp barrels, rear insertion/rear extraction*

IEC 60811-403, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 403: Miscellaneous tests – Ozone resistance test on cross-linked compounds*

IEC 60811-404:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 404: Miscellaneous tests – Mineral oil immersion tests for sheaths*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 44: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61076-2-114:2020, *Connectors for electrical and electronic equipment – Product requirements – Part 2-114: Circular connectors – Detail specification for connectors with M8 screw- locking with power contacts and signal contacts for data transmission up to 100 MHz*

IEC 61131-2:2017, *Industrial-process measurement and control − Programmable controllers – Part 2: Equipment requirements and tests*

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[3] There exists a new edition of IEC 60794-1-2 (2021). Cross-references to 2003 version is described in informative Annex A.

IEC 61156-1:2007, *Multicore and symmetrical pair/quad cables for digital communications – Part 1: Generic specification*

IEC 61158-3-20:2023, *Industrial communication networks – Fieldbus specifications – Part 3-20: Data-link layer service definition – Type 20 elements*

IEC 61158-4-2:2023, *Industrial communication networks – Fieldbus specifications – Part 4-2: Data-link protocol specification – Type 2 elements*

IEC 61158-4-3:2019, *Industrial communication networks – Fieldbus specifications – Part 4-3: Data-link protocol specification – Type 3 elements*

IEC 61169-8:2007, *Radio-frequency connectors – Part 8: Sectional specification – RF coaxial connectors with inner diameter of outer conductor 6,5 mm (0,256 in) with bayonet lock – Characteristic impedance 50 Ω (type BNC)*

IEC 61210:2010, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

IEC 61754-2, *Fibre optic connector interfaces – Part 2: Type BFOC/2,5 connector family*

IEC 61754-13, *Fibre optic connector interfaces – Part 13: Type FC-PC connector*

IEC 61754-22, *Fibre optic connector interfaces – Part 22: Type F-SMA connector family*

IEC 63171, *Connectors for electrical and electronic equipment − Shielded or unshielded free and fixed connectors for balanced single-pair data transmission with current carrying capacity – General requirements and tests*

ISO/IEC 7498 (all parts), *Information technology – Open Systems Interconnection – Basic Reference Model*

ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO/IEC 8482, *Information technology – Telecommunications and information exchange between systems – Twisted pair multipoint interconnections*

ISO/IEC/IEEE 8802-3:2021, *Telecommunications and information exchange between systems – Requirements for local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

ISO 9314-1, *Information processing systems – Fibre Distributed Data Interface (FDDI) Part 1: Token Ring Physical Layer Protocol (PHY)*

ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

ISO 4892-1, *Plastics – Methods of exposure to laboratory light sources – Part 1: General guidance*

TIA-422-B:1994, *Electrical Characteristics of Balanced Voltage Digital Interface Circuits*

TIA-485-A:1998, *Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems*

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# 3 Terms and definitions

For the purposes of this document, the terms and definitions of the ISO/IEC 7498 series, and the following definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

## 3.1 Common terms and definitions

NOTE Many definitions are common to more than one protocol type; they are not necessarily used by all protocol types.

**3.1.1**
**activity**
presence of a signal or noise at the input terminals of a fieldbus device that is of a level that is above the receiver signal level threshold of that device

**3.1.2**
**barrier**
physical entity that limits current and voltage into a hazardous area in order to satisfy intrinsic safety requirements

**3.1.3**
**bit**
unit of data consisting of a 1 or a 0

Note 1 to entry: A bit is the smallest data unit that can be transmitted.

**3.1.4**
**bus**
trunk and all devices connected to it

**3.1.5**
**cable plant interface connector**
**CPIC**
point at which test and conformance measurements are made and that the interface between the network device and the cable plant

**3.1.6**
**communication element**
part of a fieldbus device that communicates with other elements via the bus

**3.1.7**
**connector**
coupling device employed to connect the medium of one circuit or communication element with that of another circuit or communication element

**3.1.8**
**coupler**
physical interface between trunk and spur or trunk and device

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**3.1.9**
**Data Communications Equipment**
**DCE**
embodiment of the media, modulation and coding-dependent portion of a fieldbus-connected device, comprising the lower portions of the physical layer within the device

**3.1.10**
**Data Terminal Equipment**
**DTE**
embodiment of the media, modulation and coding-independent portion of a fieldbus-connected device, comprising the uppermost portion of the physical layer and all higher layers within the device

**3.1.11**
**decibel(milliwatt)**
**dB(mW)**
logarithmic unit of power, referenced to 1 mW

$$P_{dBm} = 10 \log (P_{mW})$$

Note 1 to entry: db(mW) is also written dBm.

Note 2 to entry: If $P_{mW}$ is the measured power in mW, then $P_{dBm}$ is the power expressed logarithmically in dB(mW), or equivalently, dBm.

**3.1.12**
**delimiter**
flag that separates and organizes items of data

**3.1.13**
**device**
physical entity connected to the fieldbus composed of at least one communication element (the network element) and which may have a control element and/or a final element (transducer, actuator, etc.)

Note 1 to entry: A device may contain more than one node.

**3.1.14**
**effective launch power**
effective power coupled into the core of a fiber optic waveguide by the transmitter

Note 1 to entry: Effective launch power is measured with a standard test fiber connected to the CPIC.

**3.1.15**
**effective power**
the difference, expressed in dBm, between the absolute optical power measured in milliwatt at the midpoint in time of the Hi level to the absolute optical power measured in milliwatt at the midpoint of the Lo level

Note 1 to entry: Effective power is believed to give a more accurate measurement of the conditions that affect the receivers than traditional measurements, such as peak and average power. methods for measuring effective power are for further study.

**3.1.16**
**error**
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

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**3.1.17**
**extinction ratio**
ratio of the absolute optical power measured in milliwatt at the midpoint in time of the Hi level to the absolute optical power measured in milliwatt at the midpoint in time of the Lo level.

Note 1 to entry: The following gives an example of the computation of effective power and extinction ratio. If the midpoint of Hi level is measured as 105 µW, and if the midpoint of Lo level is measured as 5 µW, then the difference is 100 µW. Therefore, the effective power is 10 log ((100 µW) / 1 mW)), which equals −10,0 dBm. The extinction ratio is (105/5), which equals 21:1.

**3.1.18**
**fiber optic cable**
cable containing one or more fiber optic waveguides with jacketing material provided to facilitate handling and to protect the fiber

**3.1.19**
**fiber optic receiver**
combined optics and electronics in the communicating device that accept the optical signal received by the communicating device through the CPIC

**3.1.20**
**fiber optic receiver operating range**
range of optical power that has to be present at the CPIC to ensure that the bit error rate specifications are met

**3.1.21**
**fiber optic transmitter**
device that emits optical signals for propagation into a fiber optic waveguide through the CPIC

**3.1.22**
**fiber optic waveguide**
flexible, optically transparent strand that is used to transport optical signals from one geographic point to another geographic point

**3.1.23**
**frame**
set of consecutive digit time slots in which the position of each digit time slot can be identified by reference to a framing signal

**3.1.24**
**intrinsic safety**
design methodology for a circuit or an assembly of circuits in which any spark or thermal effect produced under normal operating and specified fault conditions is not capable under prescribed test conditions of causing ignition of a given explosive atmosphere

**3.1.25**
**isolation**
physical and electrical arrangement of the parts of a signal transmission system to prevent electrical interference currents within or between the parts

**3.1.26**
**jabber**
continuous transmission on the medium due to a faulty device

**3.1.27**
**jitter**
offset of the 50 % transition points of pulse edges from their ideal position as the result of all causes

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**3.1.28**
**Manchester encoding**
means by which separate data and clock signals can be combined into a single, self-synchronizing data stream, suitable for transmission on a serial channel

**3.1.29**
**medium**
cable, optical fiber, or other means by which communication signals are transmitted between two or more points

Note 1 to entry: In this part of IEC 61158, "media" is used only as the plural of medium.

**3.1.30**
**network**
all of the media, connectors, repeaters, routers, gateways and associated node communication elements by which a given set of communicating devices are interconnected

**3.1.31**
**node**
end-point of a branch in a network or a point at which one or more branches meet

**3.1.32**
**optical active star**
active device in which a signal from an input fiber is received, amplified and retransmitted to a larger number of output optical fibers

Note 1 to entry: Retiming of the received signal is optional.

**3.1.33**
**optical fall time**
time it takes for a pulse to go from 90 % effective power to 10 % effective power, specified as a per cent of the nominal bit time

**3.1.34**
**optical passive star**
passive device in which signals from input fibers are combined and then distributed among output optical fibers

**3.1.35**
**optical rise time**
time it takes for a pulse to go from 10 % effective power to 90 % effective power, specified as a per cent of the nominal bit time

**3.1.36**
**peak emission wavelength**
**λp**
wavelength at which radiant intensity is maximized

**3.1.37**
**receiver**
receive circuitry of a communication element

**3.1.38**
**repeater**
two-port active physical layer device that receives and retransmits all signals to increase the distance and number of devices for which signals can be correctly transferred for a given medium

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**3.1.39**
**segment**
trunk-cable section of a fieldbus that is terminated in its characteristic impedance

Note 1 to entry: Segments are linked by repeaters within a logical link and by bridges to form a fieldbus network.

**3.1.40**
**separately powered device**
device that does not receive its operating power via the fieldbus signal conductors

**3.1.41**
**shield**
surrounding earthed metallic layer to confine the electric field within the cable and to protect the cable from external electrical influence

Note 1 to entry: Metallic sheaths, armours and earthed concentric conductors may also serve as a shield.

**3.1.42**
**spur**
branch-line (i.e. a link connected to a larger one at a point on its route) that is a final circuit

Note 1 to entry: The alternative term 'drop cable' is used in this document.

**3.1.43**
**terminator**
resistor connecting conductor pairs at both ends of a wire medium segment to prevent reflections from occurring at the ends of cables

Note 1 to entry: For Type 2 the terminator is mounted in a BNC or TNC plug.

**3.1.44**
**transceiver**
combination of receiving and transmitting equipment in a common housing employing common circuit components for both transmitting and receiving

Note 1 to entry: A medium attachment unit can be the transceiver or can contain the transceiver, depending on Type and implementation.

[SOURCE: IEEE Std 100-1996 modified for non-radio use]

**3.1.45**
**transmitter**
transmit circuitry of a communication element

**3.1.46**
**trunk**
main communication highway acting as a source of main supply to a number of other lines (spurs)

**3.1.47**
**typical half-intensity wavelength**
**Δλ**
range of wavelength of spectral distribution in which the radiant intensity is no less than one-half of the maximum intensity

### 3.2 Type 1: Terms and definitions

**3.2.1**
**activity**
[SEE: 3.1.1]

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**3.2.2**
**barrier**
[SEE: 3.1.2]

**3.2.3**
**bus**
[SEE: 3.1.4]

**3.2.4**
**cable plant interface connector**
**CPIC**
[SEE: 3.1.5]

**3.2.5**
**communication element**
[SEE: 3.1.6]

**3.2.6**
**connector**
[SEE: 3.1.7]

**3.2.7**
**coupler**
[SEE: 3.1.8]

**3.2.8**
**Data Communications Equipment**
**DCE**
[SEE: 3.1.9]

**3.2.9**
**Data Terminal Equipment**
**DTE**
[SEE: 3.1.10]

**3.2.10**
**dBm**
[SEE: 3.1.11]

**3.2.11**
**delimiter**
[SEE: 3.1.12]

**3.2.12**
**device**
[SEE: 3.1.13]

**3.2.13**
**effective launch power**
[SEE: 3.1.14]

**3.2.14**
**effective power**
[SEE: 3.1.15]

**3.2.15**
**fiber optic cable**
[SEE: 3.1.18]

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**3.2.16**
**fiber optic receiver**
[SEE: 3.1.19]

**3.2.17**
**fiber optic receiver operating range**
[SEE: 3.1.20]

**3.2.18**
**fiber optic transmitter**
[SEE: 3.1.21]

**3.2.19**
**fiber optic waveguide**
[SEE: 3.1.22]

**3.2.20**
**frame**
[SEE: 3.1.23]

**3.2.21**
**intrinsic safety**
[SEE: 3.1.24]

**3.2.22**
**isolation**
[SEE: 3.1.25]

**3.2.23**
**jabber**
[SEE: 3.1.26]

**3.2.24**
**Manchester encoding**
[SEE: 3.1.28]

**3.2.25**
**medium**
[SEE: 3.1.29]

**3.2.26**
**network**
[SEE: 3.1.30]

**3.2.27**
**node**
[SEE: 3.1.31]

**3.2.28**
**optical fall time**
[SEE: 3.1.33]

**3.2.29**
**optical rise time**
[SEE: 3.1.35]

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**3.2.30**
**peak emission wavelength**
**λp**
[SEE: 3.1.36]

**3.2.31**
**repeater**
[SEE: 3.1.38]

**3.2.32**
**segment**
[SEE: 3.1.39]

**3.2.33**
**separately powered device**
[SEE: 3.1.40]

**3.2.34**
**shield**
[SEE: 3.1.41]

**3.2.35**
**spur**
[SEE: 3.1.42]

**3.2.36**
**terminator**
[SEE: 3.1.43]

**3.2.37**
**transceiver**
[SEE: 3.1.44]

**3.2.38**
**transmitter**
[SEE: 3.1.45]

**3.2.39**
**trunk**
[SEE: 3.1.46]

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### 3.3 Type 2: Terms and definitions

**3.3.1**
**activity**
[SEE: 3.1.1]

**3.3.2**
**bit**
[SEE: 3.1.3]

**3.3.3**
**blanking or blanking time**
length of time required after transmitting before a node is allowed to receive

**3.3.4**
**bus**
[SEE: 3.1.4]

**3.3.5**
**communication element**
[SEE: 3.1.6]

**3.3.6**
**connector**
[SEE: 3.1.7]

**3.3.7**
**Data Communications Equipment**
**DCE**
[SEE: 3.1.9]

**3.3.8**
**dBm**
[SEE: 3.1.11]

**3.3.9**
**delimiter**
[SEE: 3.1.12]

**3.3.10**
**device**
[SEE: 3.1.13]

**3.3.11**
**end delimiter**
unique sequence of symbols that identifies the end of a frame

**3.3.12**
**end node**
producing or consuming node

**3.3.13**
**error**
[SEE: 3.1.16]

**3.3.14**
**frame**
[SEE: 3.1.23]

**3.3.15**
**isolation**
[SEE: 3.1.25]

**3.3.16**
**jabber**
[SEE: 3.1.26]

**3.3.17**
**Manchester encoding**
[SEE: 3.1.28]

**3.3.18**
**medium**
[SEE: 3.1.29]

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**3.3.19**
**M_symbol**
representation of the MAC data bits to be encoded and transmitted by the physical layer

**3.3.20**
**MAC frame**
collection of M_symbols transmitted on the medium that contains a preamble, start delimiter, data, CRC and end delimiter

**3.3.21**
**network**
[SEE: 3.1.30]

**3.3.22**
**network access port**
physical layer variant that allows a temporary node to be connected to the link by connection to the NAP of a permanent node

**3.3.23**
**node**
[SEE: 3.1.31]

Note 1 to entry: A node is additionally a connection to a link that requires a single M_ID.

**3.3.24**
**non-data symbol**
physical layer Manchester coded signal, used for delimiters, carrying no data

**3.3.25**
**optical isolators, optos**
components located within the physical layer transceiver of a node that converts current into light, and then back to an electrical signal

**3.3.26**
**permanent node**
node whose connection to the network does not utilize the network access port (NAP) physical layer variant

Note 1 to entry: This node may optionally support a NAP physical layer variant to allow temporary nodes to connect to the network.

**3.3.27**
**redundant media**
more than one medium to minimize communication failures

**3.3.28**
**repeater**
[SEE: 3.1.38]

**3.3.29**
**segment**
[SEE: 3.1.39]

**3.3.30**
**shield**
[SEE: 3.1.41]

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**3.3.31**
**slot time**
maximum time required for detecting an expected transmission

Note 1 to entry: Each node waits a slot time for each missing node during the implied token pass.

**3.3.32**
**spur**
[SEE: 3.1.42]

Note 1 to entry: This is an integral part of network taps.

**3.3.33**
**start delimiter**
unique sequence of symbols that identifies the beginning of a frame

**3.3.34**
**tap**
point of attachment from a node or spur to the trunk cable

Note 1 to entry: A tap provides easy removal of a node without disrupting the link.

**3.3.35**
**terminator**
[SEE: 3.1.43]

**3.3.36**
**tool**
executable software program that interacts with the user to perform some function

**3.3.37**
**transceiver**
[SEE: 3.1.44]

**3.3.38**
**transient node**
node that is only intended to be connected to the network on a temporary basis using the NAP physical layer medium connected to the NAP of a permanent node

**3.3.39**
**transmitter**
[SEE: 3.1.45]

**3.3.40**
**trunk**
[SEE: 3.1.46]

**3.3.41**
**trunk cable**
bus or central part of a cable system

**3.3.42**
**trunk-cable section**
length of trunk cable between any two taps

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### 3.4 Type 3: Terms and definitions

**3.4.1**
**activity**
[SEE: 3.1.1]

**3.4.2**
**barrier**
[SEE: 3.1.2]

**3.4.3**
**bit time**
time to transmit one bit

**3.4.4**
**bus**
[SEE: 3.1.4]

**3.4.5**
**communication element**
[SEE: 3.1.6]

**3.4.6**
**confirmation (primitive)**
[SOURCE: ISO/IEC 10731:1994]

**3.4.7**
**connector**
[SEE: 3.1.7]

**3.4.8**
**coupler**
[SEE: 3.1.8]

**3.4.9**
**Data Communications Equipment**
**DCE**
[SEE: 3.1.9]

**3.4.10**
**Data Terminal Equipment**
**DTE**
[SEE: 3.1.10]

**3.4.11**
**dBm**
[SEE: 3.1.11]

**3.4.12**
**device**
[SEE: 3.1.13]

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**3.4.13**
**DL-entity**
active element within an DL-subsystem embodying a set of capabilities defined for the DL-layer that corresponds to a specific DL-entity-type (without any extra capabilities being used)

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.11, modified – (N) replaced by DL for the data link layer.]

**3.4.14**
**fiber optic cable**
**FOC**
[SEE: 3.1.18]

**3.4.15**
**frame**
[SEE: 3.1.23]

**3.4.16**
**indication (primitive)**

[SOURCE: ISO/IEC 10731:1994]

**3.4.17**
**intrinsic safety**
[SEE: 3.1.24]

**3.4.18**
**isolation**
[SEE: 3.1.25]

**3.4.19**
**jabber**
[SEE: 3.1.26]

**3.4.20**
**medium**
[SEE: 3.1.29]

**3.4.21**
**(N)-entity**
active element within an (N)-subsystem embodying a set of capabilities defined for the(N)-layer that corresponds to a specific (N)-entity-type (without any extra capabilities being used)

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.11]

**3.4.22**
**(N)-service**

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.5]

**3.4.23**
**network**
[SEE: 3.1.30]

**3.4.24**
**node**
[SEE: 3.1.31]

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**3.4.25**
**Ph-entity**
active element within an DL-subsystem embodying a set of capabilities defined for the DL-layer that corresponds to a specific DL-entity-type (without any extra capabilities being used)

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.11, modified – (N) replaced by Ph for the physical layer.]

**3.4.26**
**Ph-service**
capability of the Ph-layer and the layers beneath it, which is provided to DL-entities at the boundary between the Ph-layer and the DL-layer

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.5, modified – (N) replaced by Ph for the physical layer.]

**3.4.27**
**repeater**
[SEE: 3.1.38]

**3.4.28**
**request (primitive)**

[SOURCE: ISO/IEC 10731:1994]

**3.4.29**
**reset**

[SOURCE: ISO/IEC 7498-1:1994, 5.8.1.17]

**3.4.30**
**segment**
[SEE: 3.1.39]

**3.4.31**
**separately powered device**
[SEE: 3.1.40]

**3.4.32**
**shield**
[SEE: 3.1.41]

**3.4.33**
**spur**
[SEE: 3.1.42]

**3.4.34**
**station**
node

**3.4.35**
**terminator**
[SEE: 3.1.43]

**3.4.36**
**transceiver**
[SEE: 3.1.44]

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**3.4.37**
**transmitter**
[SEE: 3.1.45]

**3.4.38**
**trunk**
[SEE: 3.1.46]

### 3.5 Type 4: Terms and definitions

**3.5.1**
**activity**
[SEE: 3.1.1]

**3.5.2**
**bus**
[SEE: 3.1.4]

**3.5.3**
**connector**
[SEE: 3.1.7]

**3.5.4**
**Data Communications Equipment**
**DCE**
[SEE: 3.1.9]

**3.5.5**
**Data Terminal Equipment**
**DTE**
[SEE: 3.1.10]

**3.5.6**
**device**
[SEE: 3.1.13]

**3.5.7**
**idle counter**
counter to measure the number of bit periods for which the signal level on the physical link has been high for normal class and simple class devices in half duplex mode

**3.5.8**
**isolation**
[SEE: 3.1.25]

**3.5.9**
**medium**
[SEE: 3.1.29]

**3.5.10**
**network**
[SEE: 3.1.30]

**3.5.11**
**normal class device**
device that initiates transmission and replies to requests and that can act as a server (responder) and as a client (requestor) (also called a peer)

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**3.5.12**
**shield**
[SEE: 3.1.41]

**3.5.13**
**simple class device**
device that replies to requests from Normal Class Devices and acts as a server or responder only

**3.5.14**
**transmitter**
[SEE: 3.1.45]

### 3.6 Void

NOTE Subclause 3.6 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

### 3.7 Type 8: Terms and definitions

**3.7.1**
**activity**
[SEE: 3.1.1]

**3.7.2**
**bus coupler**
device that divides the ring into segments by opening the ring and integrating another ring at this point

**3.7.3**
**cable plant interface connector**
**CPIC**
[SEE: 3.1.5]

**3.7.4**
**communication element**
[SEE: 3.1.6]

**3.7.5**
**connector**
[SEE: 3.1.7]

**3.7.6**
**dBm**
[SEE: 3.1.11]

**3.7.7**
**effective launch power**
[SEE: 3.1.14]

**3.7.8**
**effective power**
[SEE: 3.1.15]

**3.7.9**
**fiber optic cable**
[SEE: 3.1.18]

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**3.7.10**
**fiber optic receiver**
[SEE: 3.1.19]

**3.7.11**
**fiber optic receiver operating range**
[SEE: 3.1.20]

**3.7.12**
**fiber optic transmitter**
[SEE: 3.1.21]

**3.7.13**
**fiber optic waveguide**
[SEE: 3.1.22]

**3.7.14**
**frame**
[SEE: 3.1.23]

**3.7.15**
**incoming interface**
interface to receive data from the previous device and to send data, which are received via an outgoing interface, to the previous device

**3.7.16**
**isolation**
[SEE: 3.1.25]

**3.7.17**
**local bus**
ring segment of a network with alternate media specifications, which is coupled to a remote bus via the bus coupler

**3.7.18**
**local bus device**
device that operates as a slave on a local bus

**3.7.19**
**master**
device that controls the data transfer on the network and initiates the media access of the slaves by sending messages and that constitutes the interface to the control system

**3.7.20**
**medium**
[SEE: 3.1.29]

**3.7.21**
**minimum optical receiver sensitivity**
minimum optical power at the optical receiver input required to achieve a bit error rate of less than $10^{-9}$ for the optical transmission system

**3.7.22**
**network**
[SEE: 3.1.30]

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**3.7.23**
**optical fall time**
[SEE: 3.1.33]

**3.7.24**
**optical rise time**
[SEE: 3.1.35]

**3.7.25**
**outgoing interface**
interface to send data to the next slave in a way, that data that is received through this interface is sent via another outgoing interface to the next slave or via an incoming interface to the previous slave and back to the master

**3.7.26**
**peak emission wavelength**
**λp**
[SEE: 3.1.36]

**3.7.27**
**polymer optical fiber**
**POF**
plastic fiber optic waveguide whose nominal characteristics are compatible with IEC 60793-2-40 [fiber type: A4a (980/1000)]

**3.7.28**
**plastic clad silica fiber**
**PCS**
fiber optic waveguide consisting of a glass core and a plastic cladding and whose nominal characteristics are compatible with IEC 60793-2-30 [fiber type: A3c (200/230 µm)]

**3.7.29**
**remote bus**
ring segment of a network

**3.7.30**
**remote bus device**
device operating as a slave on a remote bus

**3.7.31**
**remote bus link**
connection of two remote bus devices

**3.7.32**
**ring segment**
one section of a network

Note 1 to entry: The master constitutes the first ring segment, further ring segments may be linked by bus couplers.

**3.7.33**
**shield**
[SEE: 3.1.41]

**3.7.34**
**slave**
device that accesses the medium only after it has been initiated by the preceding slave or master

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**3.7.35**
**spectral full width half maximum**
**Δλ**
range of wavelength of spectral distribution in which the radiant intensity is no less than one-half of the maximum intensity

**3.7.36**
**terminator**
[SEE: 3.1.43]

## 3.8 Type 12: Terms and definitions

**3.8.1**
**2 Pair Powering**
**2PP**
powering concept providing 2 independent channels for power sourcing in combination with a Ethernet 100BASE-TX

Note 1 to entry: One pair is used for powering the device itself including the Ethernet components and for other reliable power consumers and the other pair is used powering external components or elements in the PD that have specific power requests.

**3.8.2**
**Powered Device**
**PD**
portion of a device that is drawing power and possible connect two or more PI

Note 1 to entry: It is an abstraction of the elements that consumes power and do not contain any functional behavior of the components.

**3.8.3**
**Power Interface**
**PI**
mechanical and electrical connection of the PSE or PD and the transmission medium

Note 1 to entry: In an Endpoint PSE and in a PD, the PI is encompassed within the MDI of a 100BASE-TX link of Ethernet.

**3.8.4**
**Power Sourcing Equipment**
**PSE**
portion of the end station equipment that provides the power to a PD

Note 1 to entry: It is an abstraction of the elements that provides power and do not contain any functional behavior of the components. DTE powering is intended to provide 100BASE-TX devices with interfaces for both the reception and transmission of data as well as two power sources to operate. A PSE is electrically specified at the point of the physical connection to the cabling.

## 3.9 Type 16: Terms and definitions

**3.9.1**
**attenuation**
fact that the optical power at the receiver is less than at the transmitter

**3.9.2**
**barrier**
[SEE: 3.1.2]

**3.9.3**
**bit**
[SEE: 3.1.3]

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**3.9.4**
**bit stuffing**
procedure, by which after five logical 1's, the transmitter automatically inserts a zero which is then removed again by the receiver

Note 1 to entry: This zero causes a change in signal edges which makes it possible for the receiver to retrieve a receiving clock.

**3.9.5**
**connector**
[SEE: 3.1.7]

**3.9.6**
**Data Communications Equipment**
**DCE**
[SEE: 3.1.9]

**3.9.7**
**Data Terminal Equipment**
**DTE**
[SEE: 3.1.10]

**3.9.8**
**dBm**
[SEE: 3.1.11]

**3.9.9**
**delimiter**
[SEE: 3.1.12]

**3.9.10**
**device**
[SEE: 3.1.13]

**3.9.11**
**error**
[SEE: 3.1.16]

**3.9.12**
**fiber optic cable**
[SEE: 3.1.18]

**3.9.13**
**frame**
[SEE: 3.1.23]

**3.9.14**
**F-SMA connector**
connector meeting the F-SMA standard in accordance with IEC 61754-22

**3.9.15**
**fill signals**
sequence of seven 1's followed by a 0

**3.9.16**
**jitter**
[SEE: 3.1.27]

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**3.9.17**
**medium**
[SEE: 3.1.29]

**3.9.18**
**network**
[SEE: 3.1.30]

**3.9.19**
**node**
[SEE: 3.1.31]

**3.9.20**
**non-return-to-zero-inverted**
**NRZI**
signal exchanges taking place only at regular, fixed points in time in synchronization with the transmitting clock pulse of the bit rate

Note 1 to entry: A signal edge change is assigned to a logical 0 only.

**3.9.21**
**optical fall time**
[SEE: 3.1.33]

**3.9.22**
**optical rise time**
[SEE: 3.1.35]

**3.9.23**
**pad**
sequence of octets added to assure that the telegram is long enough for proper operation

**3.9.24**
**peak emission wavelength**
**λp**
[SEE: 3.1.36]

**3.9.25**
**receiver**
[SEE: 3.1.37]

**3.9.26**
**repeater**
[SEE: 3.1.38]

**3.9.27**
**repeater function**
feature by which a telegram that has been received by a node is passed on and reclocked to the next node on the network, while being logically unchanged

**3.9.28**
**transmitter**
[SEE: 3.1.45]

**3.9.29**
**typical half-intensity wavelength**
**Δλ**
[SEE: 3.1.47]

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**3.9.30**
**zero bit stream**
sequence of logical zeros which, in NRZI coding, results in a regular signal edge change on the transmission line (only used in test mode)

### 3.10 Type 18: Terms and definitions

**3.10.1**
**activity**
[SEE: 3.1.1]

**3.10.2**
**bit**
[SEE: 3.1.3]

**3.10.3**
**bus**
[SEE: 3.1.4]

**3.10.4**
**communication element**
[SEE: 3.1.6]

**3.10.5**
**connector**
[SEE: 3.1.7]

**3.10.6**
**Data Communications Equipment**
**DCE**
[SEE: 3.1.9]

**3.10.7**
**Data Terminal Equipment**
**DTE**
[SEE: 3.1.10]

**3.10.8**
**device**
[SEE: 3.1.13]

**3.10.9**
**error**
[SEE: 3.1.16]

**3.10.10**
**isolation**
[SEE: 3.1.25]

**3.10.11**
**medium**
[SEE: 3.1.29]

**3.10.12**
**network**
[SEE: 3.1.30]

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**3.10.13**
**node**
[SEE: 3.1.31]

**3.10.14**
**receiver**
[SEE: 3.1.37]

**3.10.15**
**segment**
[SEE: 3.1.39]

**3.10.16**
**shield**
[SEE: 3.1.41]

**3.10.17**
**spur**
[SEE: 3.1.42]

**3.10.18**
**station**
network device embodying one node

**3.10.19**
**terminator**
[SEE: 3.1.43]

**3.10.20**
**transceiver**
[SEE: 3.1.44]

**3.10.21**
**transmitter**
[SEE: 3.1.45]

**3.10.22**
**trunk**
[SEE: 3.1.46]

### 3.11 Type 24: Terms and definitions

**3.11.1**
**bit**
[SEE: 3.1.3]

**3.11.2**
**bus**
[SEE: 3.1.4]

**3.11.3**
**communication element**
[SEE: 3.1.6]

**3.11.4**
**connector**
[SEE: 3.1.7]

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**3.11.5**
**Data Communications Equipment**
**DCE**
[SEE: 3.1.9]

**3.11.6**
**delimiter**
[SEE: 3.1.12]

**3.11.7**
**device**
[SEE: 3.1.13]

**3.11.8**
**error**
[SEE: 3.1.16]

**3.11.9**
**frame**
[SEE: 3.1.23]

**3.11.10**
**isolation**
[SEE: 3.1.25]

**3.11.11**
**Isolator**
parts for signal isolation by inductive or capacitive elements

**3.11.12**
**Manchester encoding**
[SEE: 3.1.28]

**3.11.13**
**medium**
[SEE: 3.1.29]

**3.11.14**
**network**
[SEE: 3.1.30]

**3.11.15**
**node**
[SEE: 3.1.31]

**3.11.16**
**Photo coupler**
Parts for signal isolation by optical elements

**3.11.17**
**repeater**
[SEE: 3.1.38]

**3.11.18**
**shield**
[SEE: 3.1.41]

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**3.11.19**
**terminator**
[SEE: 3.1.43]

**3.11.20**
**transceiver**
[SEE: 3.1.44]

**3.11.21**
**transmitter**
[SEE: 3.1.45]

### 3.12 Type 20: Terms and definitions

**3.12.1**
**analog signal**
low frequency current, predominantly 4 mA to 20 mA signal sent to or originating from a field device

**3.12.2**
**analog signal spectrum**
frequencies from zero to 25 Hz at unit amplitude and decreasing at 40 dB per decade above 25 Hz

**3.12.3**
**analog test filter**
two-pole low-pass Butterworth filter with the cutoff frequency of 25 Hz

**3.12.4**
**barrier**
physical entity which limits current and voltage into a hazardous area in order to satisfy intrinsic safety requirements

**3.12.5**
**cable capacitance per unit length**
capacitance per unit length of cable, measured at 1 kHz from one conductor other than the shield to all other conductors including the shield

Note 1 to entry: For networks comprised of more than one type or gauge of cable, the highest capacitance value of any cable type or gauge is used to determine this value.

**3.12.6**
**character**
the 8-bits of data and overhead bits that are transmitted as one continuous unit by the PhE

**3.12.7**
**character time**
amount of time required to transmit one character

**3.12.8**
**current sense resistor**
resistor that is used to convert analog current signal into a voltage signal

**3.12.9**
**delay distortion**
difference in propagation time delays of sine waves of different frequencies when observing the time delay through a network or circuit

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**3.12.10**
**device**
any entity containing an implementation of this document

**3.12.11**
**digital signal**
communication of information using the 1 200 bits per second frequency shift keying signal

**3.12.12**
**digital frequency band**
range of frequencies from 950 Hz to 2 500 Hz that is used for digital signal

**3.12.13**
**digital signal spectrum**
frequencies from 500 Hz to 10 kHz at unit amplitude, decreasing at 40 dB per decade below 500 Hz and decreasing at 20 dB per decade above 10 kHz

**3.12.14**
**extended frequency band**
range of frequencies from 500 Hz to 10 kHz

Note 1 to entry: This frequency band is digital frequency band plus guard band.

**3.12.15**
**field device**
physical entity that is connected to the process or to plant equipment and has at least one signalling element that communicates with other signalling element(s) via a cable

Note 1 to entry: It directly connects to the sensor or actuator or performs process control function and it is directly connected to the physical layer specified in this document. It may generate or receive an analog signal in addition to a digital signal.

**3.12.16**
**ground**
surface of the earth or the conduits or pipes that are so connected, or the safety bus bar or the zero volt rail to which the barriers are connected

Note 1 to entry: It is possible that ground can be the same as network power supply common, or not.

**3.12.17**
**intrinsic safety**
design methodology for a circuit or an assembly of circuits in which any spark or thermal effect produced under normal operating and specified fault conditions is not capable under prescribed test conditions of causing ignition of a given explosive atmosphere

**3.12.18**
**junction**
any splice of two cables or any attachment point of another cable or of a field device to an existing cable

**3.12.19**
**multi-drop network**
network with more than one slave device connected to one network

**3.12.20**
**network power supply**
source that supplies operating power directly to a network

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**3.12.21**
**network resistance**
resistance or real part of the impedance of a network

Note 1 to entry: It is computed as the equivalent impedance of all devices connected in parallel to the network. Therefore, it is usually dominated by one low impedance device.

**3.12.22**
**non-signaling element**
physical entity or an element that does not use or produce analog signal or digital signal

Note 1 to entry: A network power supply is an example of non-signaling element.

**3.12.23**
**point-to-point network**
network with only one slave and zero or one master device

Note 1 to entry: The point-to-point Network need not have any master device. This situation would exist, for example, when only an analog controller is used, the single field device having been programmed by a secondary master that was subsequently disconnected.

**3.12.24**
**signaling element**
physical entity or an element that uses or produces digital signal

Note 1 to entry: The entity that only uses or produces an analog signal is not part of this definition; the entity that uses/produces only a digital signal, but not an analog signal is part of this definition.

**3.12.25**
**silence**
state of the network when there is no digital signal is present

**3.12.26**
**start of message**
the preamble of physical layer protocol data unit followed by the delimiter of data link layer protocol data unit without any reception error and inter-character gap

### 3.13 Type 28: Terms and definitions

**3.13.1**
**carrier mode**
data transfer mode over available resources made up of OFDM symbols

**3.13.2**
**clock synchronization**
clock calibration of the terminal node device

**3.13.3**
**code block**
octet sequence of data interaction between the Type 28 physical layer entity and the Type 28 data-link layer entity

**3.13.4**
**control device**
device that controls all field devices for logical operations, timing, calculations and so on

**3.13.5**
**cyclic frame**
signal frames which are processed in a regular and repetitive manner

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**3.13.6**
**cyclic symbol**
OFDM symbols in signal frames which are processed in a regular and repetitive manner

**3.13.7**
**half sideband**
upper sideband or lower sideband of an OFDM symbol

**3.13.8**
**lower sideband**
subcarriers with a frequency range from 1,536 MHz to 16,896 MHz on an OFDM symbol

**3.13.9**
**management node**
device for allocating and managing Type 28 network physical communication resources

**3.13.10**
**orthogonal frequency division multiplexing (OFDM) symbol**
minimum data transmission unit in time domain that include all subcarriers in frequency based on OFDM technology

**3.13.11**
**terminal node**
device in Type 28 network that communicates based on allocated physical communication resources

**3.13.12**
**two-wire non-bridged**
devices are connected by physical media with two wires, without being connected through a bridge device

**3.13.13**
**upper sideband**
subcarriers with a frequency range from 16,896 MHz to 32,256 MHz on an OFDM symbol

**3.13.14**
**working mode**
OFDM operation in a specific transmission mode, RS code, convolutional code, and modulation mode

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# 4 Symbols and abbreviated terms

## 4.1 Symbols

### 4.1.1 Type 1: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| $A_{max}$ | Maximum inter-device attenuation | dB |
| $AD_{max}$ | Maximum inter-device attenuation distortion | dB |
| BR | Nominal bit rate | Mbit/s |
| $\Delta$BR | Maximum deviation from BR | - |
| $CS_{max}$ | Maximum coupler spacing to form a cluster | m |
| $Din_{min}$ | Minimum device input impedance | kΩ |
| dBm | Logarithmic unit of power referenced to 1 mW | dB(mW) |
| $F_c$ | Center carrier frequency used in frequency shift keying | kHz |
| $F_{c+f}$ | Frequency that corresponds to logical 1 in frequency shift keying | kHz |
| $F_{c-f}$ | Frequency that corresponds to logical 0 in frequency shift keying | kHz |
| $f_r$ | Frequency corresponding to the nominal bit rate | MHz |
| $f_{min}$ | Nominal minimum frequency for the nominal bit rate | MHz |
| $f_{max}$ | Nominal maximum frequency for the nominal bit rate | MHz |
| $fQTO_{max}$ | Maximum frequency for $QTO_{max}$ measurement | MHz |
| $L_{max}$ | Maximum inter-device distance | m |
| $MD_{max}$ | Maximum inter-device mismatching distortion | dB |
| N+ | Non-data symbol - positive; Manchester coded signal with a high level for one bit time, used for delimiters, carrying no data | - |
| N- | Non-data symbol - negative; Manchester coded signal with a low level for one bit time, used for delimiters, carrying no data | - |
| $N_{max}$ | Maximum number of devices | - |
| P | Nominal period of octet transmission | s |
| PICS | Protocol Implementation Conformance Statement | - |
| $QTO_{max}$ | Maximum quiescent transmitter output | mV |
| $T_{bit}$ | Nominal bit duration | µs |
| $\Delta T_{bit}$ | Maximum deviation from $T_{bit}$ | - |
| $T_{rf}$ | Maximum signal rise or fall time | ns |
| $V_{DD}$ | The most positive (or least negative) supply level | V |
| $V_{IH}$ | Minimum high-level input voltage | V |
| $V_{IL}$ | Maximum low-level input voltage | V |
| $V_{OH}$ | Minimum high-level output voltage | V |
| $V_{OL}$ | Maximum low-level output voltage | V |
| Z | Impedance; vector sum of resistance and reactance (inductive or capacitive) | Ω |
| $Z_{f_r}$ | Characteristic impedance; impedance of a cable, and of its terminators, at frequency $f_r$ | Ω |
| $Z_o$ | Characteristic impedance; impedance of a cable, and of its terminators, over the defined frequency range | Ω |

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### 4.1.2 Type 2: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| dBm | Logarithmic unit of power referenced to 1 mW | dB (mW) |
| $f_r$ | Frequency corresponding to the bit rate | Hz |
| GND | Ground supply level | V |
| H | Physical symbol - high level | - |
| L | Physical symbol - low level | - |
| M_0 | Medium Access Control - data symbol - "zero";<br>Symbol at the DL-Ph interface, representing the transmitted and received Manchester coded signal with a high level for half a bit time, and a low level for half a bit time, carrying data "zero" | - |
| M_1 | Medium Access Control - data symbol - "one";<br>Symbol at the DL-Ph interface, representing the transmitted and received Manchester coded signal with a low level for half a bit time, and a high level for half a bit time, carrying data "one" | - |
| M_ND+ | Medium Access Control - non-data symbol - positive;<br>Symbol at the DL-Ph interface, representing the transmitted and received Manchester coded signal with a high level for one complete bit time, used for delimiters, carrying no data | - |
| M_ND- | Medium Access Control - non-data symbol - negative;<br>Symbol at the DL-Ph interface, representing the transmitted and received Manchester coded signal with a low level for one complete bit time, used for delimiters, carrying no data | - |
| Rx_H | Receive - high level (NAP interface) | V |
| Rx_L | Receive - low level (NAP interface) | V |
| Tx_H | Transmit - high level (NAP interface) | V |
| Tx_L | Transmit - low level (NAP interface) | V |
| $V_{in}$ | Voltage on the coaxial cable center conductor ($V_{in}$+ or $V_{in}$-) as referenced to the coaxial shield | V |
| $V_{sense}$+ | Positive data sensitivity limit | V |
| $V_{sense}$- | Negative data sensitivity limit | V |
| $V_{sense}$H | High carrier sensitivity limit | V |
| $V_{sense}$L | Low carrier sensitivity limit | V |

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### 4.1.3 Type 3: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| dBm | Logarithmic unit of power referenced to 1 mW | dB (mW) |
| $f_r$ | Frequency corresponding to the bit rate | Hz, kHz, MHz |
| N- | Non-data symbol - negative; Manchester coded signal with a low level for one bit time, used for delimiters, carrying no data | - |
| N+ | Non-data symbol - positive; Manchester coded signal with a high level for one bit time, used for delimiters, carrying no data | - |
| P | Nominal period of octet transmission | s |
| $R_d$ | Pull-down resistor | Ω |
| $R_t$ | Bus terminator | Ω |
| $R_u$ | Pull-up resistor | Ω |
| SYN | Synchronizing bits of a frame (period of idle) | s |
| $t_{BIT}$ | The bit time $t_{BIT}$ is the time, which elapses during the transmission of one bit | s |
| $T_{SBIT}$ | Extended tolerance (only for stop bit) | s |
| $T_{SYN}$ | Synchronization time | s |
| $T_{SYNI}$ | Synchronization interval time | s |
| $V_{DD}$ | The most positive (or least negative) supply level | V |
| $V_{IH}$ | Minimum high-level input voltage | V |
| $V_{IL}$ | Maximum low-level input voltage | V |
| $V_{OH}$ | Minimum high-level output voltage | V |
| $V_{OL}$ | Maximum low-level output voltage | V |
| VP | Voltage-Plus | V |
| Z | Impedance; vector sum of resistance and reactance (inductive or capacitive) | Ω |
| $Z_o$ | Characteristic impedance; impedance of a cable, and of its terminators, over the defined frequency range | Ω |

### 4.1.4 Type 4: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| $V_{CC}$ | The most positive (or least negative) supply level | V |
| GND | Ground supply level | V |

### 4.1.5 Void

NOTE Subclause 4.1.5 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

### 4.1.6 Type 8: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| dBm | Logarithmic unit of power referenced to 1 mW | dB (mW) |
| $f_r$ | Frequency corresponding to the bit rate | Hz |
| $V_{DD}$ | The most positive (or least negative) supply level | V |
| GND | Ground supply level | V |

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### 4.1.7 Type 12: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| dB | Decibel, a logarithmic unit (base 10) used to express the ratio of power between a send signal and a receive signal | - |

### 4.1.8 Type 16: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| j | Jitter | µs |
| $J_{noise}$ | Jitter of the optical signal | µs |
| $J_{t2}$ | Jitter in $t_2$ | µs |
| $J_{tscyc}$ | Jitter in $t_{Scyc}$ | µs |
| $P$ | Power | dBm or µW |
| $P_{RmaxH}$ | Maximum received power at optical high level | dBm or µW |
| $P_{RmaxL}$ | Maximum received power at optical low level | dBm or µW |
| $P_{RminH}$ | Minimum received power at optical high level | dBm or µW |
| $P_{TmaxH}$ | Maximum transmission power at optical high level | dBm or µW |
| $P_{TmaxL}$ | Maximum transmission power at optical low level | dBm or µW |
| $P_{TminH}$ | Minimum transmission power at optical high level | dBm or µW |
| $P_X$ | Power threshold | dBm or µW |
| $t_{cable}$ | Time, by which the transmitted signal is delayed by the cable, for each unit of length (approx., 5 ns/m) | ns |
| $t_{fri}$ | Time for the optical low level at the input of a slave | ns |
| $t_{fro}$ | Time for the optical low level at the output of a slave | ns |
| $t_{rep}$ | Time, by which the received signal is delayed by a forwarding slave (input-output) | ns |
| $t_{ring}$ | Time, which a master telegram needs, until it has passed through the network and reached the master again | µs |
| $t_{RPAT}$ | Maximum transition time in a slave to switch from the repeater function to the transmitter function for the AT | µs |
| $t_{RPAT.2}$ | Maximum transition time in slave 2 to switch from the repeater function to the transmitter function for the AT | µs |

### 4.1.9 Type 18: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| $V_{DD}$ | Voltage potential supplied to power digital logic components | V |
| $V_{OL}$ | Output voltage, low level | V |
| $V_{OH}$ | Output voltage, high level | V |
| $V_{IL}$ | Input voltage, low level | V |
| $V_{IH}$ | Input voltage, high level | V |

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### 4.1.10 Type 24: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| GND | Ground supply level | V |
| H | Physical symbol - high level | - |
| L | Physical symbol - low level | - |
| DL_Symbols | representation of the DL data bits to be encoded and transmitted by the physical layer | - |
| Ph_Symbols | representation of data bits which shall be encoded by the MAC (Medium Access Control) and transmitted by the physical layer | - |
| $V_{DD}$ | The most positive supply level | V |

### 4.1.11 Type 20: Symbols

| Symbol | Definition |
|---|---|
| $C_{cbl}$ | Cable capacitance per unit length |
| $C_{dev}$ | Equivalent device capacitance |
| $C_{tg}$ | Terminal to ground capacitance |
| $C_{tt}$ | Terminal to terminal capacitance |
| HOLD | Hold time |
| $R_{cbl}$ | Cable resistance per unit length |
| $R_{dev}$ | Equivalent device resistance |
| Rp | Network parallel resistance |
| RT1 | Link quiet time |
| RT2 | Link grant time |
| $R_{tg}$ | Terminal to ground resistance |
| $R_{tt}$ | Terminal to terminal resistance |
| STO | Slave time out |
| $Z_{tt}$ | Terminal to terminal impedance |

### 4.1.12 Type 28: Symbols

| Symbol | Definition | Unit |
|---|---|---|
| $T_S$ | Sampling interval | ns |
| $N_{CBIB}$ | Bit interleaving block length | - |
| $N_{COL}$ | Column number of bits interleaving | - |
| $N_{BPS}$ | Bit interleaving symbol bit number | - |
| $N_{SD}$ | Number of subcarriers of an OFDM symbol | - |
| $N_{SYM}$ | Number of OFDM symbols of a signal Frame | - |

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## 4.2 Abbreviated terms

### 4.2.1 Type 1: Abbreviations

| | |
|---|---|
| CTS | Clear-to-send signal (from DCE) |
| DCE | Data communication equipment |
| DIS | DCE independent sublayer |
| DL | Data-link (as a prefix) [ISO/IEC 7498-1] |
| DLE | Data-link entity |
| DLL | Data-link layer [ISO/IEC 7498-1] |
| DTE | Data terminal equipment |
| EMI | Electro-magnetic interference |
| IDU | Interface data unit [ISO/IEC 7498-1] |
| IS | Intrinsic safety |
| LbE | Loopback-enable signal (to MAU) |
| MAU | Medium attachment unit (for wire media, MAU = transceiver) |
| MDS | Medium dependent sublayer |
| min o/p | Minimum output voltage peak-to-peak |
| MIS | Media independent sublayer |
| NRZ | Non-return-to-zero code |

NOTE High level = logic 1, Low level = logic 0

| | |
|---|---|
| Ph | Physical (as a prefix) [ISO/IEC 7498-1] |
| PhE | Physical layer entity [ISO/IEC 7498-1] |
| PhL | Physical layer [ISO/IEC 7498-1] |
| PhICI | Physical layer interface control information [ISO/IEC 7498-1] |
| PhID | Physical layer interface data [ISO/IEC 7498-1] |
| PhIDU | Physical layer interface data unit [ISO/IEC 7498-1] |
| PhPCI | Physical layer protocol control information [ISO/IEC 7498-1] |
| PhPDU | Physical layer protocol data unit [ISO/IEC 7498-1] |
| PhS | Physical layer service [ISO/IEC 7498-1] |
| PhSAP | Physical layer service access point [ISO/IEC 7498-1] |
| PhSDU | Physical layer service data unit [ISO/IEC 7498-1] |
| pk | Peak |
| pk-pk | Peak-to-peak |
| RDF | Receive-data-and-framing signal (from DCE) |
| RFI | Radio frequency interference |
| RTS | Request-to-send signal (to DCE) |
| RxA | Receive-activity signal (from DCE) |
| RxC | Receive-clock signal (from DCE) |
| RxS | Receive signal (from MAU) |
| SDU | Service data unit [ISO/IEC 7498-1] |
| TxC | Transmit-clock signal (from DCE) |
| TxD | Transmit-data signal (to DCE) |
| TxE | Transmit-enable signal (to MAU) |
| TxS | Transmit signal (to MAU) |

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### 4.2.2 Type 2: Abbreviations

| | |
|---|---|
| BNC | Bayonet Neill Concelman (connector for coaxial cable having a bayonet-type shell with two small knobs on the female connector, which lock into spiral slots in the male connector when it is twisted) [IEC 61169–8] |
| DCE | Data communication equipment |
| DL | Data-link (as a prefix) [ISO/IEC 7498-1] |
| DLL | Data-link layer [ISO/IEC 7498-1] |
| MAC | Medium access control (lower section of the data-link layer, interfacing with the physical layer) |
| MAC ID | Medium access control identification - address of a node |
| MAU | Medium attachment unit (for wire media, MAU = transceiver) |
| MDS | Medium dependent sublayer |
| MIS | Media independent sublayer |
| NAP | Network access port (local access to a device, i.e. not via the bus) |
| NetEnable | Transmit-enable signal |
| NUT | Network update time [IEC 61158-4-2] |
| Ph | Physical (as a prefix) [ISO/IEC 7498-1] |
| PhL | Physical layer [ISO/IEC 7498-1] |
| pk | Peak |
| Rcv | Receive |
| Rx | Receive |
| RxCarrier | Receive-carrier signal |
| RxData | Receive-data signal |
| RxPTC | Receive-data signal (NAP interface) |
| RM | Repeater machine (mechanism for extending bus length, providing multiple medium interfaces, and allowing medium redundancy) |
| RRM | Ring repeater machine (mechanism for providing a ring topology on optical medium) |
| SMAX | Scheduled maximum address [IEC 61158-4-2] |
| TNC | Threaded Neill Concelman (threaded version of the BNC connector) [IEC 60169–17] |
| Tx | Transmit |
| TxDataBar | Transmit-data signal (inverted) |
| TxDataOut | Transmit-data signal |
| TxPTC | Transmit-data signal (NAP interface) |
| Xmit | Transmit |

### 4.2.3 Type 3: Abbreviations

| | |
|---|---|
| ASC | Active star coupler |
| BER | Bit error rate |
| CO | Converter |
| CTS | Clear-to-send signal (from DCE) |
| DCE | Data communication equipment |
| DGND | Data ground |
| DIS | DCE independent sublayer |
| DL | Data-link (as a prefix) |

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| | |
|---|---|
| DLE | Data-link entity |
| DLL | Data-link layer [ISO/IEC 7498-1] |
| DLPDU | Data-link protocol data unit [ISO/IEC 7498-1] |
| DTE | Data terminal equipment |
| DUT | Device under test |
| EMC | Electro-magnetic-compatibility |
| EMI | Electro-magnetic interference |
| FEC | Forward error correction |
| FISCO | Fieldbus intrinsically safe concept |
| FO | Fiber optic |
| FOC | Fiber optic cable |
| IS | Intrinsic safety |
| LbE | Loopback enable signal (to MAU) |
| LSS | Line selector switch |
| M/S | Master/slave station |
| MAU | Medium attachment unit (for wire media, MAU = transceiver) |
| MDS | Medium dependent sublayer |
| MIS | Media independent sublayer |
| n | Number of a station |
| NRZ | Non-return-to-zero code |

NOTE High level = logic 1, Low level = logic 0

| | |
|---|---|
| OST | Overshot of transition |
| PC | Physical contact |
| Ph | Physical (as a prefix) |
| Ph-AS YN-DATA | Physical data service for asynchronous transmission |
| PhE | Physical layer entity [ISO/IEC 7498-1] |
| PhICI | Physical layer interface control information [ISO/IEC 7498-1] |
| PhID | Physical layer interface data [ISO/IEC 7498-1] |
| PhIDU | Physical layer interface data unit [ISO/IEC 7498-1] |
| PhL | Physical layer [ISO/IEC 7498-1] |
| PhM | Ph-management |
| PhMS | Ph-management service |
| PhPCI | Physical layer protocol control information [ISO/IEC 7498-1] |
| PhPDU | Physical layer protocol data unit [ISO/IEC 7498-1] |
| PhS | Physical layer service [ISO/IEC 7498-1] |
| PhSAP | Physical layer service access point [ISO/IEC 7498-1] |
| PhSDU | Physical layer service data unit [ISO/IEC 7498-1] |
| pk-pk | Peak-to-peak |
| RDF | Receive-data-and-framing signal (from DCE) |
| REP | Repeater |
| RFI | Radio frequency interference |
| RS 485 | TIA-RS485-A:1998 |
| RTS | Request-to-send signal (to DCE) |

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RxA Receive-activity signal (from DCE)
RxC Receive-clock signal (from DCE)
RxS Receive Signal (from MAU)
Stn Stations (master or slave)
TPC Twisted-pair cable
TxC Transmit-clock signal (from DCE)
TxD Transmit-data signal (to DCE)
TxE Transmit-enable signal (to MAU)
TxS Transmit Signal (to MAU)
UART Universal asynchronous receiver/transmitter

#### 4.2.4 Type 4: Abbreviations

CTS Clear-to-send signal (from DCE)
DCE Data communication Equipment
DL Data-link (as a prefix) [ISO/IEC 7498-1]
DLE Data-link entity
DLL Data-link layer [ISO/IEC 7498-1]
DTE Data terminal equipment
MAU Medium attachment unit (for wire media, MAU = transceiver)
MDS Medium dependent sublayer
MIS Media independent sublayer
NRZ Non-return-to-zero code

NOTE High level = logic 1, Low level = logic 0

Ph Physical (as a prefix) [ISO/IEC 7498-1]
PhE Physical layer entity [ISO/IEC 7498-1]
PhL Physical layer [ISO/IEC 7498-1]
PhID Physical layer interface data [ISO/IEC 7498-1]
PhPDU Physical layer protocol data unit [ISO/IEC 7498-1]
RS-485 TIA-RS485-A:1998
RTS Request-to-send signal (to DCE)
RxS Receive Signal (from MAU)
TxE Transmit-enable signal (to MAU)
TxS Transmit Signal (to MAU)

#### 4.2.5 Void

NOTE Subclause 4.2.5 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

#### 4.2.6 Type 8: Abbreviations

BC Bus connector
BLL Basic link layer
BSY Busy
CPIC Cable plant interface connector
CRC Cyclic redundancy check
CTS Clear-to-send

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| | |
|---|---|
| DL | Data-link (as a prefix) [ISO/IEC 7498-1] |
| DLL | Data-link layer [ISO/IEC 7498-1] |
| DI | Data in |
| DLPDU | Data-link process data unit |
| DO | Data out |
| DS | Data select |
| GND | Ground |
| ICI | Interface control information |
| ID | Identifier |
| LbE | Loopback enable |
| LSB | Least significant byte (octet) |
| MA | Medium activity |
| MAC | Medium access control |
| MAU | Medium attachment unit |
| MDS | Medium dependent sublayer |
| MIS | Media independent sublayer |
| MSB | Most significant bit |
| NRZ | Non-return-to-zero |
| PCS | Plastic-clad silica fiber |
| Ph | Physical (as a prefix) [ISO/IEC 7498-1] |
| PhE | Physical layer entity [ISO/IEC 7498-1] |
| PhICI | Physical interface control information |
| PhIDU | Physical interface data unit |
| PhL | Physical layer [ISO/IEC 7498-1] |
| PhPDU | Physical protocol data unit |
| PhSDU | Physical service data unit |
| PNM1 | Peripherals network management of layer 1 |
| POF | Polymer optical fiber |
| RI | Reset-in |
| RO | Reset-out |
| RqDly1 | Request delay 1 |
| RqDly2 | Request delay 2 |
| RTS | Request-to-send |
| RxA | Receive-activity |
| RxC | Receive-clock |
| RxCR | Receive control line |
| RxD | Receive data |
| RxS | Receive sequence |
| RxSL | Receive select line |
| SL | Select line |
| TRst | Coding and decoding (of the Reset PhPDU) |
| TxC | Transmit clock |
| TxCR | Transmit control line |

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TxD Transmit data
TxS Transmit sequence
TxSL Transmit select line

#### 4.2.7 Type 12: Abbreviations

2PP Two Pair Power
AWG American wire gauge
DCE Data Circuit-terminating Equipment
DTE Data Terminal Equipment
M8P Connector according to IEC 61076-2-114, P-coding
MDI Medium Dependant Interface [ISO/IEC/IEEE 8802-3:2021]
PD Powered Device
PHY Physical Layer Device [ISO/IEC/IEEE 8802-3:2021]
PI Power Interface
PSE Power Sourcing Equipment

#### 4.2.8 Type 16: Abbreviations

DPLL digital phase locked loop
HCS hard clad silica (glass fiber)
IC integrated circuit
LED light emitting diode
LSB least significant bit
MSB most significant bit
NRZI non-return-to-zero-inverted
POF polymer optical fiber (plastic fiber)
RxCLK receiving clock
RxD received data
TxCLK transmitting clock
TxD transmitted data

#### 4.2.9 Type 18: Abbreviations

AWG American wire gauge
CMOS Complementary Metal Oxide Silicon - a class of digital logic interface specifications
DA / DB Data A and Data B - the communications signal pair
DG Data Ground - zero potential communications signal reference
FG Field Ground - the zero potential device reference
NRZI Non-Return to Zero Inverted
PhL-B Physical layer - Basic type
PhL-P Physical layer - Powered type
RxS Receive Signal
SLD Shield - linear Faraday cage
TTL Transistor-Transistor Logic - a class of digital logic interface specifications
TxE Transmit Enable
TxS Transmit Signal

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| | |
|---|---|
| UL | Unit Load |

#### 4.2.10 Type 24: Abbreviations

| | |
|---|---|
| AUX | Auxiliary signal |
| AWG | American wire gauge |
| DL | Data-link (as a prefix) [ISO/IEC 7498-1] |
| DLL | Data-link layer [ISO/IEC 7498-1] |
| NC | No connection |
| Ph | Physical (as a prefix) [ISO/IEC 7498-1] |
| PhL | Physical layer [ISO/IEC 7498-1] |
| pk | Peak |
| pk-pk | Peak-to-peak |
| SRD | Send data Receive data |
| RxS | Receive signal |
| TxE | Transmit enable signal |
| TxS | Transmit signal |

#### 4.2.11 Type 20: Abbreviations

| | |
|---|---|
| AWG | American wire gauge |
| bit/s | Bits per second |
| DUT | Device under test |
| EMI | Electro-magnetic interference |
| FSK | Frequency shift keying |
| HCF | HART™ Communication Foundation |
| RMS | Root mean square |
| SOM | Start of message |
| STX | Start of transaction |

#### 4.2.12 Type 28: Abbreviations

| | |
|---|---|
| AL | Application layer |
| BPSK | Binary phase shift keying |
| DCE | Data communication equipment |
| DL | Data-Link (as a prefix) [ISO/IEC 7498-1] |
| DLDE | Data-link Data Entity |
| DLE | Data-link entity |
| DLL | Data-link layer [ISO/IEC 7498-1] |
| DLP | Data-link protocol |
| DLPDU | Data-link protocol data unit |
| DIS | DCE independent sublayer |
| DTC | Data transmission channel |
| DTE | Data terminal equipment |
| LbE | Loopback-enable signal |
| MAU | Medium attachment unit |
| MCS | Modulation coding scheme |
| MDS | Medium dependent sublayer |

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| | |
|---|---|
| MIS | Media independent sublayer |
| MN | Management node |
| NodeID | Node identifier |
| OFDM | Orthogonal Frequency Division Multiplexing |
| PhE | Physical layer entity [ISO/IEC 7498-1] |
| PhL | Physical layer [ISO/IEC 7498-1] |
| PhL- | Physical layer (as a prefix) |
| PhLDE | Physical layer data entity |
| PhLME | Physical layer management entity |
| PhICI | Physical layer interface control information [ISO/IEC 7498-1] |
| PhID | Physical layer interface data [ISO/IEC 7498-1] |
| PhIDU | Physical layer interface data unit [ISO/IEC 7498-1] |
| PhPCI | Physical layer protocol control information [ISO/IEC 7498-1] |
| PhPDU | Physical layer protocol data unit [ISO/IEC 7498-1] |
| PhS | Physical layer service [ISO/IEC 7498-1] |
| PhSDU | Physical layer service data unit [ISO/IEC 7498-1] |
| QAM | Quadrature amplitude modulation |
| RF | Radio frequency |
| RMS | Root mean square |
| RS | Reed-Solomon |
| RxS | Receive signal (from MAU) |
| SF | Signal frame |
| SyC | Synchronization confirm |
| SynS | Synchronization signal |
| SyR | Synchronization request |
| TM | Transmit mode |
| TN | Terminal node |
| TxD | Transmit data |
| TxE | Transmit-enable signal (to MAU) |
| TxR | Transmit request |
| TxS | Transmit signal (to MAU) |

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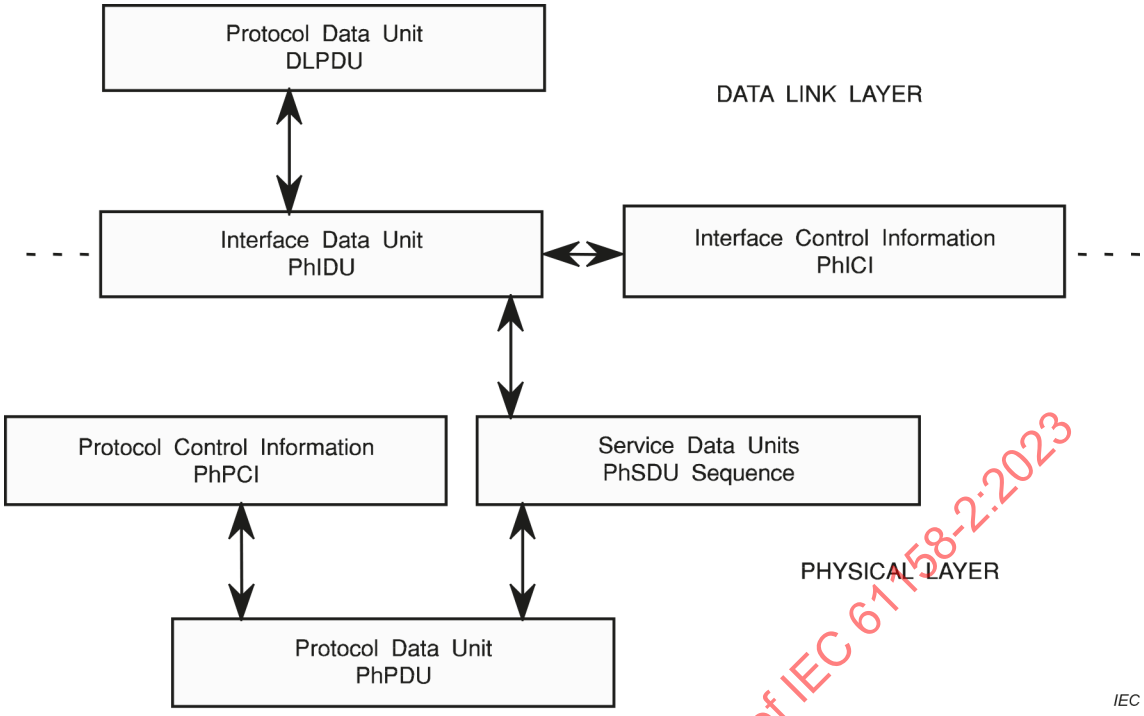
## 5 DLL – PhL interface

### 5.1 General

Clause 5 defines the required physical service (PhS) primitives and constraints on their use.

NOTE 1 The data-link - Physical interface is a virtual service interface between virtual machines; there are no requirements for physical signal lines as the document does not require this interface to be exposed.

PhIDUs shall be transferred between the DLL and the PhL in accordance with the requirements of ISO/IEC 7498 as shown in Figure 2.




NOTE PhPCI and PhICI support are type specific.

**Figure 2 – Mapping between data units across the DLL-PhL interface**

NOTE 2 These services provide for the interchange of PhIDUs between a DLL entity and its associated PhL entity. Such a transfer is part of a transaction between cooperating DLL entities. The services listed in this section are the minimum that can jointly provide the means by which cooperating DLL entities can coordinate their transmission and their exchange of data on the shared communication medium. Synchronization of data exchange and related actions is also provided if needed.

NOTE 3 Proper layering ensures that an (N+1)-layer entity be not concerned with, and that an (N)-service interface not overly constrain, the means by which an (N)-layer provides its (N)-services. Thus, the Ph-service interface does not demand that DLEs are aware of internal details of the PhE (e.g. preamble, postamble and frame delimiter signal patterns, number of bits per baud), and prevents the PhE not from using appropriate evolving technologies.

NOTE 4 A number of different DLL-PhL interfaces are specified, based on industry practice.

## 5.2 Type 1: Required services

### 5.2.1 Primitives of the PhS

#### 5.2.1.1 General

The granularity of PhS-user data exchanged at the PhL-DLL interface is one octet.

#### 5.2.1.2 Ph-CHARACTERISTICS Indication

The PhS shall provide the following service primitive to report essential PhS characteristics (which may be used in DLL transmission, reception, and scheduling activities):

Ph-CHARACTERISTICS indication (minimum-data-rate, framing-overhead)

where

minimum-data-rate - shall specify the effective minimum rate of data conveyance in bits/s, including any timing tolerances

NOTE 1 A PhE with a nominal data rate of 1 Mbit/s with a tolerance of ± 0,01 % would specify a minimum data rate of 0,999 9 Mbit/s.

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framing overhead - shall specify the maximum number of bit periods (where the period is the inverse of the data rate) used in any transmission for PhPDUs that do not directly convey data (e.g. PhPDUs conveying preamble, frame delimiters, postamble, inter-frame "silence", etc.).

NOTE 2 If the framing overhead is F and two DL message lengths are $L_1$ and $L_2$, then the time to send one message of length $L_1 + F + L_2$ will be at least as great as the time required to send two immediately consecutive messages of lengths $L_1$ and $L_2$.

#### 5.2.1.3 PhS transmission and reception services

The PhS shall provide the following service primitives for transmission and reception:

PH-DATA request (class, data)

PH-DATA indication (class, data)

PH-DATA confirm (status)

where

class - shall specify the PhICI component of the PhIDU.

For a PH-DATA request, its possible values shall be:

START-OF-ACTIVITY - transmission of the PhPDUs which precede Ph-user data shall commence;

DATA - the single-octet value of the associated data parameter shall be transmitted as part of a continuous correctly formed transmission; and

END-OF-DATA-AND-ACTIVITY - the PhPDUs that terminate Ph-user data shall be transmitted after the last preceding octet of Ph-user data, culminating in the cessation of active transmission.

For a PH-DATA indication, its possible values shall be:

START-OF-ACTIVITY - reception of an apparent transmission from one or more PhEs has commenced;

DATA - the associated data parameter was received as part of a continuous correctly formed reception;

END-OF-DATA - the ongoing continuous correctly formed reception of Ph-user data has concluded with correct reception of PhPDUs implying END-OF-DATA;

END-OF-ACTIVITY – the ongoing reception (of an apparent transmission from one or more PhEs) has concluded, with no further evidence of PhE transmission; and

END-OF-DATA-AND-ACTIVITY - simultaneous occurrence of END-OF-DATA and END-OF-ACTIVITY.

data - shall specify the PhID component of the PhIDU. It consists of one octet of Ph-user-data to be transmitted (PH-DATA request) or which was received successfully (PH-DATA indication).

status - shall specify either success or the locally detected reason for inferring failure.

The PH-DATA confirm primitive shall provide the critical physical timing feedback necessary to inhibit the DLE from starting a second transmission before the first is complete. The final PH-DATA confirm of a transmission shall not be issued until the PhE has completed the transmission.

### 5.2.2 Notification of PhS characteristics

The PhE has the responsibility for notifying the DLE of those characteristics of the PhS that can be relevant to DLE operation. The PhE shall do this by issuing a single Ph-CHARACTERISTICS indication primitive at each of the PhEs PhSAPs at PhE start-up.

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### 5.2.3 Transmission of Ph-user-data

The PhE shall determine the timing of all transmissions. When a DLE transmits a sequence of PhSDUs, the DLE shall send the sequence of PhSDUs by making a well-formed sequence of PH-DATA requests, consisting of a single request specifying START-OF-ACTIVITY, followed by 3 to 300 consecutive requests, inclusive, specifying DATA, each conveying a PhSDU, and concluded by a single request specifying END-OF-DATA-AND-ACTIVITY.

The PhE shall signal its completion of each PH-DATA request, and its readiness to accept a new PH-DATA request, by issuing a PH-DATA confirm primitive; the status parameter of the PH-DATA confirm primitive shall convey the success or failure of the associated PH-DATA request. A second PH-DATA request shall not be issued by the DLE until after the PH-DATA confirm corresponding to the first request has been issued by the PhE.

### 5.2.4 Reception of Ph-user-data

The PhE shall report a received transmission with a well-formed sequence of PH-DATA indications, which shall consist of

a) a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA, each conveying a PhSDU; followed by a single indication specifying END-OF-DATA; and concluded by a single indication specifying END-OF-ACTIVITY; or

b) a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA, each conveying a PhSDU; followed by a single indication specifying END-OF-DATA-AND-ACTIVITY; or

c) a single indication specifying START-OF-ACTIVITY; optionally followed by one or more consecutive indications specifying DATA, each conveying a PhSDU; and concluded by a single indication specifying END-OF-ACTIVITY.

This last sequence is indicative of an incomplete or incorrect reception. Detection of an error in the sequence of received PhPDUs, or in the PhEs reception process, shall disable further PH-DATA indications with a class parameter specifying DATA, END-OF-DATA, or END-OF-DATA-AND-ACTIVITY until after both the end of the current period of activity and the start of a subsequent period of activity have been reported by PH-DATA indications specifying END-OF-ACTIVITY and START-OF-ACTIVITY, respectively.

## 5.3 Type 2: Required services

### 5.3.1 General

Subclause 5.3 defines the required physical service (PhS) primitives and constraints on their use.

The DLL-PhL interface need not be exposed in the implementation of any PhL variant. This interface may be internal to the node and may be implemented as internal to a semiconductor device. If, however, conformance to the DLL-PhL interface is claimed, it shall conform to the requirements of 5.3.

### 5.3.2 M_symbols

The PhL Interface Data Units present at the DLL-PhL interface shall be M_symbols, as shown in Table 1. The M_ND symbols shall be used to create unique data patterns used for start and end delimiters.

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**Table 1 – Data encoding rules**

| Data bits (common name) | M_symbol representation |
|---|---|
| data "zero" | M_0 or {0} |
| data "one" | M_1 or {1} |
| "non_data+" | M_ND+ or {+} |
| "non_data-" | M_ND- or {-} |

### 5.3.3 PH-LOCK indication

PH-LOCK indication shall provide an indication of either data lock or Ph-symbol synchronization by the MDS. Valid states for PH-LOCK indication shall be true and false. PH-LOCK indication shall be true whenever valid Ph-symbols are present at the MDS-MAU interface and the DLL-PhL interface timing of M_symbols conform to the requirements for clock accuracy. It shall be false between frames (when no Ph-symbols are present on the medium) or whenever data synchronization is lost or the timing fails to conform to the requirements for clock accuracy. PH-LOCK indication shall be true prior to the beginning of the start delimiter.

### 5.3.4 PH-FRAME indication

PH-FRAME indication shall provide an indication of a valid data frame from the MAU. Valid states for PH-FRAME indication shall be true and false. PH-FRAME indication shall be true upon PH-LOCK indication = true and reception of the first valid start delimiter. PH-FRAME indication shall be false at reception of next M_ND symbol (following the start delimiter) or PH-LOCK indication = false.

NOTE This signal provides octet synchronization to the DLL.

### 5.3.5 PH-CARRIER indication

PH-CARRIER indication shall represent the presence of a signal carrier on the medium. PH-CARRIER indication shall be true if RXCARRIER at the MDS-MAU interface has been true during any of the last 4 M_symbol times and it shall be false otherwise.

### 5.3.6 PH-DATA indication

PH-DATA indication shall represent the M_symbols shown in Table 1. Valid symbols shall be M_0, M_1, M_ND+ or M_ND- (or M_symbols). The PH-DATA indication shall represent the M_Symbols as decoded from the MAU whenever PH-LOCK indication is true.

### 5.3.7 PH-STATUS indication

PH-STATUS indication shall represent the status of the frame that was received from the MAU as shown in Table 2. Valid symbols shall be Normal, Abort, and Invalid. PH-STATUS indication shall indicate Normal after reception of a frame (PH-FRAME indication = true) composed of a start delimiter, valid Manchester encoded data (no M_ND symbols) and an end delimiter. PH-STATUS indication shall indicate Abort after reception of a frame (PH-FRAME indication = true) composed of a start delimiter, valid Manchester encoded data, and a second start delimiter. PH-STATUS indication shall indicate Invalid after reception of a frame (PH-FRAME indication = true) composed of a start delimiter and the detection of any M_ND symbol that was not part of a start or end delimiter.

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**Table 2 – Ph-STATUS indication truth table**

| Ph-STATUS indication | Ph-FRAME indication | Start delimiters in a single frame | End delimiter detection | Any non-delimiter Manchester violations |
|---|---|---|---|---|
| Normal | true | 1 | true | false |
| Abort | true | 2 | don't care | false |
| Invalid | true | 1 | don't care | true |

### 5.3.8 PH-DATA request

PH-DATA request shall represent the M_symbols to be transmitted. Valid symbols shall be M_0, M_1, M_ND+ or M_ND- as shown in Table 1. PH-DATA request shall indicate M_0 when no data is to be transmitted (and PH-FRAME request = false).

### 5.3.9 PH-FRAME request

PH-FRAME request shall be true when PH-DATA request represents M_symbols to be encoded to the appropriate Ph-symbols and transferred to the MAU, and shall be false when no valid M_symbols are to be transferred to the MAU.

### 5.3.10 PH-JABBER indication

PH-JABBER indication shall be true if the MDS-MAU interface detects a single frame (PH-FRAME indication = true) that equals or exceeds 1 024 octets (8 192 M_symbols) and PH-JABBER-TYPE request is true. PH-JABBER indication shall be true if the MDS-MAU interface detects a single frame (PH-FRAME indication = true) that equals or exceeds 2 048 octets (16 384 M_symbols) and PH-JABBER-TYPE request is false. PH-JABBER indication shall be false otherwise. If PH-JABBER indication goes true, it shall be latched in this state by the MDS until the Ph-JABBER-CLEAR request is true or power to the node is removed and restored or the node is initialised.

### 5.3.11 Ph-JABBER-CLEAR request

Ph-JABBER-CLEAR request (optional) shall be false under normal operating conditions and shall be true to reset a PH-JABBER indication that has been latched in a true state.

### 5.3.12 Ph-JABBER-TYPE request

PH-JABBER-TYPE request shall be true if the node is the source of transmit data ("NODE") and shall be false if the node is retransmitting data received from another node (e.g. acting as a "REPEATER" of data from another node, see Annex G).

The combinations for PH-JABBER indication and PH-JABBER-TYPE request shall be as shown in Table 3.

**Table 3 – Jabber indications**

| Ph-JABBER indication | Ph-JABBER-TYPE request | Frame length |
|---|---|---|
| true | true = "NODE" | ≥ 1 024 octets |
| true | false = "REPEATER" | ≥ 2 048 octets |
| false | true = "NODE" | < 1 024 octets |
| false | false = "REPEATER" | < 2 048 octets |

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## 5.4 Type 3: Required services

### 5.4.1 Synchronous transmission

The services specified for Type 1 shall be used (see 5.2).

### 5.4.2 Asynchronous transmission

#### 5.4.2.1 PhS transmission and reception services

The data service for asynchronous transmission (Ph-ASYN-DATA) includes two service primitives. A request primitive is used to request a service by the DLE; an indication primitive is used to indicate a reception to the DLE. The names of the respective primitives are as follows:

Ph-ASYN-DATA request

Ph-ASYN-DATA indication

The temporal relationship of the primitives is shown in Figure 3.

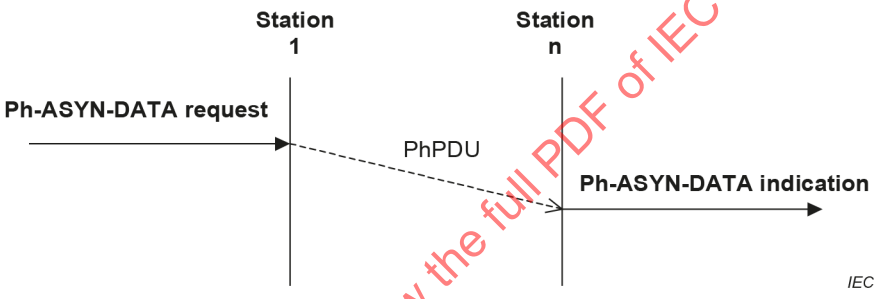


**Figure 3 – Data service for asynchronous transmission**

#### 5.4.2.2 Detailed specification of the service and interaction

Subclause 5.4.2.2 describes in detail the service primitives and the related parameter in an abstract way. The parameter contains the PhS-user data exchanged at the PhL-DLL interface with the granularity of one bit.

**Parameters of the primitives:**

Ph-ASYN-DATA request (DL_symbol)

The parameter DL_symbol shall have one of the following values specifying the PhID component of the PhIDU. Its possible values shall be:

a) ZERO corresponds to a binary "0";
b) ONE corresponds to a binary "1";
c) SILENCE disables the transmitter when no DL_symbol is to be transmitted.

The Ph-ASYN-DATA request primitive is passed from the DLE to the PhE to request that the given symbol shall be sent to the fieldbus medium.

The reception of this primitive shall cause the PhE to attempt encoding and transmission of the DL-symbol.

The Ph-ASYN-DATA request is a primitive, which shall only be generated once per DL-symbol period ($t_{BIT}$). The PhE may confirm this primitive with a locally defined confirmation primitive.

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Ph-ASYN-DATA indication (DL_symbol).

The parameter DL_symbol shall have one of the following values:

a) ZERO corresponds to a binary "0";

b) ONE corresponds to a binary "1".

The Ph-ASYN-DATA indication primitive is passed from the PhE to the DLE to indicate that a DL-symbol was received from the fieldbus medium. The effect of receipt of this primitive by the DLE is not specified.

The Ph-ASYN-DATA indication is a primitive, which shall only be generated once per received DL-symbol period ($t_{BIT}$).

## 5.5 Type 4: Required services

### 5.5.1 General

PhIDUs shall be transferred between the DLL and the PhL in accordance with the requirements of the ISO/IEC 7498 series.

### 5.5.2 Primitives of the PhS

#### 5.5.2.1 General

The granularity of transmission in the fieldbus protocol is one octet. This is the granularity of PhS-user data exchanged at the PhL-DLL interface.

#### 5.5.2.2 PhS Transmission and reception services

The PhS shall provide the following service primitives for transmission and reception:

PH-DATA request (class, data)

PH-DATA indication (class, data, status)

PH-DATA confirm (status)

where

**class** - specifies the Ph-interface-control-information (PhICI) component of the Ph-interface-data-unit (PhIDU).

For a PH-DATA request, its possible values are

START-OF-ACTIVITY-**11** - the PhE shall initiate transmission by transmitting the associated data parameter as an "Address character". The PhE shall do this immediately, though not until the value of the PhEs idle counter has reached 11. This class only applies to half duplex mode.

START-OF-ACTIVITY-**2** - the PhE shall enable its driver, and initiate transmission by transmitting the associated data parameter as an "Address character". The PhE shall do this immediately, though not until the value of the PhEs idle counter modulus 10 has reached 2 if in half duplex mode.

DATA - the PhE shall transmit the associated data parameter as a "Data character".

END-OF-ACTIVITY - the PhE shall wait until transmission of all formerly received data from the DLE has finished, and then terminate transmission. The associated data parameter shall not be transmitted.

For a PH-DATA indication, its possible values are

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START-OF-ACTIVITY - the PhE has received an "Address character", the value of which is reported in the associated data parameter. The associated status parameter specifies success or the locally detected reason for failure.

DATA - the PhE has received a "Data character", the value of which is reported in the associated data parameter. The associated status parameter specifies success or the locally detected reason for failure.

LINK-IDLE - the PhE has detected, that the signal level on the Link has been "Idle" for 30, 35, 40, 50, 60… bit periods. The associated status parameter specifies if the Link has been idle for 30 bit periods, for 35 bit periods, or for 40 or more bit periods. This class only applies to half duplex mode.

**data** - specifies the Ph-interface-data (PhID) component of the PhIDU. It consists of one octet of Ph-user data to be transmitted (PH-DATA request), or one octet of Ph-user data that was received (PH-DATA indication).

**status** - specifies either success or the locally detected reason for failure, or specifies if the associated LINK-IDLE indication indicates "30", "35" or "40 or more" bit periods of idle after Link activity.

The PH-DATA confirm primitive provides the feedback necessary to enable the DLE to report failures such as Link short-circuit or noise resulting in framing error to the DLS-user, and provides the critical physical timing necessary to prevent the DLE from starting a second transmission before the first is complete.

### 5.5.3 Transmission of Ph-user data

#### 5.5.3.1 General

When a DLE has a DLPDU to transmit, and the Link-access system gives that DLE the right to transmit, then the DLE should send the DLPDU, including a concatenated FCS. Making a sequence of PH-DATA requests as follows does this:

a) In half duplex mode, the first request should specify START-OF-ACTIVITY-11 if the DLPDU to transmit is an Acknowledge or Immediate-reply DLPDU, or if the transmission is an immediate re-transmission of a Confirmed or Unconfirmed DLPDU. The first request should specify START-OF-ACTIVITY-2 if transmission of a Confirmed or Unconfirmed DLPDU from the queue is commenced. In full duplex mode, the first request should always specify START-OF-ACTIVITY-2.

b) This first request should be followed by consecutive requests specifying DATA, and concluded by a single request specifying END-OF-ACTIVITY.

The PhE signals its completion of each PH-DATA request, and its readiness to accept a new PH-DATA request, with a PH-DATA confirm primitive. The status parameter of the PH-DATA confirm primitive conveys the success or failure of the associated PH-DATA request.

#### 5.5.3.2 Reception of Ph-user data

The PhE reports a received transmission with PH-DATA indications, which shall consist of either

– a single indication specifying START-OF-ACTIVITY, or

– a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA.

Each indication has an associated status parameter, specifying successful reception of the associated data, or the locally detected reason for failure.

### 5.6 Void

NOTE Subclause 5.6 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

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## 5.7 Type 8: Required services

### 5.7.1 General

PhIDUs are exchanged between the DLL (DLL) and the PhL (PhL). For the data transfer, the DL-Ph interface (MAC-MIS interface) shall make the following service primitives available:

PH-DATA request

PH-DATA confirm

PH-DATA indication

### 5.7.2 Primitives of the PhS

#### 5.7.2.1 PH-DATA request (PhICI, PhIDU)

This service primitive is used to transfer a data unit from the MAC sublayer to the MIS. The **PhICI** parameter determines the interface components of the interface data unit (PhIDU) to be transmitted and can contain the following values:

**ID_transfer**
The beginning of a data sequence for the transmission of identification/control data is requested.

**data_transfer**
The beginning of a data sequence for the transmission of user data is requested.

**start_ID_cycle**
The beginning of an identification cycle for the transmission of identification/control data is requested by the master.

**start_data_cycle**
The beginning of a data cycle for the transmission of user data is requested by the master.

**user_data**
The transmission of the data unit of user data defined by the PhIDU parameter (identification/control data or user data) is requested.

**CRC_data**
The transmission of the data unit of checksum data defined by the PhIDU parameter is requested.

**CRC_status**
The transmission of the data unit for the checksum status defined by the PhIDU parameter is requested.

**user_data_idle**
The transmission of user_data_idle messages is requested.

**CRC_data_idle**
The transmission of CRC_data_idle messages is requested.

**CRC_status_idle**
The transmission of CRC_status_idle messages is requested.

NOTE The start_data_cycle and start_ID_cycle parameters are supported by the MAC sublayer of a master only.

The **PhIDU** parameter defines the data component of the interface data unit to be transmitted. It consists of one bit, only if PhICI = user_data, CRC_data or CRC_status

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#### 5.7.2.2 PH-DATA confirm (status)

This service primitive is the acknowledgement to a PH-DATA request primitive and is used for synchronisation. The **status** parameter indicates whether the associated PH-DATA request primitive was executed successfully or not.

#### 5.7.2.3 PH-DATA indication (PhICI, PhIDU)

This service primitive is used to transfer a data unit from the MIS to the MAC sublayer. The **PhICI** parameter defines the interface component of the interface data unit (PhIDU) to be transmitted and can assume the following values:

**ID_transfer**
Indicates the beginning of a data sequence for the transmission of identification/control data.

**data_transfer**
Indicates the beginning of a data sequence for the transmission of user data.

**user_data**
The correct receipt of the data unit for the transmission of user data (identification/control data or user data) defined by the PhIDU parameter is indicated.

**CRC_data**
The correct receipt of the data unit for transmission of the checksum defined by the PhIDU parameter is indicated.

**CRC_status**
The correct receipt of the data unit for the transmission of the checksum status defined by the PhIDU parameter is indicated.

**user_data_idle**
The receipt of user_data_idle messages is indicated.

**CRC_data_idle**
The receipt of CRC_data_idle messages is indicated.

**CRC_status_idle**
The receipt of CRC_status_idle messages is indicated.

The **PhIDU** parameter defines the data components of the received interface data unit. It consists of one bit.

### 5.7.3 Overview of the Interactions

#### 5.7.3.1 General

NOTE For the data transfer via the DL-Ph interface, a difference is made between the data sequence (transmission of user or identification data) and the check sequence (transmission of checksum data).

The following apply to Figure 4 through Figure 7.

– If a data sequence of a data cycle is followed by a data sequence of an identification cycle, the interactions marked with (+) are omitted for an identification cycle.

– If a data sequence of an identification cycle is followed by a data sequence of a data cycle, the interactions marked with (+) are omitted for a data cycle.

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#### 5.7.3.2 Data Sequence

##### 5.7.3.2.1 Master

Figure 4 and Figure 5 show the interactions for a data sequence (identification cycle and data cycle) at the DL-Ph interface of a master (controller board).

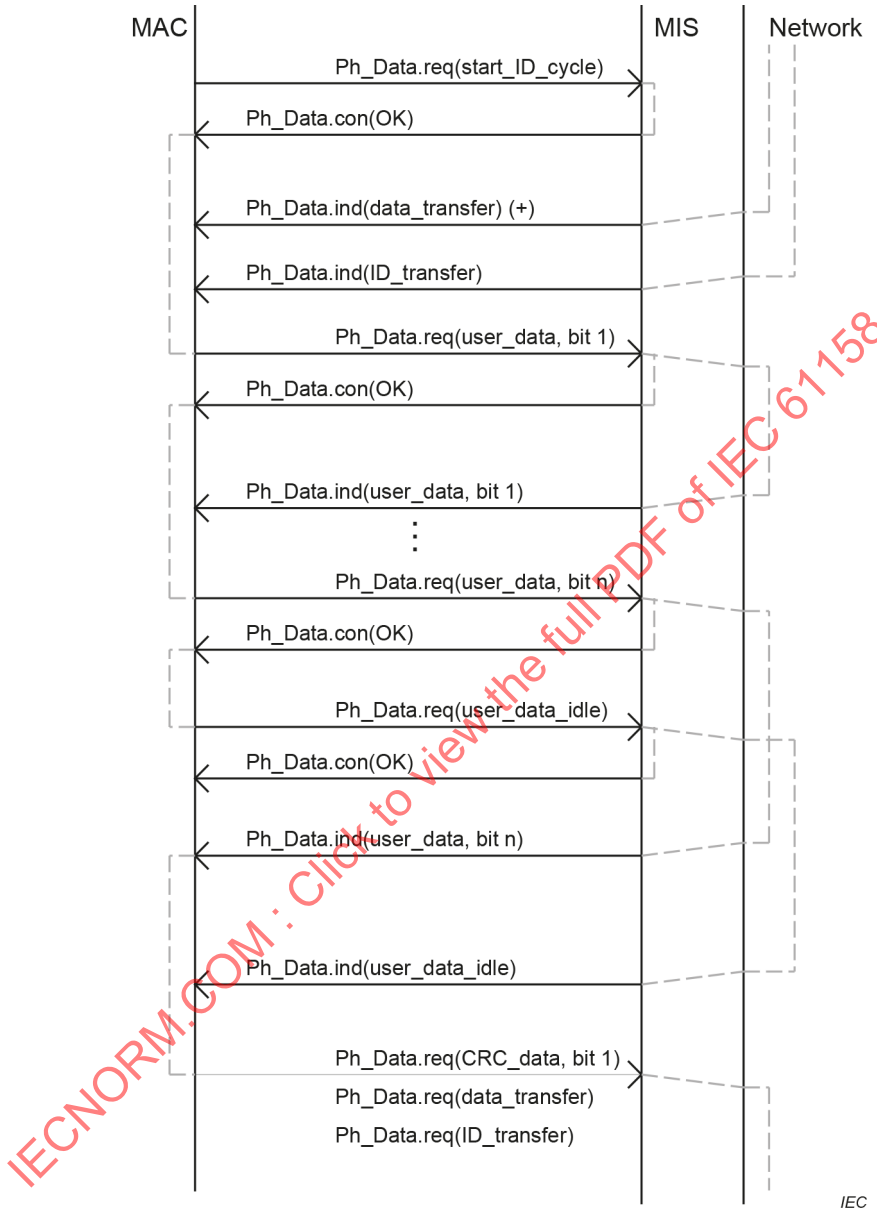


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**Figure 4 – Interactions for a data sequence of a master: identification cycle**

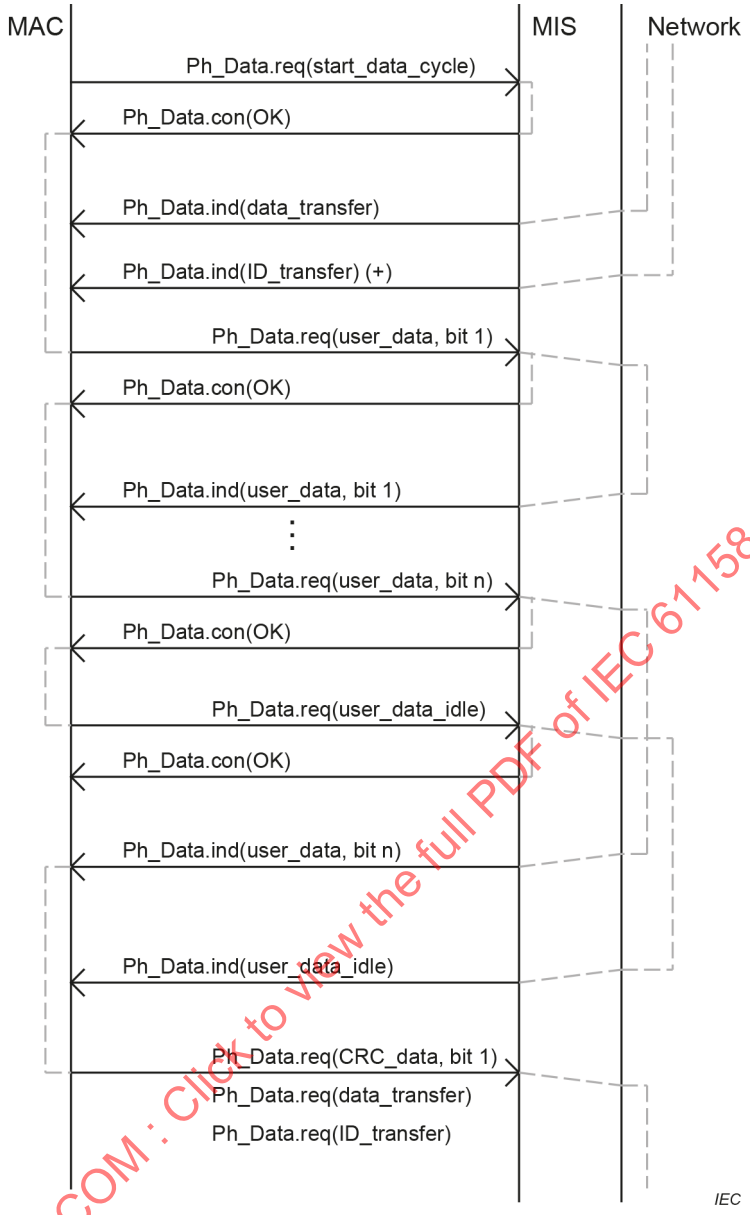


**Figure 5 – Interactions for a data sequence of a master: data cycle**

#### 5.7.3.2.2 Slave

Figure 6 and Figure 7 show the interactions for a data sequence (identification cycle and data cycle) at the DL-Ph interface of a slave (remote bus device, local bus device or bus coupler).

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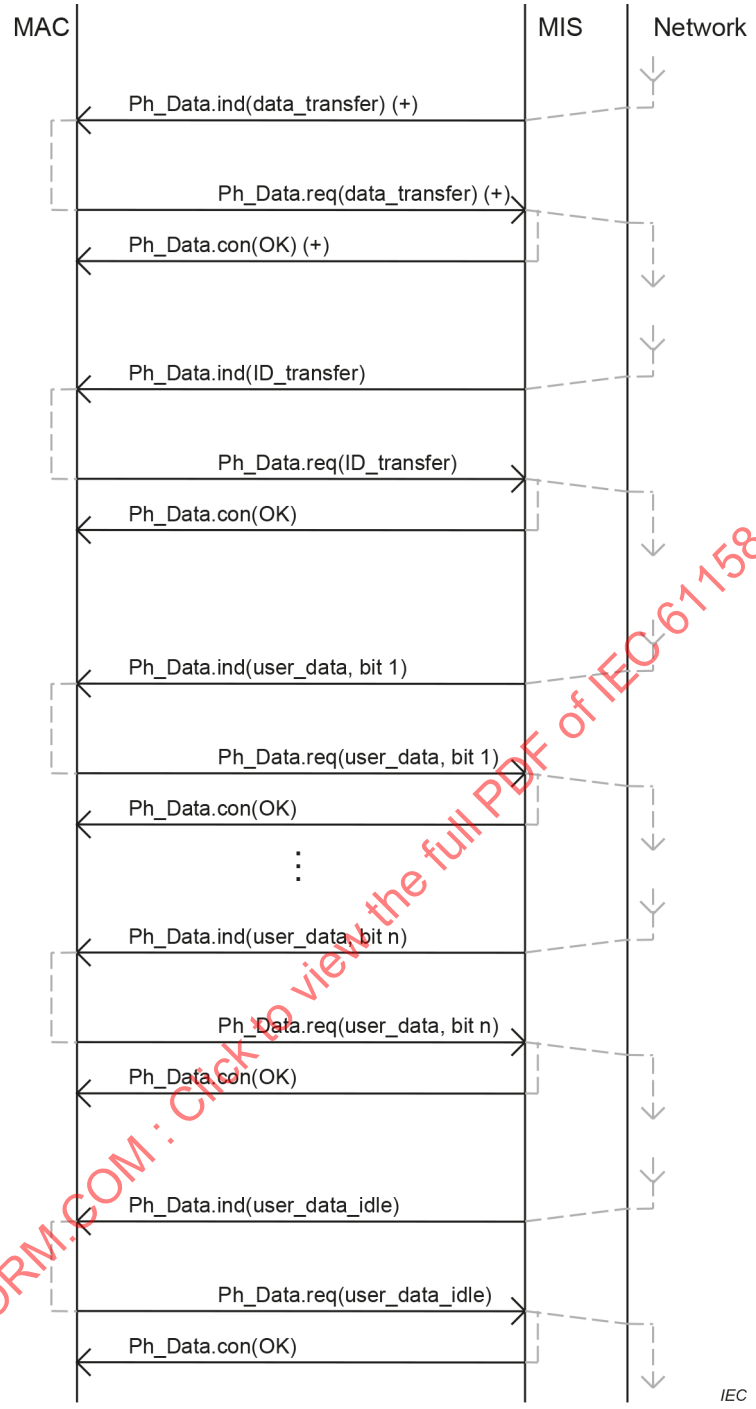


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**Figure 6 – Interactions for a data sequence of a slave: identification cycle**

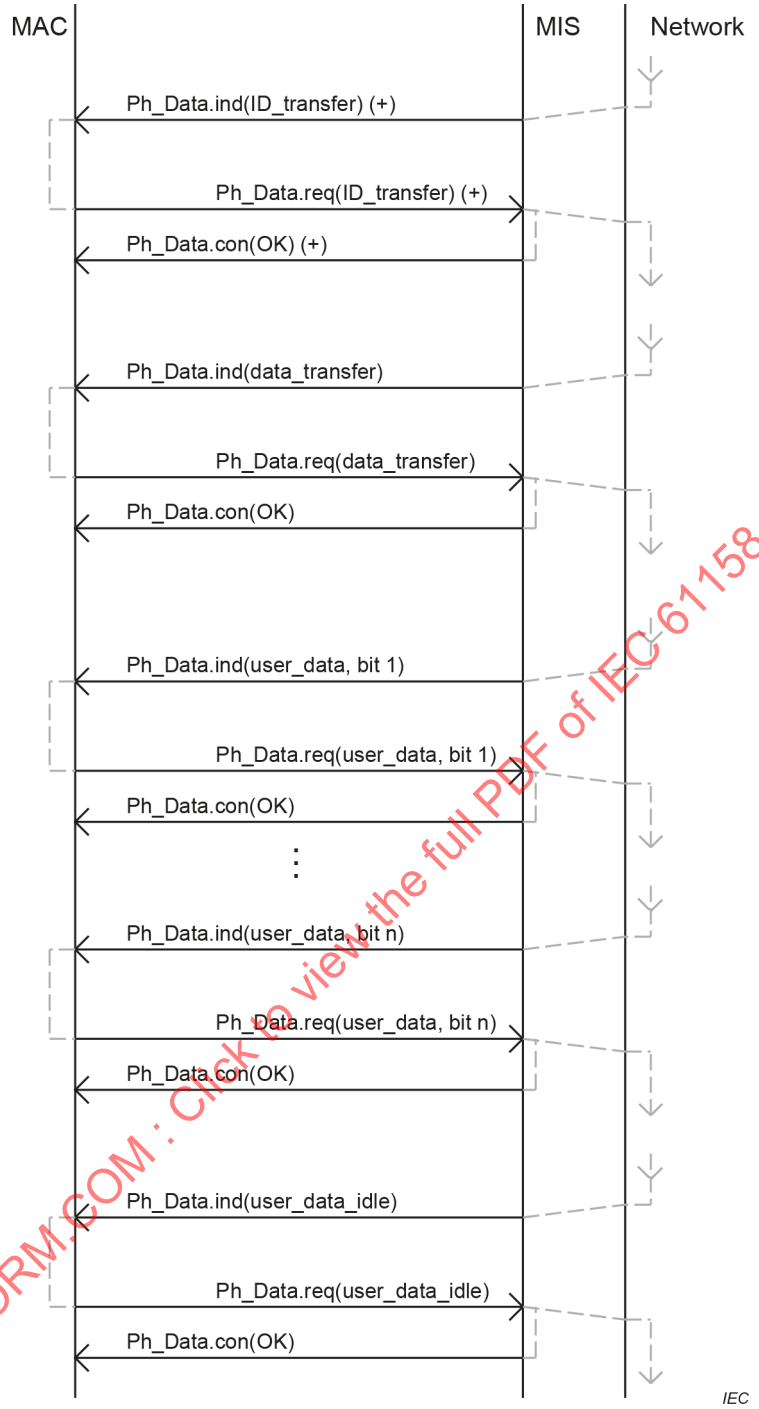


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**Figure 7 – Interactions for a data sequence of a slave: data cycle**

#### 5.7.3.3 Check sequence

##### 5.7.3.3.1 Master

Figure 8 shows the interactions for a check sequence at the DL-Ph interface of a master.

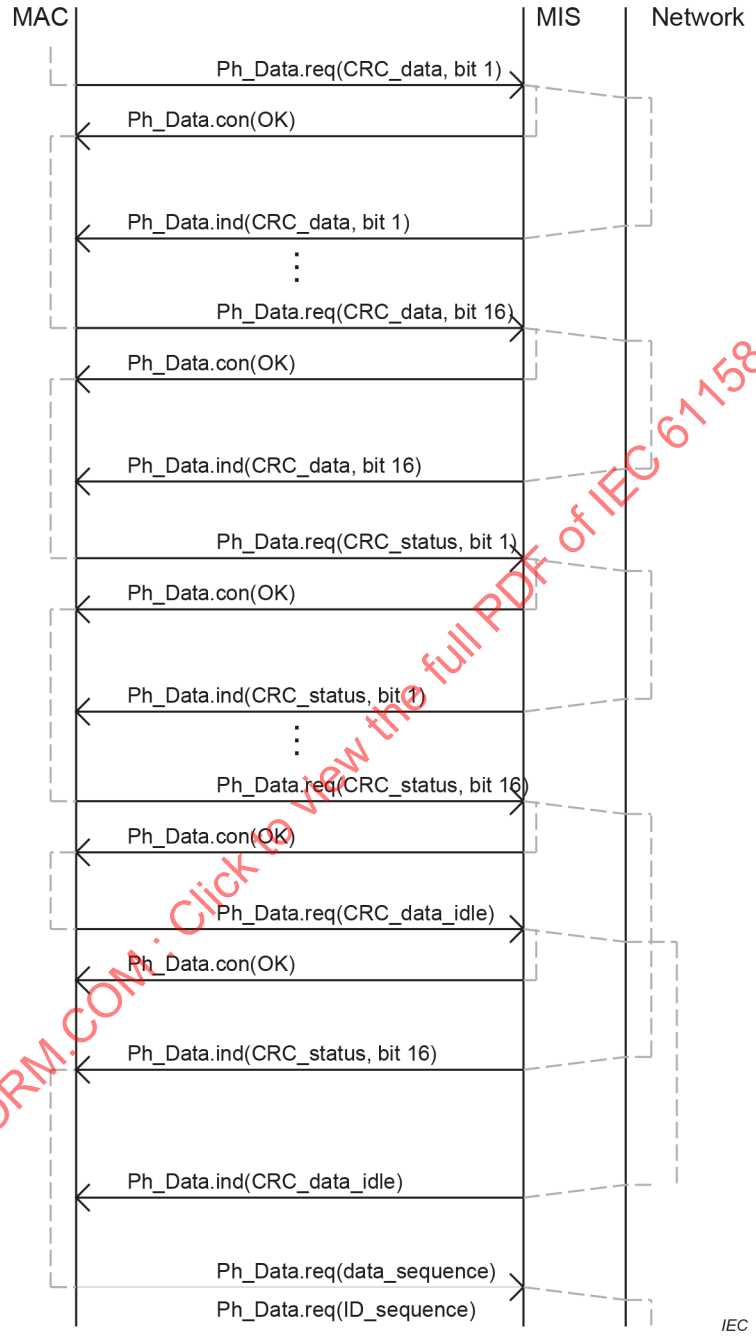


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**Figure 8 – Interactions for a check sequence of a master**

#### 5.7.3.3.2 Slave

Figure 9 shows the interactions for a check sequence at the DL-Ph interface of a slave.

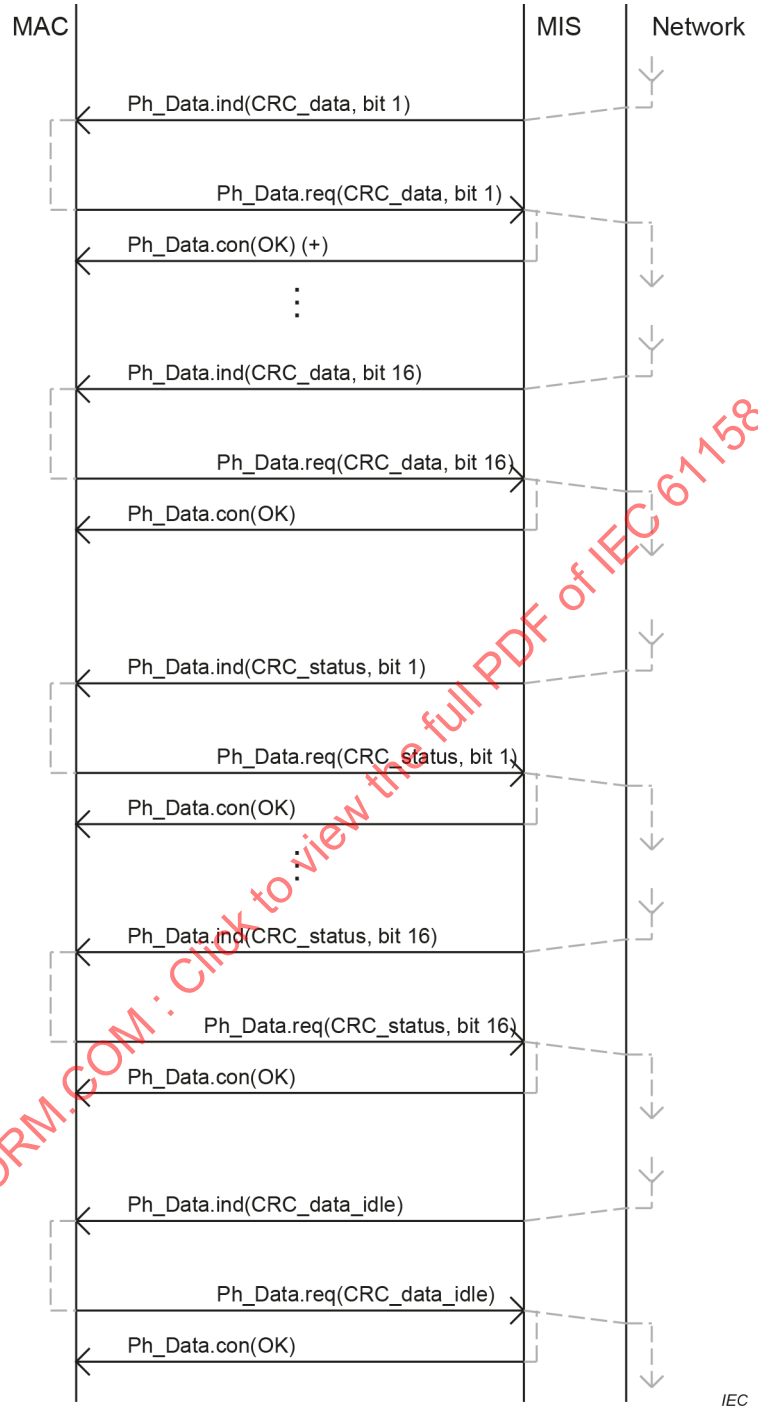


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**Figure 9 – Interactions for a check sequence of a slave**

## 5.8 Type 12: Required services

This Interface conforms to the media independent interface described in ISO/IEC/IEEE 8802-3:2021, Clause 22.

## 5.9 Type 16: Required services

### 5.9.1 Primitives of the PhS

#### 5.9.1.1 General

The granularity of PhS-user data exchanged at the PhL-DLL interface shall be one octet.

#### 5.9.1.2 PhS transmission and reception services

The PhS shall provide the following service primitives for transmission and reception:

– Ph-Data request (class, data);
– Ph-Data indication (class, data);
– Ph-Data confirm (status)

where

– class - shall specify the PhICI component of the PhIDU.

For a Ph-Data request, its possible values shall be:

– start-of-activity - transmission of the PhPDUs which precede Ph-user data shall commence;
– data - the single-octet value of the associated data parameter shall be transmitted as part of a continuous correctly formed transmission; and
– end-of-data-and-activity - the PhPDUs that terminate Ph-user data shall be transmitted after the last preceding octet of Ph-user data, culminating in the cessation of active transmission.

For a Ph-Data indication, its possible values shall be:

– start-of-activity - reception of an apparent transmission from the PhE has commenced;
– data - the associated data parameter was received as part of a continuous correctly formed reception;
– end-of-data - the ongoing continuous correctly formed reception of Ph-user data has concluded with correct reception of PhPDUs implying end-of-data;
– data - shall specify the PhID component of the PhIDU. It consists of one octet of Ph-user-data to be transmitted (Ph-Data request) or which was received successfully (Ph-Data indication);
– status - shall specify either success or the locally detected reason for inferring failure.

The Ph-Data confirm primitive shall provide the critical physical timing feedback necessary to inhibit the DLE from starting a second transmission before the first is complete. The final Ph-Data confirm of a transmission shall not be issued until the PhE has completed the transmission.

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### 5.9.2 Transmission of Ph-user-data

The PhE shall determine the timing of all transmissions. When the DLE transmits a sequence of PhSDUs, it shall send the sequence of PhSDUs by making a well-formed sequence of Ph-Data requests, consisting of a single request specifying start-of-activity, followed by the required number of consecutive requests, inclusive, specifying data, each conveying a PhSDU, and concluded by a single request specifying end-of-data-and-activity.

The PhE shall signal its completion of each Ph-Data request, and its readiness to accept a new Ph-Data request, by issuing a Ph-Data confirm primitive; the status parameter of the Ph-Data confirm primitive shall convey the success or failure of the associated Ph-Data request. A second Ph-Data request shall not be issued by the DLE until after the Ph-Data confirm corresponding to the first request has been issued by the PhE.

#### 5.9.3 Reception of Ph-user-data

The PhE shall report a received transmission with a well-formed sequence of Ph-Data indications, which shall consist of

a) a single indication specifying start-of-activity; followed by consecutive indications specifying data, each conveying a PhSDU; followed by a single indication specifying end-of-data; and concluded by a single indication specifying end-of-activity; or

b) a single indication specifying start-of-activity; followed by consecutive indications specifying data, each conveying a PhSDU; followed by a single indication specifying end-of-data-and-activity; or

c) a single indication specifying start-of-activity; optionally followed by one or more consecutive indications specifying data, each conveying a PhSDU; and concluded by a single indication specifying end-of-activity.

This last sequence is indicative of an incomplete or incorrect reception. Detection of an error in the sequence of received PhPDUs, or in the PhEs reception process, shall disable further Ph-Data indications with a class parameter specifying data, end-of-data, or end-of-data-and-activity until after both the end of the current period of activity and the start of a subsequent period of activity have been reported by Ph-Data indications specifying end-of-activity and start-of-activity, respectively.

### 5.10 Type 18: Required services

#### 5.10.1 General

The DLL-PhL interface need not be exposed in the implementation of a Type 18 PhE. This interface may be internal to the node and may be implemented as internal to a semiconductor device.

#### 5.10.2 Primitives of the PhS

##### 5.10.2.1 General

The granularity of PhS-user data exchanged at the DLL-PhL interface is one bit.

##### 5.10.2.2 PhS transmission and reception services

The PhS shall provide the following service primitives for transmission and reception:

– PH-DATA request (class, data);
– PH-DATA indication (class, data);
– PH-DATA confirm (status).

where:

- **class** - specifies the Ph-interface-control-information (PhICI) component of the Ph-interface-data-unit (PhIDU).

For a PH-DATA request, possible values of class are:

– START-OF-ACTIVITY - transmission of the PhPDUs which precede Ph-user data shall commence;
– DATA - the single-bit value of the associated data parameter shall be transmitted as part of a continuous correctly formed transmission; and
– END-OF-ACTIVITY - the PhPDUs that terminate Ph-user data shall be transmitted after the last preceding bit of Ph-user data, culminating in the cessation of active transmission.

For a PH-DATA indication, possible values of class are:

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– START-OF-ACTIVITY - reception of an apparent transmission from one or more PhEs has commenced;

– DATA - the associated data parameter was received as part of a continuous correctly formed reception;

– END-OF-ACTIVITY - the ongoing reception (of an apparent transmission from one or more PhEs) has concluded, with no further evidence of PhE transmission; and

- **data** - shall specify the PhID component of the PhIDU. It consists of one bit of Ph-user-data to be transmitted (PH-DATA request) or which was received successfully (PH-DATA indication).

  and

- **status** - shall specify either success or the locally detected reason for inferring failure.

The PH-DATA confirm primitive shall provide the critical physical timing feedback necessary to inhibit the DL-user from starting a second transmission before the first is complete. The final PH-DATA confirm of a transmission shall not be issued until the PhE has completed the transmission.

### 5.10.3 Transmission of Ph-user-data

The PhE shall determine the timing of all transmissions. When a DLE transmits a sequence of PhSDUs, the DLE shall send the sequence of PhSDUs by making a well-formed sequence of PH-DATA requests, consisting of a single request specifying START-OF-ACTIVITY, followed by a series of consecutive requests specifying DATA, each conveying a PhSDU, and concluded by a single request specifying END-OF-ACTIVITY.

The PhE shall signal its completion of each PH-DATA request, and its readiness to accept a new PH-DATA request, by issuing a PH-DATA confirm primitive; the status parameter of the PH-DATA confirm primitive shall convey the success or failure of the associated PH-DATA request. A second PH-DATA request shall not be issued by the DLE until after the PH-DATA confirm corresponding to the first request has been issued by the PhE.

### 5.10.4 Reception of Ph-user-data

The PhE shall report a received transmission with a well-formed sequence of PH-DATA indications, which shall consist of a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA, each conveying a PhSDU; followed by a single indication specifying END-OF-ACTIVITY.

## 5.11 Type 24: Required services

### 5.11.1 General

The DLL-PhL interface need not be exposed in the implementation of Type 24 PhL. This interface may be internal to the node and may be implemented as internal to a semiconductor device.

Table 4 shows the primitives and the parameters that are exchanged between DLL and PhL.

**Table 4 – Primitives and parameters in DLL-PhL interface**

| Service primitives | Parameters |
|---|---|
| PLS_CARRIER.indication {CARRIER_STATUS} | CARRIER_ON, CARRIER_OFF |
| PLS_DATA_VALID.indication {DATA_VALID_STATUS} | DATA_VALID, DATA_NOT_VALID |
| PLS_SIGNAL.indication {SIGNAL_STATUS} | SIGNAL_ERROR, NO_SIGNAL_ERROR |
| PLS_DATA.indication {INPUT_UNIT} | ZERO, ONE |
| PLS_DATA.request {OUTPUT_UNIT} | ZERO, ONE |

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### 5.11.2 DL_Symbols

The PhL Interface Data Units present at the DLL-PhL interface shall be DL_symbols. DL_symbol shall have one of the following values:

a) ZERO corresponds to a binary "0";

b) ONE corresponds to a binary "1".

### 5.11.3 PLS_CARRIER indication

PLS_CARRIER indication shall represent the presence of a signal carrier on the medium. The parameter CARRIER_STATUS shall take on one of two values; CARRIER_ON or CARRIER_OFF. The CARRIER_ON indicates that the MDS detect the change of Ph_Symbol that has been inputted from MAU. The CARRIER_OFF indicate that the MDS detected the state without the change in Ph_Symbol continuing more than 3 times. This primitive is generated whenever the CARRIER_STATUS make a transition from CARRIER_OFF to CARRIER_ON or vice versa.

### 5.11.4 PLS_SIGNAL indication

PLS_SIGNAL indication shall provide an indication of decoding status by the MDS. The parameter SIGNAL_STATUS shall take on one of two values; NO_SIGNAL_ERROR or SIGNAL_ERROR. The NO_SIGNAL_ERROR indicates that MDS detect the manchester code pattern "L, H" or "H, L" from Ph_Symbols that has been inputted from MAU. The SIGNAL_STATUS indicates that the MDS detect manchester violation. This primitive is generated whenever the SIGNAL_STATUS make a transition from SIGNAL_ERROR to NO_SIGNAL_ERROR or vice versa.

### 5.11.5 PLS_DATA_VALID indication

PLS_DATA_VALID indication shall provide an indication of Ph_Symbol synchronization by the MDS. The parameter DATA_VALID_STATUS shall take on one of two values; DATA_VALID or DATA_NOT_VALID. The DATA_VALID indicates that MDS detect the sequence of bit pattern "0, 1, 0" or "1, 0 , 1" from DL_Symbol to be passed to DLL. The DATA_NOT_VALID indicates that the MDS detect carrier off. This primitive is generated whenever the DATA_VALID_STATUS make a transition from DATA_NOT_VALID to DATA_VALID or vice versa.

### 5.11.6 PLS_DATA indication

PLS_DATA indication shall represent the DL_Symbol. Valid symbols shall be ZERO {0} or ONE {1}. PLS_DATA indication shall represent the DL_Symbol as decoded from the MAU whenever the parameter of PLS_DATA_VALID indication is DATA_VALID.

### 5.11.7 PLS_DATA request

PLS_DATA request shall represent the DL_Symbol to be transmitted. The OUTPUT_UNIT parameter shall take on one of tree value, ZERO, ONE.

## 5.12 Type 20: Required services

### 5.12.1 Facilities of the physical layer services

The PhE provides following services:

- Data service - it supports the transfer of Physical layer service (PhS) -user-data from a source PhS-user to a destination PhS-user, and
- PhL-management services - it supports configuration of the PhL.

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### 5.12.2 Sequence of primitives

The relations of primitives of each type at the interface of PhS-user and one PhE to primitives at the PhS-user and the other PhEs are summarized in the diagrams of Figure 10.

Before using the PhE, the PhS-user should start transmission of the activity on the medium using service shown in the sequence of Figure 10 a). At the destination, the reception starts with PH-START indication after the activity has been detected by the PhE. The sequence of Figure 10 b) shows the transmission of PhPDU from the source PhL entity (PhE) to the destination PhE, one octet data per request. The reception ends with Ph-Data indication at the destination. If there is any error in the reception, then the PhE at the destination indicates it by a status parameter and may deliver PhS-user-data. After transmitting all data, the PhS-user should stop transmission of the activity as shown in the sequence of Figure 10 c).

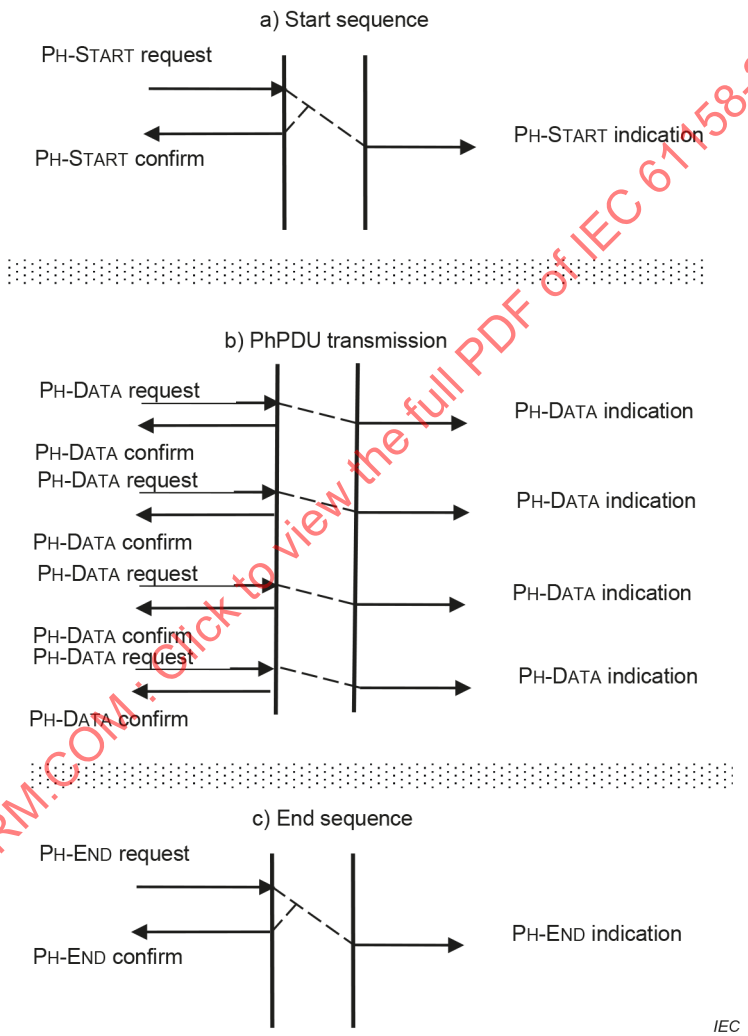


**Figure 10 – Physical layer data service sequences**

### 5.12.3 PH-START service

#### 5.12.3.1 Types of primitives and parameters

Table 5 indicates the types of primitives and the parameters needed for the PH-START service. This service is used to start the activity in the medium and transmit the PhPDUs which precede Ph-user data. The request service is successful only if the medium is in idle state. The confirm primitive does not imply the successful indication at any other device connected to the medium. The receiving device senses the presence of the activity and after a delay it provides the indication to the PhS-user.

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**Table 5 – PH-START primitives and parameters**

| Parameter name | Request | Indication | Confirm |
|---|---|---|---|
| Status | | | M |

#### 5.12.3.2 Parameters

The request primitive does not require any parameter. The indication primitive does not convey any parameter. The confirm primitive indicates either success or a reason for error.

### 5.12.4 PH-DATA service

#### 5.12.4.1 Types of primitives and parameters

Table 6 indicates the types of primitives and the parameters needed for the PH-DATA service.

**Table 6 – PH-DATA primitives and parameters**

| Parameter name | Request | Indication | Confirm |
|---|---|---|---|
| PhS-user-data | M | C(=) | |
| Status | | M | M |

#### 5.12.4.2 Parameters

##### 5.12.4.2.1 PhS-user-data

This parameter allows the transmission of single-octet data between PhS-users without alteration by the PhS-provider. After PH-START confirm, the PhS-users should issue PH-DATA requests such that all data is transmitted as part of a continuous correctly formed transmission. If there is any error in reception then this parameter is either absent in the indication primitive, or its value may have error. Else, its value is identical to the value in the request primitive.

##### 5.12.4.2.2 Status

In the indication primitive, this parameter indicates either success or one of the following reasons for error:

– receive buffer overflow,
– parity error,
– framing error,
– discontinuous data reception.

In the Confirm primitive, this parameter indicates either success or one of the following reasons for error:

– transmitter busy,
– inactive medium.

### 5.12.5 PH-END service

This service is used to end the activity in the medium and transmit the PhPDUs which follow Ph user data. The confirm primitive does not imply the successful indication at any device connected to the medium. This service does not require any parameter. The indication primitive is provided by the PhE when lack of medium activity is detected.

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## 5.13 Type 28: Required services

### 5.13.1 General

The Physical layer Entity (PhE) provides the following services:

Ph-Param - It supports the PhE to notify the Data-link Entity (DLE) of the current Physical Layer (PhL) parameter configuration.

Ph-Data - It supports data transmission between Physical layer Service (PhS) users.

Ph-Clock-Sync - It supports PhS users to implement clock synchronization.

### 5.13.2 Ph-Param (para, value)

The PhE informs DLE of the current working mode, coding and modulation related parameters. The DLE should implement the encapsulation and processing of the PhL Service Data Unit (PhLSDU) according to the parameters. Table 7 shows the primitives and parameters of the Ph-Param service. The primitive parameters are described in Table 8.

**Table 7 – Ph-Param service primitives and parameters**

| Parameter name | Indication |
|---|---|
| para | M |
| value | M |

**Table 8 – Ph-Param service primitive parameter**

| para | | value |
|---|---|---|
| para index | para description | |
| 0 | Transmit_mode | 0 to 3, see Table 50, current system TM |
| 1 | Work_mode | 0 to 21, see Table 51 and Table 52, current working mode parameter<br>0 to 9, corresponding to working mode A0 to A9<br>10 to 21 corresponding to working mode B0 to B11 |
| 2 | Rs_code | 0 to 11, see Table 71, RS code mode |
| 3 | Con_code | 0 to 2, see Table 72, Convolutional code mode |
| 4 | Qam_mode | 0 to 2, respectively corresponding to three mapping mode of 16QAM, 64QAM and 64QAM |

Figure 11 shows this service primitive process.

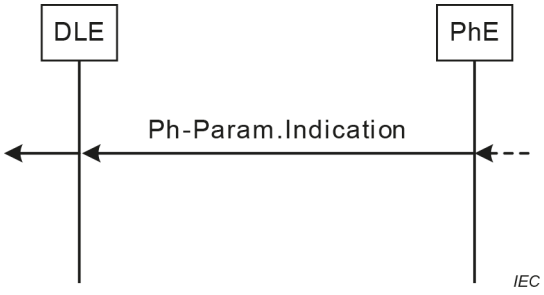


**Figure 11 – Ph-Param service primitive process**

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### 5.13.3 Ph-Data (length, data, status)

The PhE provides the DLL functions for transmitting and receiving data based on the service. Table 9 shows the service primitives and parameters. The length of primitive parameter is octet. Parameter data is Data-link Protocol Data Unit (DLPDU) and status is the processing result of the corresponding service primitive. The primitive parameters are described in Table 10.

**Table 9 – Ph-Data service primitives and parameters**

| Parameter name | Request | Indication | Confirm |
|---|---|---|---|
| length | M | M | M |
| data | M | M | |
| status | | M | M |

**Table 10 – Ph-Data service primitive parameter**

| Parameter name | Description |
|---|---|
| length | Specify the octet length of data |
| data | Transmitting or receiving DLPDU, data is invalid when the flag is the transmitting confirmation |
| status | This parameter is a 16-bit length value<br>Status information indicated by bit<br>bit 0 indicates transmitting or receiving status<br>The corresponding bit set to 0 indicates transmitting and set to 1 indicates receiving<br>bit 1 indicates data status<br>bit 2 indicates CRC check status<br>The corresponding bit set to 0 indicates that the status is correct, and set to 1 indicates status error<br>bit 3 to bit 15 are reserved |

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The DLE requests the PhE to transmit the data based on the Ph-Data.request primitive. When the PhL receives the DLL Ph-Data request primitive, the PhL Data Entity (PhLDE) converts DLPDU to Physical layer Service Data Unit (PhSDU) according to the Physical layer Interface Control Information (PhICI) and add the required Physical layer Protocol Control Information (PhPCI). The Physical layer Protocol Data Unit (PhPDU) in the form of physical signal after encoding and modulation shall be transmitted to the physical medium. The transmitting result is delivered to the DLE through the Ph-Data.Confirm primitive.

The PhLDE informs the Data-link Data Entity (DLDE) to receive data based on the Ph-Data.indication primitive. When the PhL receives the PhPDU in the form of physical signal through the medium, the PhLDE should decode the PhSDU transmitted by the peer PhLDE and convert them into DLPDU according to the PhICI after demodulation and decoding, and send the information to DLE using the Ph-Data.indicaton primitive.

Figure 12 shows this service primitive process.

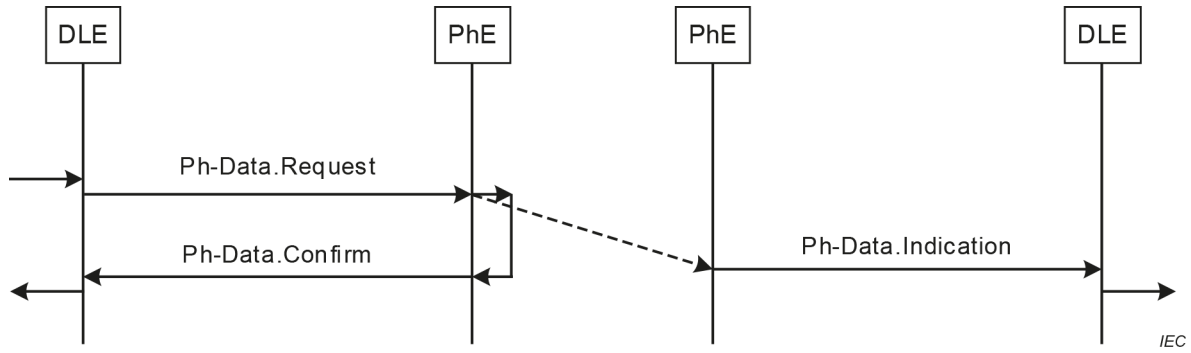


**Figure 12 – Ph-Data service primitive process**

### 5.13.4 Ph-Clock-Sync (command, data, ofdmtiming)

The PhE provides clock synchronization service to the DLL. The DLL should implement the function of clock synchronization and delay measurement based on this service. Table 11 shows the service primitives and parameters. The primitive parameters are described in Table 12.

**Table 11 – Ph-Clock-Sync service primitives and parameters**

| Parameter name | Request | Indication |
|---|---|---|
| command | M | M |
| data | M | M |
| ofdmtiming | | M |

**Table 12 – Ph-Clock-Sync service primitive parameter**

| Parameter name | Description |
|---|---|
| command | DLL requests PhL clock synchronization command<br>0: clock synchronization<br>1: delay measurement |
| data | Clock synchronous frame, fixed length |
| ofdmtiming | PhL OFDM timing information<br>Only the indication primitive is valid |

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When the DLE requests the PhE to transmit clock synchronization information (command = 0 or 1) by using the Ph-Clock-Sync.Request primitive, the PhLDE should fill the clock information field of the clock synchronization frame with the current OFDM timing information, and convert the clock synchronization frame into PhSDU according to the PhICI and add the required PhPCI information. The PhLDE encodes and modulates the PhPDU into physical signals, and then transmits signals to the physical medium. After demodulation and decoding the received signals, the PhLDE should decode the PhSDU transmitted by the peer entity and convert it into a clock synchronous frame according to the PhICI. PhLDE should transmit the PhSDU to DLL using Ph-Clock-Sync.Indicaton primitive.

When the PhLDE receives the Ph-Clock-Sync.Request (Command = 1) primitive, the PhLDE should notify the PhL Management Entity (PhLME) to perform delay measurement processing in addition to transmitting clock synchronous frames.

Figure 13 shows this service primitive process.

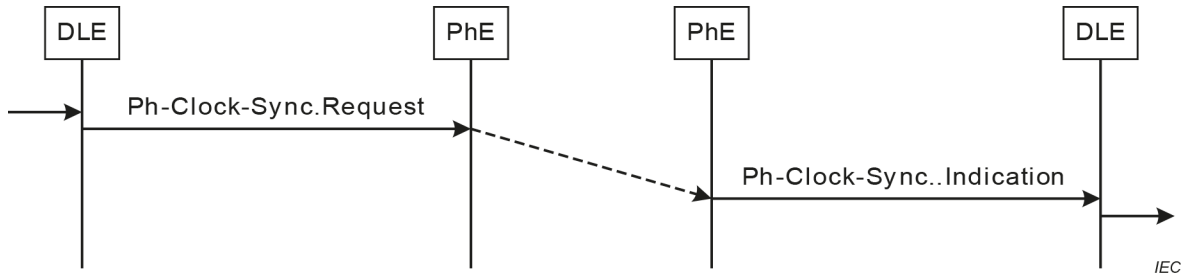


**Figure 13 – Ph-Clock-Sync service primitive process**

# 6 Systems management – PhL interface

## 6.1 General

This interface provides services to the PhL, which are required for initialisation and selection of options.

One of the objectives of the PhL is to allow for future variations such as radio, fiber optics, redundant channels (e.g. cables), different modulation techniques, etc. A general form of Systems management-PhL Interface is specified which provides the services required by implementations of these variations. Services provided by this interface are specified in 6.2 through 6.5. The document does not require this interface to be exposed.

The complete set of management services can only be used when the device is directly coupled to the medium. In the case of actively coupled equipment (e.g. active coupler, repeater, radio/telephone modem, opto-electronics, etc.) some of the services can be implicit to the active coupler. Moreover, each device can use a subset of the described primitives.

NOTE A number of different Systems management-PhL interfaces are specified, based on industry practice.

## 6.2 Type 1: Systems management – PhL interface

### 6.2.1 Required services

The minimum service primitive for PhL (PhL) management shall be:

a) PH-RESET request - reset of the Ph-layer.

The following additional services may be provided:

b) Ph-SET-VALUE request/Ph-SET-VALUE confirm - set parameters;

c) Ph-GET-VALUE request/Ph-GET-VALUE confirm - read parameters;

d) Ph-EVENT indication - report Ph-layer events.

### 6.2.2 Service primitive requirements

#### 6.2.2.1 PH-RESET request

This primitive has no parameter. Upon reception of this primitive the PhL shall reset all its functions.

#### 6.2.2.2 Ph-SET-VALUE request (parameter name, new value)

If this primitive is used it shall allow Systems management to modify the parameters of the PhL. Standard parameter names and value ranges are given in Table 13. The value assumed for each parameter at reset shall be the first of those shown for the parameter.

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**Table 13 – Parameter names and values for Ph-SET-VALUE request**

| Parameter name | Range of values |
|---|---|
| Interface mode | • FULL_DUPLEX<br>• HALF_DUPLEX |
| Loop-back mode | • DISABLED<br>• in MDS at DTE - DCE interface<br>• in MAU near line connection |
| Preamble extension | • 0..7 (preamble extension sequences) |
| Post-transmission gap extension | • 0..7 (gap extension sequences) |
| Maximum inter-channel signal skew | • 0..7 (gap extension sequences) |
| Transmitter output channel *N*<br>(1 ≤ *N* ≤ 8) | • ENABLED<br>• DISABLED |
| Receiver input channel *N*<br>(1 ≤ *N* ≤ 8) | • ENABLED<br>• DISABLED |
| Preferred receive channel | • NONE<br>• 1..8 |

NOTE 1 Not all implementations require every parameter, and some need more.

NOTE 2 Each DCE standard specifies both the basic and extension sequences of PhPDUs to be sent as preamble. These extension sequences are always prefixed to the basic sequence.

NOTE 3 Each DCE standard specifies the lengths of both the basic and extension sequences of post-transmission gap during which the transmitter is silent.

NOTE 4 From the above, the default value at reset is minimum preamble (no extension), minimum post-transmission gap (no extension), full-duplex interface mode, not in loopback, with all transmit and receive channels enabled, and with no preferred receive channel.

#### 6.2.2.3 Ph-SET-VALUE confirm (status)

This primitive has a single parameter indicating the status of the request: Success or Failure. If this primitive is used it shall acknowledge completion of the Ph-SET-VALUE request in the PhL.

#### 6.2.2.4 Ph-GET-VALUE request (parameter name)

If this primitive is used it shall allow the Systems management to read the parameters of the PhL. The parameter shall have one of the names given in Table 13.

#### 6.2.2.5 Ph-GET-VALUE confirm (current value)

This primitive is the response of the PhL to the Ph-GET-VALUE request. If this primitive is used it shall have a single parameter reporting either the failure of the request - Failure - or the present value of the requested parameter. The current value shall be one of those permitted by 6.2.2.2.

#### 6.2.2.6 Ph-EVENT indication (parameter name)

If this primitive is used it shall notify the Systems management of a PhL parameter modification which has not been requested by the Systems management. The parameter shall have one of the names given in Table 14, based on names specified in 8.2.

**Table 14 – Parameter names for Ph-EVENT indication**

| Parameter name |
|---|
| DTE fault |
| DCE fault |

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NOTE Additions to Table 14 are possible if required by specific implementations.

## 6.3 Type 3: Systems management – PhL interface

### 6.3.1 Synchronous transmission

The services and the service primitive requirements specified for Type 1 shall be used (see 6.2).

### 6.3.2 Asynchronous transmission

#### 6.3.2.1 General

Subclause 6.3.2 describe the interface between the PhL asynchronous transmission and a PhMS-user and the associated service primitives and parameters.

The service model, service primitives, and time-sequence diagrams used are entirely abstract descriptions; they do not represent a specification for implementation.

Service primitives, used to represent service user/service provider interactions (see ISO/IEC 10731), convey parameters that indicate information available in the user/provider interaction.

This Type of this document uses a tabular format to describe the component parameters of the PhMS primitives. Each table consists of up to three columns, containing the name of the service parameter, and a column each for those primitives and parameter-transfer directions used by the PhMS:

– the request primitive's input parameters;

– the indication primitive's output parameters; and

– the confirm primitive's output parameters.

One parameter (or part of it) is listed in each row of each table. Under the appropriate service primitive columns, a code is used to specify the type of usage of the parameter on the primitive and parameter direction specified in the column:

**M** – parameter is mandatory for the primitive.

**(blank)** – parameter is never present.

#### 6.3.2.2 Facilities of the PhMS

Ph-management organizes the initialisation and the configuration of the PhE, and the event and error handling between the PhMS-user and the logical functions in the PhE. The following functions are provided to the PhMS-user.

a) Reset of the local PhE

b) Request for and modification of the actual operating parameters of the local PhE

c) Notification of unexpected events and status changes of the local PhE

#### 6.3.2.3 Overview of services

Ph-management provides the following services to the PhMS-user:

a) Reset

The PhMS-user employs this service to cause Ph-management to reset the PhE. A reset is equivalent to power on. The PhMS-user receives a confirmation thereof.

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b) Set Value

The PhMS-user employs this service to assign a new value to the variables of the PhE. The PhMS-user receives a confirmation whether the specified variables have been set to the new value.

c) Get Value

This service enables Ph-management to read the variables of the PhE. The response of the Ph-management returns the actual value of the specified variables.

d) Event

Ph-management employs this service to inform the PhMS-user about certain events or errors in the PhL.

The services Reset and Event are mandatory. The services Set Value and Get Value are optional.

#### 6.3.2.4 Overview of interactions

Ph-management services and their primitives are summarized in Table 15.

**Table 15 – Summary of Ph-management services and primitives**

| Service | Primitive | Possible for the following stations |
|---|---|---|
| Reset | PhM-RESET request<br>PhM-RESET confirm | Master and slave |
| Set Value | PhM-SET-VALUE request<br>PhM-SET-VALUE confirm | Master and slave |
| Get Value | PhM-GET-VALUE request<br>PhM-GET-VALUE confirm | Master and slave |
| Event | PhM-EVENT indication | Master and slave |

The temporal relationships of the Ph-management primitives are shown in Figure 14 and Figure 15.

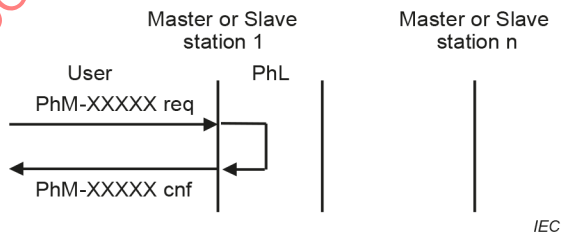


**Figure 14 – Reset, Set-value, Get-value**

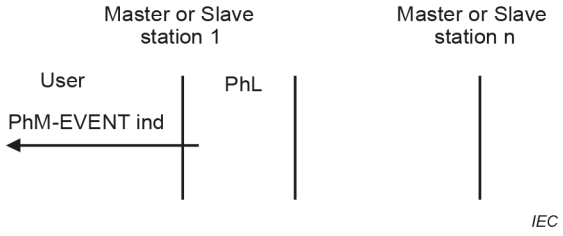


**Figure 15 – Event service**

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#### 6.3.2.5 Detailed specification of services and interactions

##### 6.3.2.5.1 Reset

###### 6.3.2.5.1.1 Function

The PhMS-user passes a PhM-RESET request primitive to Ph-management causing it to reset the PhE. This is carried out in the same manner as at a Power On (Transmitter_output: enabled; Receiver_signal_source: primary; Loop: disabled). As a result, Ph-management passes a PhM-RESET confirm primitive to the PhMS-user to indicate the success or failure of the corresponding service request.

###### 6.3.2.5.1.2 Types of primitives and parameters

Table 16 indicates the primitives and parameters of the Reset service.

**Table 16 – Reset primitives and parameters**

| PhM-RESET | Request | Confirm |
|---|---|---|
| **Parameter name** | | |
| PhM-STATUS | -- | M |
| NOTE The method by which a confirm primitive is correlated with its corresponding preceding request primitive is a local matter. | | |

**PhM-Status**

This parameter specifies the status of the execution of the associated service request. Permitted values for this parameter are specified in Table 17.

**Table 17 – Values of PhM-Status for the Reset service**

| Short name | Status | Definition | Temporary (t) or permanent (p) |
|---|---|---|---|
| OK | success | The Reset function was carried out successfully | -- |
| NO | failure | The Reset function was not carried out successfully | t/p |
| IV | failure | Invalid parameters in request | -- |

##### 6.3.2.5.2 Set Value

###### 6.3.2.5.2.1 Function

The PhMS-user passes a PhM-SET-VALUE request primitive to Ph-management to assign a desired value to one or more specified variables of the PhE. After receiving this primitive Ph-management tries to select these variables and to set the new values. If the requested service was executed Ph-management passes a PhM-SET-VALUE confirm primitive to the PhMS-user to indicate the success or failure of the corresponding service request.

###### 6.3.2.5.2.2 Types of primitives and parameters

Table 18 indicates the primitives and parameters of the Set Value service.

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**Table 18 – Set value primitives and parameters**

| PhM-SET-VALUE | Request | Confirm |
|---|---|---|
| **Parameter name** | | |
| Variable_name (1 to 3) | M | -- |
| Desired_value (1 to 3) | M | -- |
| PhM-STATUS (1 to 3) | -- | M |
| NOTE The method by which a confirm primitive is correlated with its corresponding preceding request primitive is a local matter. | | |

### Variable_name

This array parameter specifies one or more variables (1 to 3) that are to be assigned values from the corresponding elements of the Desired_value parameter. The selectable variables are operating parameters; they are specified in Table 19.

**Table 19 – Mandatory PhE-variables**

| Operating parameters | |
|---|---|
| **Name** | **Definition** |
| Transmitter_output | Transmitter output |
| Receiver_signal_source | Receiver input |
| Loop | The transmitter output is directed to the receiver input and not to the medium |

### Desired_value

This array parameter specifies the actual value to be written to the variables (1 to 3) that are specified by the Variable_name parameter. This parameter specifies a list of one or more (1 to 3) new values for the specified PhE-variables. The permissible value or range of values for each of these variables is specified in Table 20.

**Table 20 – Permissible values of PhE-variables**

| Operating parameters | |
|---|---|
| **Variable** | **Range of values** |
| Transmitter_output | enabled or disabled |
| Receiver_signal_source | primary: bus cable "a" (standard source)<br>alternative: bus cable "b" (alternative source)<br>random: either "a" or "b" |
| Loop | disabled or enabled |

### PhM-Status

This array parameter specifies, for each variable in the corresponding request, the status of that component of the requested service. Permitted values for the individual components of this array parameter are specified in Table 21.

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**Table 21 – Values of PhM-Status for the set-value service**

| Short name | Status | Definition | Temporary (t) or permanent (p) |
|---|---|---|---|
| OK | success | The variable has been set to the new value | -- |
| NO | failure | The variable does not exist or could not be set to the new value | t/p |
| IV | failure | Invalid parameters in request | -- |

#### 6.3.2.5.3 Get Value

##### 6.3.2.5.3.1 Function

The PhMS-user passes a PhM-GET-VALUE request primitive to Ph-management to read the current value of one or more variables of the PhE. After receipt of this primitive Ph-management tries to select the specified variables and to deliver their current values and passes a PhM-GET-VALUE confirm primitive to the PhMS-user to indicate the success or failure of the corresponding service request. This primitive returns as a parameter one or more of the requested variable values.

##### 6.3.2.5.3.2 Types of primitives and parameters

Table 22 indicates the primitives and parameters of the Get Value service.

**Table 22 – Get value primitives and parameters**

| PhM-GET-VALUE | Request | Confirm |
|---|---|---|
| **Parameter name** | **input** | **output** |
| Variable_name (1 to 3) | M | -- |
| Current_value (1 to 3) | -- | M |
| PhM-STATUS | -- | M |
| NOTE The method by which a confirm primitive is correlated with its corresponding preceding request primitive is a local matter. | | |

**Variable_name**

This array parameter specifies one or more variables (1 to 3) whose values are to be read. The variables that may be selected are specified in Table 19.

**Current_value**

This array parameter specifies the actual value of the (1 to 3) variables that were specified by the Variable_name parameter of the corresponding request. The permissible value, or range of values, for each of these variables is specified in Table 23.

**Table 23 – Current values of PhE-variables**

| Operating parameters | |
|---|---|
| **Variable** | **Range of values** |
| Transmitter_output | enabled or disabled |
| Receiver_signal_source | primary or alternative |
| Loop | disabled or enabled |

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**PhM-Status**

This array parameter specifies for each variable in the corresponding request a confirmation about the execution of the service. Permitted values for this parameter are specified in Table 24.

**Table 24 – Values of PhM-Status for the get value service**

| Short name | Status | Definition | Temporary (t) or permanent (p) |
|---|---|---|---|
| OK | success | The variable could be read | -- |
| NO | failure | The variable does not exist or could not be read.<br>The corresponding value of Current_value is not defined | t/p |
| IV | failure | Invalid parameters in request | -- |

#### 6.3.2.5.4 Event

##### 6.3.2.5.4.1 Function

The PhE informs Ph-management that it has detected an event. After that, Ph-management passes a Ph-EVENT indication primitive to the PhMS-user to inform it about important events in the PhL.

##### 6.3.2.5.4.2 Types of primitives and parameters

Table 25 indicates the primitive and parameters of the Event service.

**Table 25 – Event primitive and parameters**

| PhM-EVENT | Indication |
|---|---|
| **Parameter name** | **output** |
| Variable_name (1 to 2) | M |
| New_value (1 to 2) | M |

**Variable_name**

This array parameter specifies one or more variables (1 to 2) whose values were changed. The variables that may be present are specified in Table 19.

**New_value**

This parameter specifies the new value of the variable. The various values are shown in Table 26.

**Table 26 – New values of PhE-variables**

| Variable | Range of values |
|---|---|
| Transmitter_output | enabled or disabled |
| Receiver_signal_source | primary or alternative |

### 6.4 Type 4: Systems management – PhL interface

#### 6.4.1 Required Services

The services specified in 6.2 are used.

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### 6.4.2 Service primitive requirements

The service primitive requirements are specified in 6.2.2 with the following restriction:

The parameters specified in Table 13 are not supported.

The parameters that can be modified and read by the PhL management services are shown in Table 27. Supported values and default value for each parameter depend on the actual medium and implementation.

**Table 27 – Parameter names and values for management**

| Parameter name | Range of values |
|---|---|
| Interface mode | HALF_DUPLEX<br>FULL_DUPLEX_UDP |
| Baud rate (kbaud/s) | 230 400<br>76 800<br>38 400<br>19 200<br>9 600 |

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## 6.5 *Void*

NOTE Subclause 6.5 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

## 6.6 Type 8: Systems management – PhL interface

### 6.6.1 Functionality of the PhL Management

The management of the PhL is the part of the PhL that produces the management functionality of the PhL that are demanded by the PNM1. The management of the PhL handles the initialisation, the monitoring, and the error recovery in the PhL.

### 6.6.2 PhL-PNM1 Interface

#### 6.6.2.1 General

Subclause 6.6.2 defines the administrative PhL management services that are available to the PNM1, together with their service primitives and associated parameters. Figure 16 shows the interface between PhL and PNM1 in the layer model.

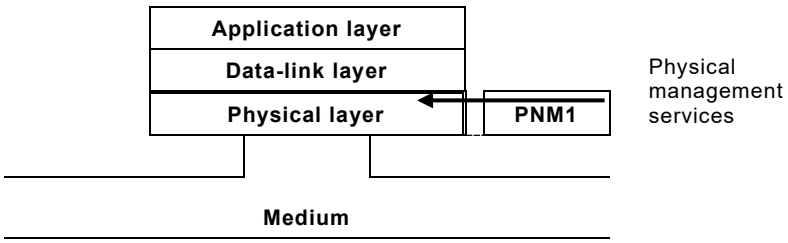


**Figure 16 – Interface between PhL and PNM1 in the layer model**

The service interface between PhL and PNM1 provides the following functions:

– Reset of the PhL
– Request and change of the current operating parameters of the PhL

– Indication of unexpected events, errors and status changes, which occurred or were detected in the PhL

#### 6.6.2.2 Overview of the Services

The PhL makes the following services available to the PNM1:

– Reset PhL
– Set Value PhL or Get Value PhL
– Event PhL

**Reset PhL (mandatory)**

The PNM1 uses this service to reset the PhL. The reset is equivalent to power on. Upon execution of the service, the PNM1 receives a confirmation.

**Set Value PhL (optional)**

The PNM1 uses this service to set new values to the PhL variables. Upon completion, the PNM1 of the PhL receives a confirmation whether the defined variables assumed the new values.

**Get Value PhL (optional)**

The PNM1 uses this service to read out variables of the PhL. The current value of the defined variable is returned in the response of the PhL.

**Event PhL (mandatory)**

The PhL uses this service to inform the PNM1 user about certain events or errors in the PhL.

#### 6.6.2.3 Overview of the Interactions

The PhL services are described by the following primitives (beginning with Ph-…):

**Reset PhL**

PH-RESET request
PH-RESET confirm

**Set Value PhL**

Ph-SET-VALUE request
Ph-SET-VALUE confirm

**Get Value PhL**

Ph-GET-VALUE request
Ph-GET-VALUE confirm

**Event PhL**
Ph-Event indication

Figure 17 and Figure 18 show the time relations of the service primitives.

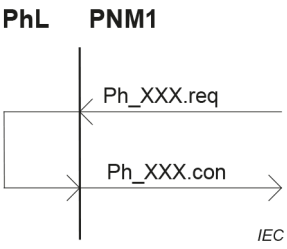


**Figure 17 – Reset, Set-value, Get-value PhL services**

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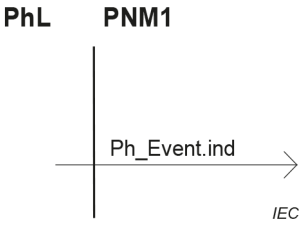


**Figure 18 – Event PhL service**

#### 6.6.2.4 Detailed definitions of the services and Interactions

##### 6.6.2.4.1 PH-RESET

The PH-RESET service is mandatory. The PNM1 transfers a PH-RESET request primitive to the PhL to reset it (see Table 28).

**Table 28 – PH-RESET**

| Parameter name | Request | Confirm |
|---|---|---|
| Argument | M | |
| Result(+) | | M |

##### 6.6.2.4.2 Ph-SET-VALUE

The Ph-SET-VALUE service is optional. The PNM1 transfers a Ph-SET-VALUE request primitive to the PhL, to set a defined Ph variable to a desired value. After receipt of this primitive, the PhL tries to select the variable and to set the new value. Upon completion, the PhL transfers a Ph-SET-VALUE confirm primitive to the PNM1 (see Table 29).

**Table 29 – Ph-SET-VALUE**

| Parameter name | Request | Confirm |
|---|---|---|
| Argument | M | |
| variable_name | M | |
| desired_value | M | |
| Result(+) | | M |

**variable_name:**

This parameter defines the PhL variable that is set to a new value.

**desired_value:**

This parameter declares the new value for the PhL variable.

Table 30 provides information on which PhL variable may be set to which new value.

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**Table 30 – PhL variables**

| Name of PhL variable |
|---|
| loopback_mode |
| medium_attachment |
| bus_ interfaces |
| short_ bus_reset_time |
| long_bus_reset_time |
| data_select |

**loopback_mode:**

This parameter defines whether the receive circuit of the MAU is connected to the send circuit or to the medium.

Parameter structure:

– interface number

  Defines the number of the incoming and outgoing interface (see Figure 19).

– status

  This parameter defines whether the receive circuit of the MAU is connected (enabled) or not (disabled). After power on this value is equivalent to "enabled".

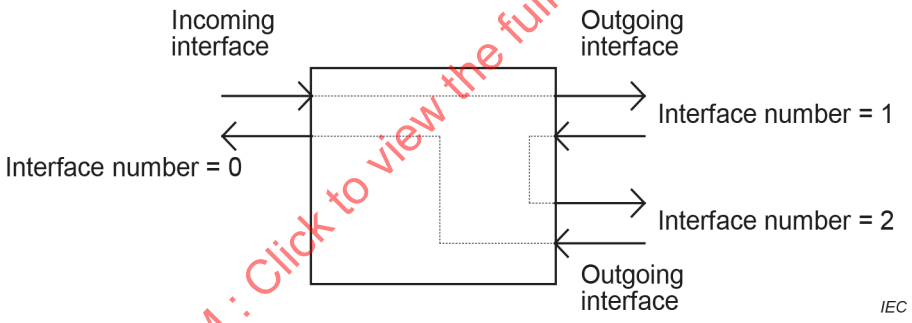


**Figure 19 – Allocation of the interface number**

NOTE A master has always the interface number = 2.

**medium_attachment:**

This parameter indicates whether the MAU is coupled to the transmission medium. This is done by detecting whether a connector is plugged to the outgoing interface.

Parameter structure:

– interface number

  Declares the number of the bus interface (see Figure 19).

– attachment

  This parameter defines whether the interface is connected to the transmission medium.

**bus_interfaces:**

– interface number

  Declares the number of the bus interface (see Figure 19).

– interface type

  Defines the type of the physical interface and the transmission medium:

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- Incoming interface, 2-wire
- Outgoing interface, 2-wire

**short_bus_reset_time:**

This parameter defines the duration of the short reset. The value after power on is 5 ms.

**long_bus_reset_time:**

This parameter defines the duration of the long reset. The value after power on is 100 ms.

**data_select:**

This parameter indicates a Reset_PhPDU or a medium_activity_status_PhPDU is sent on the transmission medium for a passive outgoing MAU (loopback mode= disable)

Parameter structure

– interface number

  Defines the number of the bus interface (see Figure 19). Value range (1 to 2)

– coupling

  Disable: A reset PHPDU is transmitted on the transmission medium;

  Enable: The medium activity status PhPDU is transmitted on the transmission medium after "power on" this value is "disable".

#### 6.6.2.4.3 Ph-GET-VALUE

The Ph-GET-VALUE service is optional. The PNM1 transfers a Ph-GET-VALUE request primitive to the PhL to read out the current value of a defined PhL variable. After the PhL has received this primitive it tries to select the defined variable and to transfer the present value to the PNM1 by means of a Ph-GET-VALUE confirm primitive (see Table 31).

**Table 31 – Ph-GET-VALUE**

| Parameter name | Request | Confirm |
|---|---|---|
| Argument | M | |
| variable_name | M | |
| Result(+) | | M |
| current_value | | M |

**variable_name:**

This parameter defines the PhL variable the value of which is to be read out.

**current_value:**

This parameter contains the read-out value of the PhL variable. The PhL variables to be read are those variables that can be written to with the Ph-SET-VALUE.

#### 6.6.2.4.4 Ph-EVENT

The Ph-EVENT service is mandatory. The PhL transfers a Ph-EVENT indication primitive to the PNM1, to inform it about important events or errors in the PhL (see Table 32).

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**Table 32 – Ph-EVENT**

| Parameter name | Indication |
|---|---|
| Argument | M |
| event | M |

**event:**

This parameter defines the event that occurred or the error source in the PhL and may have the values according to Table 33:

**Table 33 – PhL events**

| Name | Meaning |
|---|---|
| stop_bit_error | Stop bit error detected in the MDS sublayer |
| medium_attachment | The medium attachment changed at an outgoing MAU |

## 6.7 Type 12: Systems management – PhL interface

This Interface conforms to the management functions described in ISO/IEC/IEEE 8802-3:2021, 22.2.4.

## 6.8 Type 18: Systems management – PhL interface

### 6.8.1 General

The Systems management-PhL interface need not be exposed in the implementation of a Type 18 PhE. This interface may be internal to the node and may be implemented as internal to a semiconductor device.

### 6.8.2 Required services

The minimum service primitive for PhL management shall be:

a) PH-RESET request - reset of the Ph-layer;

b) Ph-SET-VALUE request - set parameters.

### 6.8.3 Service primitive requirements

#### 6.8.3.1 PH-RESET request

This primitive has no parameter. Upon reception of this primitive the PhL shall reset all its functions.

#### 6.8.3.2 Ph-SET-VALUE request (parameter name, new value)

This primitive shall allow Systems management to modify the parameters of the PhL. Standard parameter names and value ranges are given in Table 34.

Not all values are supported by all Type 18 PhE variants. Baud rate limitations are associated with the Type 18 MAU variant implemented.

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**Table 34 – Parameter names and values for Ph-SET-VALUE request**

| Parameter name | Range of values |
|---|---|
| Baud rate (kbaud/s) | 10 000 |
| | 5 000 |
| | 2 500 |
| | 625 |
| | 156 |

### 6.9 Type 24: Systems management – PhL interface

The following service primitives for PhL management shall be supported. Detailed specification for each service primitive depends on the actual medium and implementation.

a) PH-RESET request - reset of the Ph-Layer

b) Ph-SET-VALUE request/Ph-SET-VALUE confirm - set parameters

c) Ph-GET-VALUE request/Ph-GET-VALUE confirm - read parameters

d) Ph-EVENT indication - report Ph-Layer events

### 6.10 Type 28: Systems management – PhL interface

#### 6.10.1 General

This interface provides services to the PhL, which are required for initialisation and selection of options.

The system management user handles the related content of the PhLME based on this interface. The service interface parameter named parameter_index should be consistent with the PhLME. See 6.10.2 for related information about PhL entity and system management information. Subclause 6.10 does not require this interface to be exposed. Each device in the network can use a subset of the described primitives in this document.

#### 6.10.2 PhL related management information table

##### 6.10.2.1 General

The PhL management information includes physical device configuration information, system configuration information, PhL synchronization management information, system diagnosis and maintenance information and physical communication resource management information. The system management user or data-link management user is permitted to access the corresponding information table through the service interface provided by the PhL.

##### 6.10.2.2 Physical device configuration information table

Table 35 defines physical device configuration information.

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**Table 35 – Physical device configuration information table**

| Parameter index | Parameter Name | RW | Data Type | Description |
|---|---|---|---|---|
| 0x0000 | node_id | R/W | UINT16 | Device node identifier (NodeID)<br>High 8 bits are reserved, low 8 bits are valid<br>Valid Number value in range from 0 to 255<br>0: management node<br>1 to 253: terminal node or multicast group NodeID. Multicast group NodeID decreases from 253 in turn., and supports up to 16 groups<br>254: Reserved for the nodes that are not assigned NodeID<br>255: Broadcast address number |
| 0x0001 | mcn_bmp | RW | UINT16 | The multicast group to which the node belongs<br>bit 0 to bit 15: corresponding multicast group NodeID from 238 to 253<br>The corresponding bit set to 0 indicates that the node device does not belong to the multicast group, and set to 1 indicates that the node device belongs to the multicast group. |
| 0x0002 | device_role | R/W | UINT8 | Device type node role represented by bit<br>bit 0 indicates whether it is management node<br>bit 1 indicates whether it is terminal node<br>Setting the corresponding bit to 1 indicates it is corresponding role, and setting to 0 indicates it is not corresponding role<br>The values of bit 0 and bit 1 on the working node should be different<br>bit 2 to bit 7: reserved |
| 0x0003 | device_state | RO | UINT8 | The state of the node at different phases represented by bit<br>bit 0: initialization state<br>bit 1: configuration state<br>bit 2: running state<br>bit 3: synchronization state<br>Setting the corresponding bit set to 0 indicates state is normal, and setting to 1 indicates the state is abnormal.<br>bit 5 to bit 7: reserved |
| 0x0004 to 0x008F | reserved | | | Protocol reserved |
| 0x0090 to 0x00FF | reserved | | | Reserved for equipment manufacturer |

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### 6.10.2.3 System configuration related information table

Table 36 defines system configuration related information.

**Table 36 – System configuration related information table**

| Parameter Index | Parameter Name | RW | | Data Type | Description |
|---|---|---|---|---|---|
| 0x0100 | trans_mode | R/W | | UINT8 | Transmit mode<br>Value in range from 0 to 255, see Table 50 for valid value<br>0: corresponding transmit mode 0<br>1: corresponding transmit mode 1<br>2: corresponding transmit mode 2<br>3: corresponding transmit mode 3<br>The default value is 0<br>Other values are reserved |
| 0x0101 | work_mode_up | R/W | | UINT8 | Upper sideband working mode<br>Value in range from 0 to 255 and valid value in range from 0 to 21 (see 8.6.2.2.6 for working mode).<br>0 to 9: corresponding working mode A0 to A9;<br>10 to 21: corresponding working mode B0 to B11;<br>Default value is 0<br>Other values are reserved |
| 0x0102 | work_mode_down | R/W | | UINT8 | Lower sideband working mode<br>Value range and value description are same with work_mode_up |
| 0x0103 | cb_up | RO | | UINT8 | Upper sideband coding mode<br>Value in range from 0 to 255<br>High 5 bits value corresponds to RS code mode (see Table 71), and valid value range is 0 to 11. Other values are reserved.<br>Low 3 bits value corresponds to convolutional code mode (see Table 72) and valid value in range from 0 to 2. Other values are reserved. |
| 0x0104 | cb_down | RO | | UINT8 | Lower sideband coding mode<br>Value range and value description are same with cb_up. |
| 0x0105 | inter_mode | RO | | UINT8 | Interleaving mode<br>Value in range from 0 to 255<br>High 4 bits indicates the upper sideband<br>interleaving mode. Low 4 bits indicates the lower sideband interleaving mode. The valid value range of every 4 bits is 0 to 4, and other values are reserved, see Table 73 for valid value. |
| 0x0106 | power_ratio | R/W | | UINT8 | Sideband power ratio<br>Value in range from 0 to 255<br>0: Indicates upper and lower sideband power average distribution, and other values are reserved. |

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| Parameter Index | Parameter Name | RW | | Data Type | Description |
|---|---|---|---|---|---|
| 0x0107 | band_flag | R/W | | UINT8 | Sideband occupation flag represented by bit<br>bit 0: lower sideband occupation flag.<br>bit 1: upper sideband occupation flag.<br>Setting the corresponding bit to 0 indicates that it is not occupied, and setting to 1 indicates it is occupied<br>bit 2 to bit 7: reserved |
| 0x0108 | net_state | RO | | UINT8 | Network state<br>Value in range from 0 to 255<br>0: initialization state<br>1: normal working state<br>Other values are reserved |
| 0x0109 | reset_en | WO | | UINT8 | Reset flag bit represented by bit<br>bit 0: PhL reset flag<br>Setting the corresponding bit set to 0 indicates disable, and setting to 1 indicates enable.<br>bit 1 to bit 7: reserved |
| 0x010A | lb_mode | R/W | | UINT8 | Loopback mode setting indicated by bit.<br>bit 0: loopback at the DCE and DTE interfaces<br>bit 1: loopback at MAU near the cable side.<br>Setting the corresponding bit to 0 indicates disable, and setting to 1 indicates enable.<br>bit 2 to bit 7: reserved |
| 0x010B to 0x018F | reserved | | | | Protocol reserved |
| 0x0190 to 0x01FF | reserved | | | | Reserved for equipment manufacturer |

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#### 6.10.2.4 PhL synchronization management information table

Table 37 defines PhL synchronization management information table.

**Table 37 – PhL synchronization management information table**

| Parameter Index | Parameter name | RW | Data Type | Description |
|---|---|---|---|---|
| 0x0200 | sync_delay | RW | UINT8 | Synchronization delay information<br>Value in range from 0 to 255<br>0: Indicates that the synchronization is normal or it is synchronizing<br>Other values N: should wait for N Signal frames (SF) to start synchronous processing |
| 0x0201 | cycle_id | RO | UINT16 | Cycle ID value<br>Value in range from 0 to 65 536<br>Valid value range is 0 to 16 383<br>Other values are reserved |

| Parameter Index | Parameter name | RW | Data Type | Description |
|---|---|---|---|---|
| 0x0202 | symbol_id | RO | UINT8 | OFDM symbol ID<br>Value in range from 0 to 255<br>Valid value range is 0 to 63<br>Other values are reserved |
| 0x0203 | frame_id | RO | UINT64 | Signal frame (SF) ID<br>Value in range from 0 to ($2^{44}$ – 1)<br>Other values are reserved |
| 0x0204 | time_mode | R/W | UINT8 | The time information mode currently supported by the node.<br>Value in range from 0 to 255<br>0: TAI mode<br>1: UTC mode<br>Other values are reserved |
| 0x0205 | time_high | RO | UINT64 | Time information of the current above second level of the node.<br>Value in range from 0 to ($2^{48}$ – 1)<br>0: information is not available<br>Other values are reserved |
| 0x0206 | time_low | RO | UINT64 | Time information of the current below second level of the node.<br>Valid value in range from 0 to ($2^{48}$ – 1)<br>Other values are reserved |
| 0x0207 to 0x028F | reserved | | | Protocol reserved |
| 0x0290 to 0x02FF | reserved | | | Reserved for equipment manufacturer |
| 0x0300 to 0x03FD | delay_cn | RO | UINT32 | Transmission delay (calculated by the management node) between the management node and the terminal node and the unit is ns. 254 Table items correspond to the delay of NodeID 0 to NodeID 253.<br>Value in range from 0 to ($2^{32}$ – 1) |
| 0x03FE to 0x03FF | reserved | | | Protocol reserved |

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#### 6.10.2.5 System diagnosis and maintenance related information table

Table 38 defines physical communication resource management information.

**Table 38 – Physical communication resource management information table**

| Parameter Index | Parameter name | RW | Data Type | Description |
|---|---|---|---|---|
| 0x0500 | sym_down_num | R/W | UINT8 | Symbol numbers of downlink subframe<br>Value in range from 2 to 62<br>Other values are invalid |
| 0x0501 | cycle_frame_num | R/W | UINT8 | Cycle frame length<br>Value in range from 0 to 16<br>Other values are reserved |

| Parameter Index | Parameter name | RW | Data Type | Description |
|---|---|---|---|---|
| 0x0502 to 0x05FF | reserved | | | Protocol reserved |
| 0x0600 | res_blcok_id | R/W | UINT16 | The resource blocks (see Note 1) used by the node.<br>Value in range from 0 to 65 535 |
| 0x0601 | sequence_id | R/W | UINT8 | Resource sub-block (see Note 1) Sequence Number.<br>Value in range from 0 to 255 |
| 0x0602 | tx_node_id | R/W | UINT8 | The device node NodeID for transmitting data based on symbolic resources.<br>Value in range from 0 to 255 |
| 0x0603 | res_rt_attr | R/W | UINT16 | Real-time attribute of the resource<br>Value in range from 0 to 512<br>0: static resources, always occupied<br>1 to 512: number of times of corresponding resource blocks are occupied by circulation<br>Other values are reserved. |
| 0x0604 | sym_reserved | R/W | UINT8 | Reserved field |
| 0x0605 | bd_flag | R/W | UINT8 | Sideband occupation flag indicated by bit.<br>bit 0: upper sideband occupation flag<br>bit 1: lower sideband occupation flag<br>Setting the corresponding bit to 0 indicates that the half sideband is not occupied, and setting to 1 indicates that the half sideband is occupied.<br>bit 2 to bit 7: reserved |
| 0x0606 | bd_mode | R/W | UINT8 | Corresponding sideband coding mode represented by bit.<br>The high 5 bits value corresponds to RS code mode, see Table 71, the valid value range is 0 to 11. Other values are reserved.<br>The low 3 bits value corresponds to the convolutional code mode (see Table 72) and the valid value range is 0 to 2. Other values are reserved. |
| 0x0607 | sym_pos | R/W | UINT16 | Symbol resource starting position<br>Value in range from 0 to 511<br>Other values are reserved. |
| 0x0608 | sym_len | R/W | UINT16 | Symbol resource length<br>Value in range from 1 to 512<br>Value 0 is invalid<br>Other values are reserved. |
| 0x0609 | sym_cycle_num | R/W | UINT16 | Number of times symbol resources are recycled<br>Value in range from 1 to 512<br>Value 0 is invalid.<br>Other values are reserved. |
| 0x060A to 0x060F | reserved | | | Protocol reserved |
| 0x0610 to 0x09FF | | | | Resource blocks information (see Note 2) |

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| Parameter Index | Parameter name | RW | Data Type | Description |
|---|---|---|---|---|
| 0x0A00 to 0x0FFF | reserved | | | Protocol reserved |

NOTE 1 See 8.6.2.2.1 for signal frame. The node device processes the data based on the continuous half sideband or sideband symbol in the specified SF. Such continuous symbol is regarded as a resource sub-block, the device implements deterministic data communication through one or multiple resource sub-blocks. Multiple resource sub-blocks are regarded as a resource block.

NOTE 2 The index from 0x0600 to 0x0609 corresponds to a resource block information. Figure 20 shows the resource block information structure, and the indexes from 0x060A to 0x060F are reserved for the corresponding resource block. There are 64 resource blocks information is allowed on each physical device, which means the corresponding valid index range of resource information management is 0x0600 to 0x09FF.

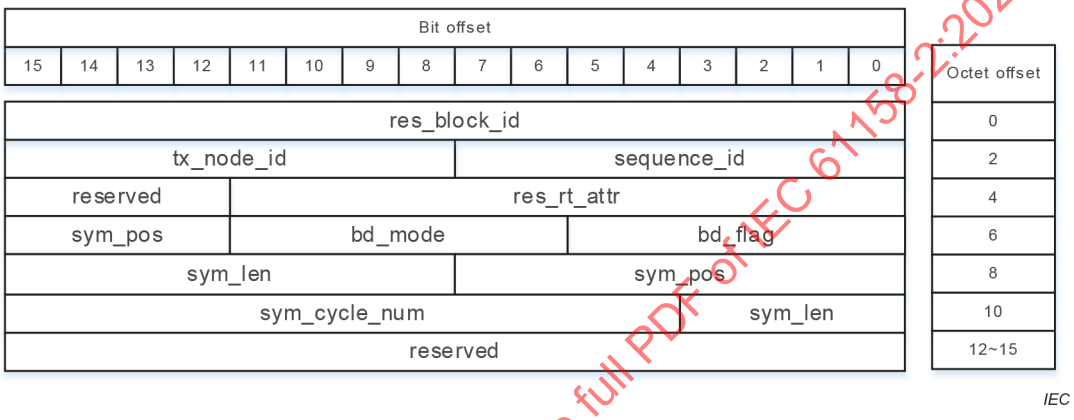


**Figure 20 – Resource block information structure**

### 6.10.3 Service primitive

#### 6.10.3.1 Ph-RESET (flag)

The PhL system management user informs the PhL to reset based on the service primitive. Table 39 shows the service primitives and parameters.

**Table 39 – Ph-RESET primitives and parameters**

| Parameter name | Request | Confirm |
|---|---|---|
| flag | M | |

The PhL judges whether it needs to be reset based on the parameter flag described in Table 40. The system management users should receive confirmation information when resetting the flag of 1.

**Table 40 – Ph-RESET service primitive parameter description**

| Parameter name | Parameter value |
|---|---|
| flag | Reset flag:<br>0: do not reset the PhL<br>1: reset all functions of the PhL and the PhL entity parameters should be initialized to the default values. |

Figure 21 shows this service primitive process.

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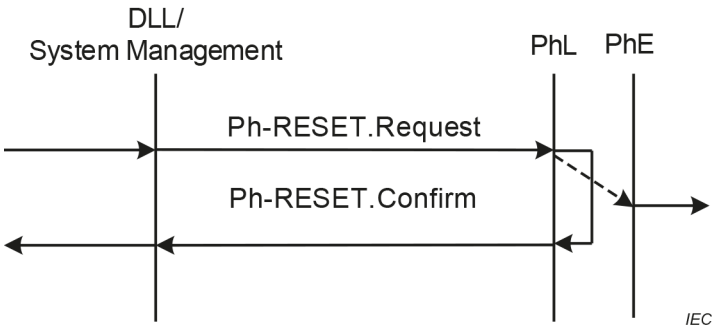


**Figure 21 – Ph-RESET service primitive process**

#### 6.10.3.2 Ph-SET-VALUE (parameter_index, value, status)

The PhL system management user uses the service to set the related parameters of PhLME. Table 41 shows the service primitives and parameters. See 6.10.2 for the specific description of the parameters named parameter_index and value. The parameter status as shown in Table 42 which indicates the confirmation status of the corresponding request service.

**Table 41 – Ph-SET-VALUE primitives and parameters**

| Parameter name | Request | Confirm |
|---|---|---|
| parameter_index | M | |
| value | M | |
| status | | M |

**Table 42 – Ph-SET-VALUE primitive parameter status**

| Parameter name | Parameter value |
|---|---|
| status | Service returns status value<br>0: success<br>1: failure |

Figure 22 shows this service primitive process.

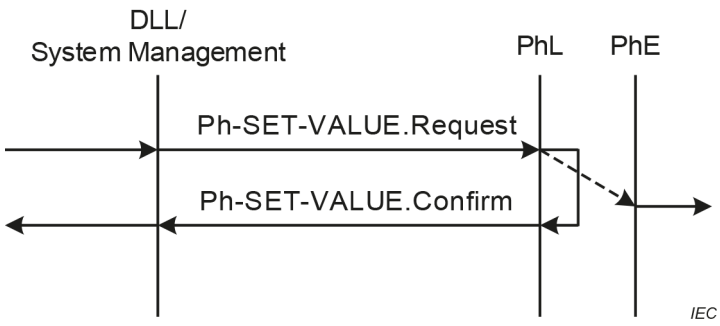


**Figure 22 – Ph-SET-VALUE service primitive process**

#### 6.10.3.3 Ph-GET-VALUE (parameter_index, value, status)

The PhL system management user uses the service to get the related parameters of the PhLME. Table 43 shows the service primitives and parameters. See 6.10.2 for the parameter

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parameter_index description. The parameter status as shown in  indicates the confirmation status of the corresponding request service.

**Table 43 – Ph-GET-VALUE service primitives and parameters**

| Parameter name | Request | Confirm |
|---|---|---|
| parameter_index | M | |
| value | | M |
| status | | M |

Figure 23 shows this service primitive process.

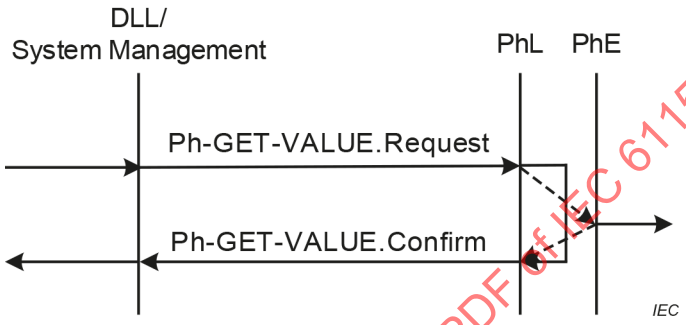


**Figure 23 – Ph-GET-VALUE service primitive process**

#### 6.10.3.4 Ph-EVENT (parameter_index, value)

The PhLME should notify the system management user based on the service when it detects an event. The service indication primitive parameter should clarify the relevant information at the time of the event. Table 44 shows the service primitive and parameters.

**Table 44 – Ph-EVENT service primitive and parameters**

| Parameter name | Indication |
|---|---|
| parameter_index | M |
| value | M |

Figure 24 shows this service primitive process.

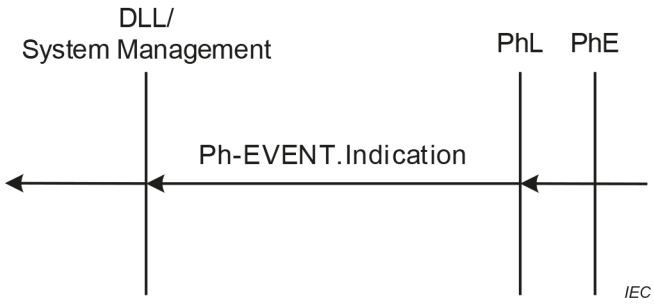


**Figure 24 – Ph-EVENT service primitive process**

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#### 6.10.3.5 Ph-SYNC (command, parameter_index, value, status)

The PhL system management user uses the service to process the synchronization related parameters of the PhLME (see 6.10.2.4). Table 45 shows the Ph-SYNC service primitives and parameters.

The parameter command indicates the specific instruction of the primitive processing. When the parameter command is 0, it indicates that the PhL system management user should read the corresponding value of the parameter_index. When the parameter command is 1, it indicates that the parameter_index in the PhLME should be set to value. The parameter status indicates the execution result of the corresponding primitive. The value is 0 indicates that the primitive process is successful, and 1 indicates that the primitive process is failed. Table 45 shows the service primitives and parameters. See 6.10.2.4 for the parameter parameter_index description.

**Table 45 – Ph-SYNC service primitives and parameters**

| Parameter name | Request | Indication | Confirm |
|---|---|---|---|
| command | M | M | |
| parameter_index | M | M | M |
| value | | M | M |
| status | | | M |

Figure 25 shows this service primitive process.

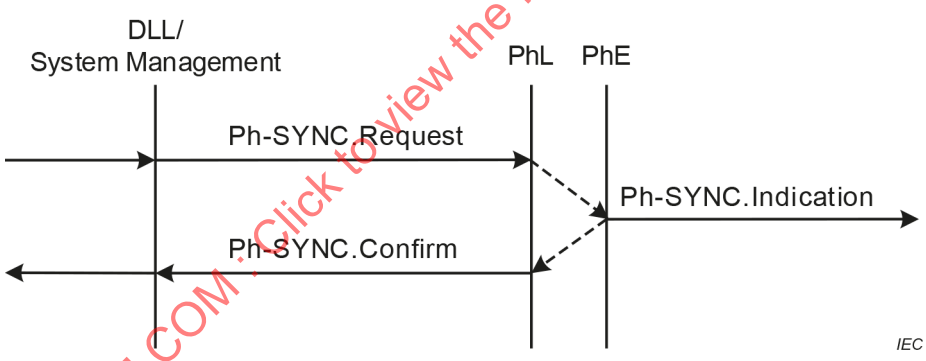


**Figure 25 – Ph-SYNC service primitive process**

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## 7 DCE independent sublayer (DIS)

### 7.1 General

The PhL entity is partitioned into a Data Terminal Equipment (DTE) component and a Data Communication Equipment (DCE) component. The DTE component interfaces with the DLL entity, and forms the DCE Independent Sublayer (DIS). It exchanges Interface Data Units across the DL-Ph interface defined in Clause 5, and provides the basic conversions between the PhIDU "at-a-time" viewpoint of the DL-Ph interface and the bit serial viewpoint required for physical transmission and reception.

This sublayer is independent of all the PhL variations, including encoding and/or modulation, speed, voltage/current/optical mode, medium etc. All these variations are grouped under the designation Data Communication Equipment (DCE).

NOTE A number of different DIS entities are specified, based on industry practice.

### 7.2 Type 1: DIS

The DIS shall sequence the transmission of the PhID as a sequence of serial PhSDUs. Similarly, the DIS shall form the PhID to be reported to the DLL from the sequence of received serial PhSDUs.

The PhID shall be converted to a sequence of PhSDUs for serial transmission in octets up to a maximum of 300 octets. A PhSDU representing more significant octets of the PhID shall be sent before or at the same time as a PhSDU representing less significant octets and such that within each octet, a PhSDU representing a more significant bit will be transmitted before or at the same time as a PhSDU representing a less significant bit. On reception, each sequence of PhSDUs shall be converted to PhID such that, in the absence of errors, the PhIDU indicated to the receiving DLL entity shall be unchanged from the PhIDU whose transmission was requested by the originating DLL entity.

NOTE This is a guarantee of transparency.

### 7.3 Type 3: DIS

#### 7.3.1 Synchronous transmission

The DCE Independent Sublayer (DIS) specified for Type 1 shall be used (see 7.2).

#### 7.3.2 Asynchronous transmission

There is no DCE Independent Sublayer (DIS) for asynchronous transmission.

### 7.4 *Void*

NOTE Subclause 7.4 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

### 7.5 Type 8: DIS

#### 7.5.1 General

The PhL is subdivided into a medium-independent sublayer (MIS), a medium-dependent sublayer (MDS) and the medium attachment unit (MAU). The MIS is independent of all characteristics of the PhL, such as coding, transmission method, transmission speed, and the type of transmission medium. All these instances are described by the sublayers MDS and MAU.

#### 7.5.2 Function

On the one hand, the MIS has to transmit the PhSDU which was received by the MAC sublayer through the DL-Ph interface in the form of a PhIDU via the MIS-MDS interface to the MDS. On the other hand, it forms the PhIDU of a PhSDU, which has been received through the MIS-MDS interface, and transfers it via the DL-Ph interface to the MAC sublayer.

In addition, the MIS allows transmitting a PhSDU between two MDSs through the MIS-MDS interface (MDS coupling).

The MIS may consist of several channels that are configured correspondingly. One channel is used to transmit the PhSDU to the MDS and to transmit one PhSDU through a PhIDU to the MAC sublayer. All other channels are used to transmit a PhSDU between two MDS sublayers.

#### 7.5.3 Serial transmission

For the serial transmission a sequence of PhIDUs shall be converted into a sequence of PhSDUs. A PhSDU that represents a more significant bit is transferred after a PhSDU that represents a less significant bit.

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When it is received each sequence of PhSDUs shall be converted into a sequence of PhIDUs so that the sequence of PhIDUs formed in such a way corresponds to the one that is transmitted from the MAC sublayer to the PhL.

### 7.5.4 MDS coupling

When MDSs are coupled in pairs and have the same or different characteristics (alternative type of transmission) each PhSDU that is received from a MDS through the MIS-MDS interface is sent unchanged via the MIS-MDS interface to another MDS.

In this case, it is allowed to buffer a received PhSDU.

Figure 26, Figure 27 and Figure 28 show possible configurations for the bus master and slaves using the 2-wire medium and an alternative type of transmission.

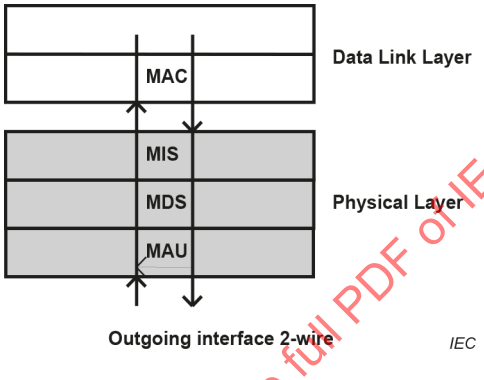


**Figure 26 – Configuration of a master**

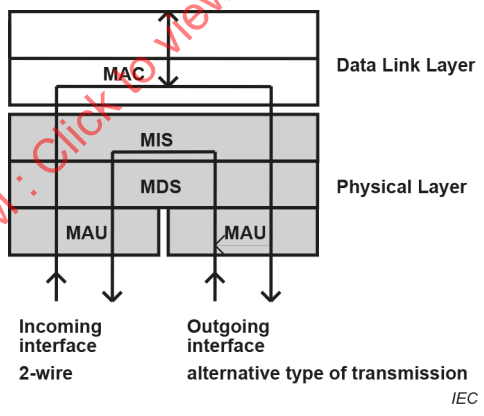


**Figure 27 – Configuration of a slave with an alternative type of transmission**

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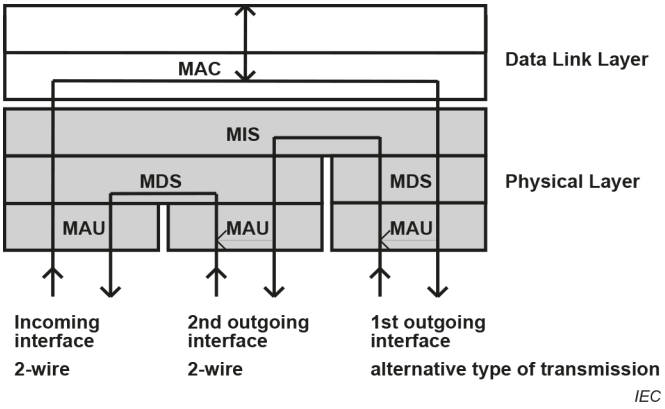


**Figure 28 – Configuration of a bus coupler with an alternative type of transmission**

### 7.6 Type 12: DIS

There is no DIS specified for Type 12.

### 7.7 Type 28: DIS

The PhL converts the data unit received from the DLL into service data unit that can be processed by PhL. It adds the required check control information and generates OFDM symbol by scrambling, encoding, and mapping. The physical signal is transmitted to the corresponding physical medium after D/A conversion. The physical signal is transmitted to one or more devices in the network through the medium. After receiving the physical signal, it performs the A/D conversion, demodulation and decoding, and removes the control information. The recovered signal is converted into the data unit which can be processed by the DLL entity.

The PhL entity is partitioned into a Data Terminal Equipment (DTE) and a Data Communication Equipment (DCE). DTE implements the conversion between the DLL Protocol Data Unit (DLPDU) and the PhLSDU. DCE performs the OFDM processing to the PhLSDU, and generates the OFDM symbols and converts them into the physical signals which can be processed by the medium.

The DIS of the PhL should order the PhID transmission as a PhSDU sequence. Conversely, DIS needs to convert the received PhSDU sequence into PhID and transmit it to DLL.

The PhSDU sequence of the PhL is composed of CBs. PhID should be converted into PhSDU for transmission in octets. The high-bit octets are sent firstly, followed by the low-bit octets, and hence the high-bit octets are firstly processed as well. In the absence of errors, the PhIDU to the receiving DLL entity should be same as the PhIDU which was requested by the original DLL entity.

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## 8 DTE – DCE interface and MIS-specific functions

### 8.1 General

The PhL entity is partitioned into a Data Terminal Equipment (DTE) component containing the DIS, and a Data Communication Equipment (DCE) component containing the MDS and lower sublayers. The DTE-DCE interface connects these two physical components, and is itself within the MIS (see Figure 1).

NOTE A number of different DTE-DCE interfaces are specified, based on industry practice.

It is not mandatory for the DTE-DCE interface, or any other interface, to be exposed.

For Type 3 synchronous transmission mode, Type 1 and Type 7, the DTE-DCE interface is a functional and electrical, but not mechanical, interface that supports a set of services. Each of these services is implemented by a sequence of defined signaling interactions at the interface.

## 8.2 Type 1: DTE – DCE interface

### 8.2.1 Services

#### 8.2.1.1 Overview

The following services, defined in 8.2, shall be supported by the DTE-DCE interface:

a) DTE to DCE reset service;
b) DTE to DCE configuration service;
c) DTE to DCE message-transmission service;
d) DCE to DTE fault notification service;
e) DCE to DTE media-activity indication service;
f) DCE to DTE message-reporting service.

#### 8.2.1.2 DTE to DCE reset service

This service shall provide a means by which the DTE, at any time, can reset the DCE to its initial (power-on) state.

#### 8.2.1.3 DTE to DCE configuration service

This service shall provide a means by which the DTE can configure various characteristics of the DCE, including those characteristics which systems management can adjust via Ph-SET-VALUE requests (see Table 13). It shall also provide a DCE-optional means by which the DTE can initiate reporting of DCE status by pre-emptive use of the DCE to DTE message-reporting service.

#### 8.2.1.4 DTE to DCE message-transmission service

This service shall provide a means by which the DTE can transmit a message through the DCE to either the connected medium (media), or back to the DTE, or both, as determined by the current operational values of the parameters specified in Table 13. The DCE shall provide the pacing for this service.

This service is invoked upon receipt of a PH-DATA request specifying START-OF-ACTIVITY at the PhL service interface, and runs until receipt of and completion of the PH-DATA request specifying END-OF-DATA-AND-ACTIVITY.

#### 8.2.1.5 DCE to DTE fault notification service

This service shall provide a means by which the DCE, at any time, can report a fault. The specific nature of the fault is not reported by this service, but may be determinable by use of the DTE to DCE configuration service to initiate a DCE-optional DCE status report.

#### 8.2.1.6 DCE to DTE media-activity indication service

This service shall provide a means by which the DCE reports the inferred detection, on any of its connected media for which receiving is enabled (see Table 13), of signaling from itself or other Ph-layer entities. While loopback is enabled, this service reports only the signaling of the DCE itself.

When the DTE-DCE interface is in half-duplex mode and loopback is not enabled, this service need not report media activity resulting directly from the DTE to DCE message-transmission service.

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#### 8.2.1.7 DCE to DTE message-reporting service

This service shall provide a means by which the DCE reports the receipt of a sequence of PhPDUs from any one of the connected media for which receiving is enabled. This service terminates with an indication of whether the sequence of received PhPDUs was well formed. Errors in the sequence, including number of PhPDUs such that they could not have been a correct transmission resulting from an invocation of the DCE to DTE message-transmission service shall be reported as a malformed (erroneous) sequence.

Errors in the octet alignment of a received end delimiter with respect to the preceding start delimiter (i.e., not separated by an integral number of octets of data bits) shall be reported as a malformed sequence.

When the DTE-DCE interface is in half-duplex mode and loopback is not enabled, this service need not report the message transmitted by the DCE to DTE message-transmission service.

### 8.2.2 Signaling interfaces

#### 8.2.2.1 Overview

Two signaling interfaces are defined for Type 1 PhLs. The first interface existed in prior editions of this document and is retained for compatibility, although there are no known implementations. It is defined in 8.2.2.2through 8.2.2.4.

The second interface uses the well-known serial peripheral interface (SPI) protocol and signals, or equivalent, in which octet registers and FIFOs in the DCE are read and written by the DTE and in which the DCE can interrupt the DTE.

NOTE There is no formal standard for the SPI protocol, although it is used by many electronics vendors.

#### 8.2.2.2 Interface signals (historic version from prior editions)

##### 8.2.2.2.1 Overview

If the DTE-DCE interface is exposed, it shall provide the signals specified in Table 46.

**Table 46 – Signals at DTE-DCE interface**

| Signal | Abbreviation | Source |
|---|---|---|
| Transmit Clock | TxC | DCE |
| Request-to-send | RTS | DTE |
| Clear-to-send | CTS | DCE |
| Transmit Data | TxD | DTE |
| Receive Clock | RxC | DCE |
| Receive Activity | RxA | DCE |
| Receive Data and Framing | RDF | DCE |

The signal levels shall be as shown in Table 47. In general, both sides of the interface shall operate with the same approximate value of $V_{DD}$. However, it is possible that a DTE and a DCE with separate power supplies can both reach operational $V_{DD}$ simultaneously, or not. It is desirable, but not mandatory, that the DTE to DCE reset service be operational when the DCE has not yet reached operational $V_{DD}$. It is also desirable that the DTE invoke this service whenever its own $V_{DD}$ is below operational margins.

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**Table 47 – Signal levels for an exposed DTE-DCE interface**

| Symbol | Parameter | Condition | Limit | Unit | Remark |
|---|---|---|---|---|---|
| VOL | Maximum low-level output voltage | $I_{out}$ = ±100 µA | 0,1 | V | see Note 1 |
| | | $I_{out}$ = +1,6 mA | 0,4 | V | |
| VOH | Min. high-level output voltage | $I_{out}$ = ±100 µA | $V_{DD}$ - 0,1 | V | see Note 1 |
| | | $I_{out}$ = −0,8 mA | $V_{DD}$ - 0,8 | V | see Note 2 |
| VIL | Max. low-level input voltage | | 0,2 $V_{DD}$ | V | |
| VIH | Min. high-level input voltage | | 0,7 $V_{DD}$ | V | see Note 3 |

NOTE 1 Provides the capability to drive two typical CMOS loads.

NOTE 2 CMOS input compatibility with TTL output requires a "pull-up" resistor from signal input to $V_{DD}$.

NOTE 3 Compatible with CMOS output for 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. Compatibility with TTL output (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) requires a "pull-up" resistor from signal input to $V_{DD}$.

The timing characteristics of these signals shall be at least equal to those specified for the relevant DCE in the requirements of this document. However, in no case shall the transition time between 0,3 $V_{DD}$ and 0,6 $V_{DD}$ be greater than either 100 ns or 0,025 *P*, whichever is smaller. *P* is defined as the nominal period of octet transmission - the inverse of the nominal PhSDU rate.

An implementation of the DTE-DCE interface shall function correctly with transmit and receive (TxC and RxC) clock frequencies between 1 kHz and 8,8 times the highest supported PhSDU rate of the DTE or DCE implementation.

NOTE The PhSDU and equivalent bit data rates available in an implementation are stated in the Protocol Implementation Conformance Statement (PICS).

#### 8.2.2.2.2 Transmit clock (TxC)

The Transmit Clock signal (TxC) shall provide the DTE with a continuous timing signal, such that any eight consecutive full cycles of this signal shall have the same octet period as the nominal transmit period for one data octet. The DCE shall source this nominally two-phase signal such that each phase has duration of at least 0,04 *P*.

NOTE This specification permits TxC to be a continuous, constant-period clock at the nominal bit rate (8 times the nominal octet rate) with a duty cycle of 32 % to 68 %, or for TxC to be a higher-frequency clock with some cycles omitted and with a duty cycle closer to 50 %. This permits, for example, simple clocking in a DCE that recodes each 4 bits into 5 bauds; the DCE could have a clock 10 times the nominal octet rate, with a duty cycle of between 40 % and 60 %, and would omit (the same) two cycles every octet.

TxC supports the DTE to DCE configuration and message-transmission services.

#### 8.2.2.2.3 Request-to-send (RTS)

The request-to-send (RTS) signal supports the DTE to DCE reset, configuration, and message-transmission services. The DTE shall source this signal. The initial (power-on) and idle (no DTE to DCE service active) state of this signal shall be low.

When referenced to TxC at the DTE-DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or 0,025 *P*; the hold time shall be zero or greater.

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#### 8.2.2.2.4 Clear-to-send (CTS)

The clear-to-send (CTS) signal supports the DTE to DCE configuration and message-transmission services. The DCE shall source this signal. The initial (power-on) and idle (no DTE to DCE service active) state of this signal shall be low.

When referenced to TxC at the DTE-DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or 0,025 *P*; the hold time shall be zero or greater.

#### 8.2.2.2.5 Transmit Data (TxD)

The Transmit Data (TxD) signal supports the DTE to DCE reset, configuration, and message-transmission services. Binary data is transmitted from DTE to DCE during one phase of the latter two services, and during this phase a binary 0 is represented by a low level on TxD and a binary 1 by a high level on TxD, both sampled at the falling edge of TxC.

The DTE shall source this signal. The initial (power-on) and idle (no DTE to DCE service active) state of this signal shall be high.

When referenced to TxC at the DTE-DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or 0,025 *P*; the hold time shall be zero or greater.

#### 8.2.2.2.6 Receive Clock (RxC)

The Receive Clock signal (RxC) shall provide the DTE with an intermittent (semi-continuous) nominally two-phase timing signal that defines the timing of information being reported via the RDF signal. The DCE shall source this signal such that, where RxC is defined to be meaningful (see 8.2.2.3.7), each phase has duration of at least 0,04 *P*.

NOTE This specification permits RxC to be a recovered clock at the nominal bit rate (8 times the nominal octet rate) with a duty cycle of 32 % to 68 %, or to be a higher-frequency clock with some cycles omitted and with a duty cycle closer to 50 %. This permits, for example, simple clocking in a DCE that decodes 4 bits from each received 5 bauds; the DCE could have a clock 10 times the nominal octet rate, with a duty cycle of between 40 % and 60 %, and would omit two cycles every octet.

This specification also permits the DCE to omit cycles of RxC during recognition of long end-delimiter sequences of PhPDUs, so that the delimiter can be reported in real time using 8 or fewer cycles of RxC (see 8.2.2.3.7).

RxC shall support the DCE to DTE message-reporting service.

#### 8.2.2.2.7 Receive Activity (RxA)

The Receive Activity (RxA) signal shall support the DCE to DTE fault notification, media-activity indication, and message-reporting services. The DCE shall source this signal. The initial (power-on) and idle (no DCE to DTE service active) state of this signal shall be low.

#### 8.2.2.2.8 Receive Data and Framing (RDF)

The Receive Data and Framing (RDF) signal shall support the DCE to DTE fault notification and message-reporting services. Binary data is transmitted from DCE to DTE during some phases of the latter service, and during these phases a binary 0 is represented by a low level on RDF and a binary 1 by a high level on RDF, both sampled at the falling edge of RxC.

The DCE shall source this signal. The initial (power-on) and idle (no DCE to DTE service active) state of this signal shall be high.

When referenced to RxC at the DTE-DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or 0,025 *P*; the hold time shall be zero or greater.

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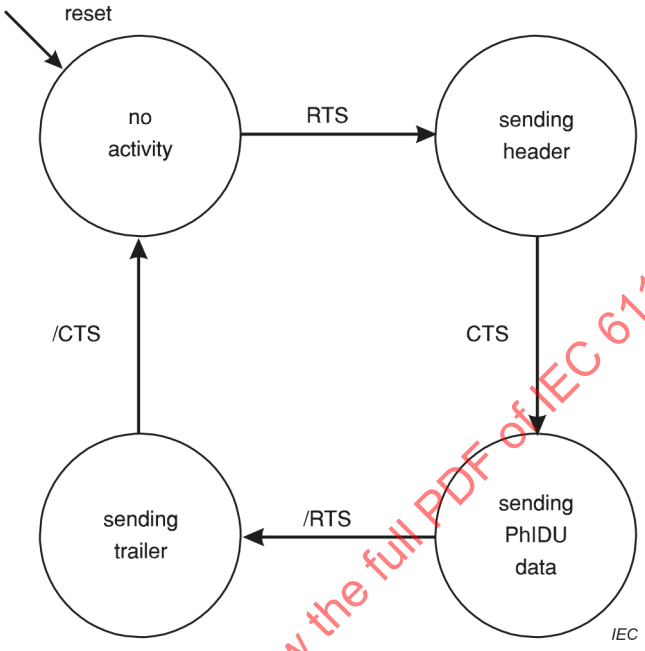
#### 8.2.2.3 Encoding of services in signals

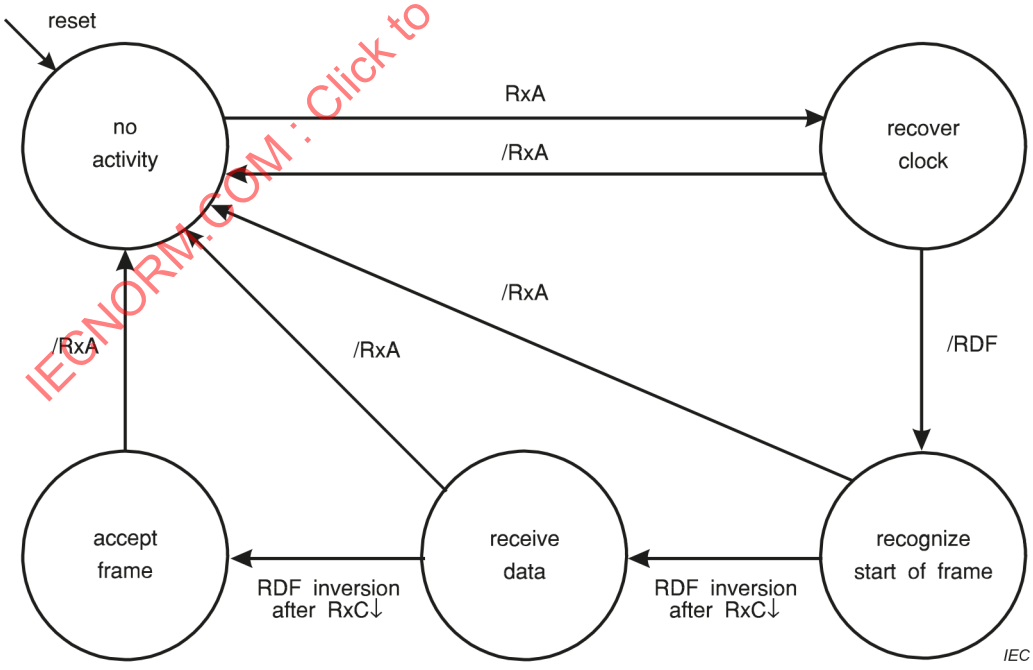
##### 8.2.2.3.1 Summary

The services of 8.1 shall be implemented by the following sequences and combinations of the signals of 8.2.

NOTE Typical transmit and receive sequencing machines are shown in Figure 29, which is included in this document for explanatory purposes and does not imply a specific implementation.




**a) Transmit machine**




**b) Receive machine**

**Figure 29 – DTE/DCE sequencing machines**

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#### 8.2.2.3.2 DTE to DCE reset service

This service shall be mutually exclusive with the DTE to DCE configuration and message-transmission services; at most one of them can be active at any given time. This service can pre-empt the DTE to DCE configuration and message-transmission services at any time.

This service shall be encoded as a simultaneous low level on both RTS and TxD. When asserted by the DTE, this simultaneous low level shall be held for at least the nominal transmission period of two PhSDUs (octets).

NOTE 1 This is an asynchronous service, and is not referenced to TxC.

When a DTE is itself being reset, possibly during power-up, it should attempt to reset the DCE even when the DTEs own $V_{DD}$ is below normal operational limits.

NOTE 2 This reset is under the control of the DTE. It does not preclude the existence of a separate reset pin on the DCE.

If the DTE concurrently changes both RTS and TxD during the implementation of either the DTE to DCE configuration or message-transmission services, then the DTE shall ensure that an interval of at least the minimum required setup time exists between changing the one signal to a high level, and subsequently changing the other signal to a low level, to eliminate potential logic hazards in the DCEs implementation of the DTE to DCE reset service.

#### 8.2.2.3.3 DTE to DCE configuration service

This service is mutually exclusive with the DTE to DCE reset and message-transmission services; at most one of them can be active at any given time. This service may initiate the DCE to DTE message-reporting service to report DCE-internal status. The DTE to DCE reset service can pre-empt this service at any time.

This service shall be implemented in three phases; each of the latter two phases shall follow immediately upon completion of the prior phase.

These phases can be implemented as a minor variation on the three phases specified for the DTE to DCE message-transmission service. As a result, the DTE to DCE configuration service induces very little added complexity on the DTE and DCE.

a) The DTE shall assert (raise) RTS after the falling edge, and before the rising edge, of TxC. The DCE shall respond by anticipating configuration data.

b) When it is ready for configuration data from the DTE, the DCE shall raise CTS before the falling edge of TxC. The DTE shall respond by encoding the first bit of configuration data (1 as high, 0 as low) on TxD before the falling edge of the next TxC, and shall continue this process without interruption until between 2 and 200 bits of data (see 8.2.2.4) have been so encoded. The DTE shall then assert (raise) TxD and negate (lower) RTS before the falling edge of the next TxC.

c) The DTE should ensure that TxD is raised at least one setup time before RTS is lowered, to avoid potential logic hazards in the DCE implementation of the DTE to DCE reset service.

d) The DCE shall conclude any necessary reconfiguration before negating (lowering) CTS, which shall occur between two consecutive falling edges of TxC.

Both standardized and extendible configuration messages are defined in 8.2.2.4. Standardized messages cover the ranges of application of this interface that are anticipated to be most cost sensitive. Extendible messages permit differing forms of DCE configuration where required, and can serve to initiate the DCE to DTE message-reporting service to report DCE-internal status (a DCE option further described in 8.2.2.4).

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#### 8.2.2.3.4 DTE to DCE message-transmission service

This service is mutually exclusive with the DTE to DCE reset and configuration services; at most one of them can be active at any given time. The DTE to DCE reset service can pre-empt this service at any time.

This service shall be implemented in three phases; each of the latter two phases shall follow immediately upon completion of the prior phase.

a) The DTE shall assert (raise) RTS after the rising edge, and before the falling edge, of TxC. The DCE shall respond by generating and transmitting the appropriate-length sequence of preamble and start delimiter PhPDUs.

b) When it is ready for transparent data from the DTE, the DCE shall raise CTS before the falling edge of TxC. The DTE shall respond by encoding the first bit of transparent data (1 as high, 0 as low) on TxD before the next falling edge of TxC, and shall continue this process without interruption until between 3 and 300 integral octets of data have been so encoded. The DTE shall then assert (raise) TxD and negate (lower) RTS before the next falling edge of TxC.The DTE shall ensure that TxD is raised at least one setup time before RTS is lowered, to avoid potential logic hazards in the DCE implementation of the DTE to DCE reset service.

c) The DCE shall conclude transmission of all of the encoded transparent data received from the DTE, shall then generate and transmit the appropriate-length sequence of end delimiter PhPDUs, and shall then cease transmission. The DCE shall then wait an amount of time equal to the configured minimum post-transmission gap (see Table 13) before negating (lowering) CTS, which shall occur after a falling edge, and before the next falling edge, of TxC.

#### 8.2.2.3.5 DCE to DTE fault notification service

This service shall be mutually exclusive with the DCE to DTE media-activity indication and message-reporting services; at most one of them can be active at any given time. This service can pre-empt the DCE to DTE media-activity indication and message-reporting services at any time.

This service shall be encoded as a simultaneous low level on both RxA and RDF. Once asserted by the DCE, this simultaneous low level shall be held until activation of either the DTE to DCE reset or configuration services.

NOTE This is an asynchronous service, and is not referenced to RxC.

The DCE may concurrently change both RxA and RDF during the concurrent termination of the DCE to DTE media-activity indication and message-reporting services. The DTE is responsible for avoiding any logic hazards induced by this concurrent change.

#### 8.2.2.3.6 DCE to DTE media-activity indication service

This service is mutually exclusive with the DCE to DTE fault notification service; at most one of them can be active at any given time. The DCE to DTE fault notification service can pre-empt this service at any time.

This service shall be encoded as a high level on RxA. Once asserted by the DCE, this high level enables recognition of a high-to-low transition on RDF to initiate the DCE to DTE message-reporting service. Any subsequent high-to-low transition on RxA terminates that DCE to DTE message-reporting service.

NOTE The DCE to DTE media-activity indication service is an asynchronous service, and is not referenced to RxC.

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#### 8.2.2.3.7 DCE to DTE message-reporting service

##### 8.2.2.3.7.1 General

This service is mutually exclusive with the DCE to DTE fault notification service; at most one of them can be active at any given time. This service can only occur while the DCE to DTE media-activity indication service is active. The DCE to DTE fault notification service can pre-empt this service at any time.

##### 8.2.2.3.7.2 Non-erroneous reception

This service shall be implemented in four phases when reporting a well-formed message, each of which shall follow immediately upon completion of the prior phase.

The following description applies to DCEs which have end delimiter sequences of eight PhPDUs or less, and which do not require any extra decoding delay for an FEC (forward error correcting) code. DCEs that do not meet these conditions can introduce extra delay into their decoding and reporting processes so that, with respect to signaling on RxC and RDF, they do meet these conditions.

a) After detecting received signaling, training on that signaling, and recovering a data clock from that signaling whose nominal octet frequency is the same as TxC, the DCE shall initiate the DCE to DTE message-reporting service by sourcing that recovered clock on RxC and then negating (lowering) RDF after the rising edge, and before the next falling edge, of RxC.

NOTE 1 RxA is already asserted at this time.

b) The DCE shall continue training and attempting to match the received signaling against its expected preamble and start delimiter PhPDUs.

If the DCE supports *N* channels of redundant media, then it may report on RDF the identity of the channel from which the signaling is being received by encoding that channel number, in the range 0 to *N*-1, as a binary number which is reported most significant bit first during reception of the last three of those start delimiter PhPDUs. The bits reported on RDF shall be presented in series after successive rising edges of RxC, each before the immediately subsequent falling edge of RxC.

Upon detecting an exact match between the received signaling and the expected start delimiter, the DCE shall invert RDF after the falling edge, and before the next rising edge, of RxC.

NOTE 2 If the identity of the receiving channel was being reported on RDF, then this inversion will occur during the low phase of \1,\2 which immediately follows the high phase (of \1,\2) during which the last (low-order) bit of the channel number was reported.

c) The DCE shall continue reception and attempting to match the received signaling against potential data and expected end delimiter PhPDUs.

The DCE shall report each data bit decoded from the received signaling on RDF. The bits reported on RDF shall be presented in series after successive rising edges of \1,\2, each before the immediately subsequent falling edge of RxC. In the absence of errors these bits shall be reported in the same order and with the same values as they were transmitted by a peer PhL entity.

NOTE 3 This is a guarantee of transparency.

An end delimiter may be composed of both data and non-data PhPDUs. The DCE may report similarly on RDF each data bit decoded from an end delimiter, and may report also on RDF an appropriate number of data values for the non-data PhPDUs decoded from an end delimiter, except that

1) the total number of "bits" so reported shall be seven or less, and
2) upon detecting an exact match between the received signaling and the expected end delimiter, the DCE shall not report on RDF another bit corresponding to the end delimiter's last "bit", but rather shall first assert (raise) RDF after the rising edge, and

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before the next falling edge, of RxC, and then shall negate (lower) RDF after the falling edge, and before the next rising edge, of RxC.

NOTE 4 Most implementations will decode, and report on RDF as data, any initial data PhPDUs in a received end-delimiter sequence. The first non-data PhPDU, and subsequent PhPDUs, need not be reported. However, a final report will be made on RDF, indicating correct end-delimiter recognition.

NOTE 5 Each reported bit, except the last, is maintained on RDF for a full cycle of RxC. The last bit is replaced by a high-low sequence, each of which is maintained for just one phase of RxC.

NOTE 6 This terminating high-low sequence will occur during the first eight "bit" reports which occur after the last (pre-delimiter) data bit was reported. That last (pre-delimiter) data bit will have been the 8*N*'th data bit so reported in this phase, where *N* should be at least three and no greater than 300.

d) The DCE shall assert (raise) RDF before the next falling edge of RxC and shall not initiate another instance of the DCE to DTE message-reporting service until after the conclusion of the current DCE to DTE media-activity indication service.

#### 8.2.2.3.7.3 Erroneous reception

An error can be detected during any phase of the reception process described in 8.2.2.3.7.2. When that occurs, the DCE shall modify its sequencing of those phases as follows.

If the DCE should detect invalid PhPDUs, or an invalid sequence of PhPDUs, or a valid end delimiter sequence of PhPDUs which is not separated from the start delimiter PhPDUs by an integral number of data-octets of PhPDUs; and if the DCE can establish a valid signal on RxC (for example, by substituting TxC or some other local signal for the recovered clock source, if necessary); then

a) if phase 2 has not already been initiated, the DCE shall immediately initiate phase 2;

b) if phase 2 has not already been concluded, the DCE shall immediately conclude phase 2 as rapidly as possible, ignoring the requirement for matching of the start delimiter PhPDU sequence;

c) otherwise, the DCE shall immediately negate (lower) RDF after the rising edge, and before the next falling edge, of RxC, and then shall assert (raise) RDF after the falling edge, and before the next rising edge, of RxC.

NOTE This sequence permits the DCE to

– enable DTE use of RxC;

– identify the channel with the erroneous signaling; and

– indicate a reception error.

When the DCE has completed as many of the above steps a), b) and c) as appropriate and possible, the DCE shall immediately initiate phase 4.

### 8.2.2.4 DCE configuration messages

#### 8.2.2.4.1 Summary

Subclause 8.2.2.4 defines both standardized configuration messages, and the standardized portion of extendible configuration messages. Standardized messages cover the ranges of application of this interface that are anticipated to be most commonly used. Extendible messages permit differing forms of DCE configuration where required, and can serve to initiate the DCE to DTE message-reporting service to report DCE-internal status (a DCE option).

Two standardized messages, and two classes of extendible messages, are defined. All messages are transmitted across the interface in the order in which the bits are defined. Integers are transmitted most significant bit (MSB) first.

The two standardized messages and two classes of extendible messages are distinguished by the first two data bits of the configuration message, as follows:

00 - basic configuration message;

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01 - path-diversity control message;

10 - extendible configuration message;

11 - extendible status-report invocation message.

#### 8.2.2.4.2 Basic configuration message

Following its initial two bits of (00), the basic configuration message specifies operational aspects common to most DCEs. The defined components of this message are, in order of transmission:

a) the operational mode of the DCE, encoded in one data bit as shown. The value for this parameter after activation of the DTE to DCE reset service is 0;

0 Two-way simultaneous (full-duplex), where each invocation of the DTE to DCE message-transmission service automatically activates the DCE to DTE media-activity indication and message-reporting services. This mode is desirable for dual-channel media such as fiber-optic-pair cabling.

NOTE 1 Some DTEs are only able to operate in this mode.

1 Two-way alternate (half-duplex), where an invocation of the DTE to DCE message-transmission service does not automatically activate the DCE to DTE media-activity indication and message-reporting services.

NOTE 2 This mode minimizes DCE and DTE-DCE interface power consumption. Some DTEs are only able to operate in this mode.

b) the selection of the DCE-internal data source for the message-reporting service, encoded in two data bits as shown (see Table 13). The value for this parameter after activation of the DTE to DCE reset service is 00. When this selection is non-zero, transmission on all attached media shall be disabled and the DTE-DCE interface shall operate in two-way simultaneous (full-duplex) mode;

00 decoded signaling, received from one of the attached media as specified in 8.2.2.4.3 b) and c). The interface mode is as specified in 8.2.2.4.2 a);

01 internal-status reporting, see 8.2.2.5.2and 8.2.2.6;

10 loopback as close as possible to the DTE-DCE interface, with no transmission to connected media, where each invocation of the DTE to DCE message-transmission service automatically activates the DCE to DTE media-activity indication and message-reporting services. This mode is desirable for DCE vs. DTE vs. inter-connect fault localization.

11 loopback as close as possible to the media interface(s), with no transmission to connected media, where each invocation of the DTE to DCE message-transmission service automatically activates the DCE to DTE media-activity indication and message-reporting services. This mode is desirable for self-assessment before entry to an operating network.

c) the amount by which the preamble, which is the initial sequence of PhPDUs in each transmission, should be extended. Its range is zero to seven units of extension, encoded in three data bits as 0 (000) to 7 (111). The value for this parameter after activation of the DTE to DCE reset service is 0 (000) (see Note 2 of 6.2.2.2);

d) the amount by which the mandatory post-transmission gap, which is the period of non-transmission between successive sequences of PhPDUs, should be extended. Its range is zero to seven units of extension, encoded in three data bits as 0 (000) to 7 (111). The value for this parameter after activation of the DTE to DCE reset service is 0 (000) (see Note 3 of 6.2.2.2).

#### 8.2.2.4.3 Path-diversity control message

Following its initial two bits of (01), the path-diversity control message specifies additional configuration data commonly required for management and fault-assessment of redundant paths: separate transmission and reception controls for each of the attached redundant media (channels and paths). The defined components of this message are, in order of transmission:

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a) two bits of zero (00), which provide quartet and octet alignment within the message for the following fields;

b) the algorithm for choosing between redundant media as the source of received signaling when more than one of the media is enabled for reception, coded in four bits as shown. The value for this parameter after activation of the DTE to DCE reset service is 0000;

   0000 - The medium selected for reception should be the first medium on which signaling which is suitable for receiver-training is detected;

   1000 to 1111 (= 7 + *N*, 1 ≤ *N* ≤ 8) - The *N*th medium should be selected, except when signaling suitable for receiver-training has been detected on another medium for a period of time equal to the extra period of inter-frame-gap extension specified in 8.2.2.4.2 d), in which case that other medium should be selected;

c) the selection of whether reception is enabled (0) or inhibited (1) on each of eight or fewer redundant media, coded in eight consecutive bits for channels 1 through 8, respectively (see Table 13). The value for this parameter after activation of the DTE to DCE reset service is 0000 0000;

d) the selection of whether transmission is enabled (0) or inhibited (1) on each of eight or fewer redundant media, coded in eight consecutive bits for channels 1 through 8, respectively (see Table 13). The value for this parameter after activation of the DTE to DCE reset service is 0000 0000;

e) the amount of post-transmission gap extension due to potential signal skew between redundant media. Its range is zero to seven units of extension, encoded in three data bits as 0 (000) to 7 (111). The value for this parameter after activation of the DTE to DCE reset service is 0 (000) (see 8.2.2.4.2 d), 8.2.2.4.3 b), and Note 3 of 6.2.2.2).

#### 8.2.2.5 Extendible configuration messages

##### 8.2.2.5.1 General format

Following its initial two bits of (10), the coding of extendible configuration messages may be implementation dependent. The structure and form of extendible configuration messages shall be the same as the basic configuration message specified in 8.2.2.4.2.

##### 8.2.2.5.2 Extendible status-report invocation messages

Following its initial two bits of (11), the coding of extendible status-report invocation messages may be implementation dependent. The structure and form of extendible status-report invocation messages shall be the same as the basic configuration message specified in 8.2.2.4.2. The information specified shall select some DCE-internal source of received signaling, and if the DCE-internal-data-source mode is status-reporting (see 8.2.2.4.2 b)), then the DCE shall generate a multi-data-octet message, padded as necessary to an octet multiple, and shall report it using the DCE to DTE media-activity indication and message-reporting services.

#### 8.2.2.6 DCE-generated status reports

These reports are generated within the DCE upon request and reported when the DCE-internal-data-source is internal-status report (see 8.2.2.4.2 b)).

### 8.3 Type 3: DTE – DCE interface

#### 8.3.1 Synchronous transmission

The DTE-DCE interface specified for Type 1 shall be used (see 8.2).

#### 8.3.2 Asynchronous transmission

The DTE-DCE interface is not exposed for asynchronous transmission.

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## 8.4 Type 8: MIS – MDS interface

### 8.4.1 General

The PhL is subdivided into a medium-independent sublayer (MIS) and a medium-dependent sublayer (MDS). The MIS-MDS interface connects these two sublayers.

The MIS-MDS interface is a functional interface that supports certain services; it is not mandatory to implement this interface electrically. Each of these services is implemented through a sequence of interactions of the interface signals.

### 8.4.2 Services

#### 8.4.2.1 General

The MIS-MDS interface supports the services listed below:

– ID cycle request service
– Data cycle request service
– Data sequence classification service
– Data sequence identification service
– Message transmission service
– Message receipt service
– Bus reset

#### 8.4.2.2 ID cycle request service

With this service the MIS starts a data sequence to transmit identification and control data (identification cycle).

NOTE This service is used by a master only.

#### 8.4.2.3 Data cycle request service

With this service, the MIS starts a data sequence for the transmission of user data (data cycle).

NOTE This service is used by a master only.

#### 8.4.2.4 Data sequence classification service

With this service the MIS starts an identification or data cycle.

NOTE This service is used by a bus coupler or a slave only.

#### 8.4.2.5 Data sequence identification service

With this service the MDS indicates the beginning of an identification or data cycle.

#### 8.4.2.6 Message transmission service

With this service the MIS sends a message via the MDS either to the connected medium or via the MDS back to another MDS. The MDS determines how fast this service is executed.

NOTE 1 This service transmits the PhIDUs that were passed on to the PhL.

NOTE 2 This service runs simultaneously with the message receipt service.

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#### 8.4.2.7 Message receipt service

With this service the MDS indicates receipt of a message to the MIS or another connected MDS. The service ends with the indication whether the received PhPDU was correctly formed.

This service shall be preceded by a data sequence identification service.

#### 8.4.2.8 Bus reset

A reset is sent to and received from all slaves with this service. Table 48 shows the parameter of the MDS bus reset.

**Table 48 – MDS bus reset**

| Service parameter | Request | Indication |
|---|---|---|
| reset_type | M | M |

**reset_type:**

This service parameter defines whether the reset is short or long.

Value range: short, long

NOTE This service is used by a master only.

### 8.4.3 Interface signals

The MIS-MDS interface makes signals available that are listed in Table 49.

**Table 49 – Signals at the MIS-MDS interface**

| Interface signal | Mnemonic | Source |
|---|---|---|
| Transmit Clock | TxC | MIS |
| Request-to-send | RTS | MIS |
| Clear-to-send | CTS | MDS |
| Transmit Sequence | TxS | MIS |
| Transmit Select Line | TxSL | MIS |
| Transmit Control Line | TxCR | MIS |
| Transmit Data | TxD | MIS |
| Request Delay 1 | RqDly1 | MIS |
| Request Delay 2 | RqDly2 | MIS |
| Busy | BSY | MDS |
| Receive Clock | RxC | MDS |
| Receive Activity | RxA | MDS |
| Receive Sequence | RxS | MDS |
| Receive Select Line | RxSL | MDS |
| Receive Control Line | RxCR | MDS |
| Receive Data | RxD | MDS |
| Reset Out | RO | MIS |
| Reset In | RI | MDS |

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### 8.4.4 Converting the services to the interface signals

#### 8.4.4.1 General

The services of the MIS-MDS interface are represented by the protocol machines and signal sequences described in 8.4.4.1 through 8.4.4.8.

NOTE The following applies to the state diagrams shown in Figure 30 to Figure 38.

The symbol "*" corresponds to "logically and", the symbol "/" corresponds to "negated".

#### 8.4.4.2 Identification cycle request service

Figure 30 describes this service with the four services marked in grey and their transitions.

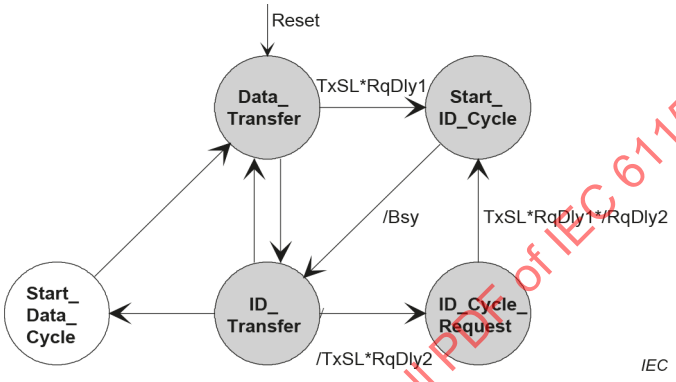


**Figure 30 – State transitions with the ID cycle request service**

NOTE 1 Transitions not shown in Figure 30 are used for other services see Figure 33 and Figure 35 for the states and transitions.

The identification cycle was preceded by a data cycle or a reset:

**Data_Transfer** state:
The MIS initiates an identification cycle request service by changing the TxSL signal from logical 0 to logical 1 and at the same time the RqDly1 signal from logical 0 to logical 1.

**Start_ID_Cycle** state:
After that, the MDS transmits the corresponding status PhPDU, starts a timer with the duration t1 and sets the BSY signal from logical 0 to logical 1. The MIS resets the RqDly1 signal to logical 0.

After the time t1 has elapsed, the MDS sets the BSY signal to logical 0 and terminates the identification cycle request service. The MIS communicates this to the DLL through a PH-DATA confirm primitive and assumes the ID_Transfer state.

The minimum time for t1 is 5 bit times.

Figure 31 shows the corresponding signal forms at the MIS-MDS interface for an identification cycle request service after a preceding data cycle.

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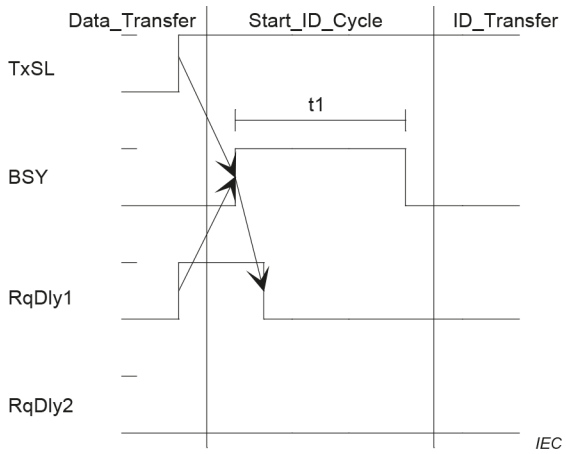


**Figure 31 – MIS-MDS interface: identification cycle request service**

The identification cycle was preceded by an identification cycle:

**ID_Transfer** state:
The MIS initiates an identification cycle request service by changing the TxSL signal from logical 1 to logical 0 and at the same time the RqDly2 signal from logical 0 to logical 1.

**ID_Cycle_Request** state:
After that, the MDS transmits the corresponding status PhPDU, starts a timer with the duration t2 and sets the BSY signal from logical 0 to logical 1. The MIS resets the RqDly2 signal to logical 0.

After the time t2 has elapsed, the MDS sets the BSY signal to logical 0. The MIS sublayer then changes the TxSL signal from logical 0 to logical 1 and at the same time the RqDly1 signal from logical 0 to logical 1.

The minimum time for t2 is 25 bit times.

**Start_ID_Cycle** state:
After that, the MDS transfers the corresponding status PhPDU, starts a timer with the duration T1 and sets the BSY signal from logical 0 to logical 1. The MIS then resets the RqDly1 signal to logical 0.

After the time t1 has elapsed, the MDS sets the BSY signal to logical 0 and terminates the identification cycle request service. The MIS communicates this to the DLL by means of a PH-DATA confirm primitive and assumes the ID_Transfer state.

Figure 32 shows the corresponding signal forms at the MIS-MDS interface for an identification cycle request service after a preceding identification cycle.

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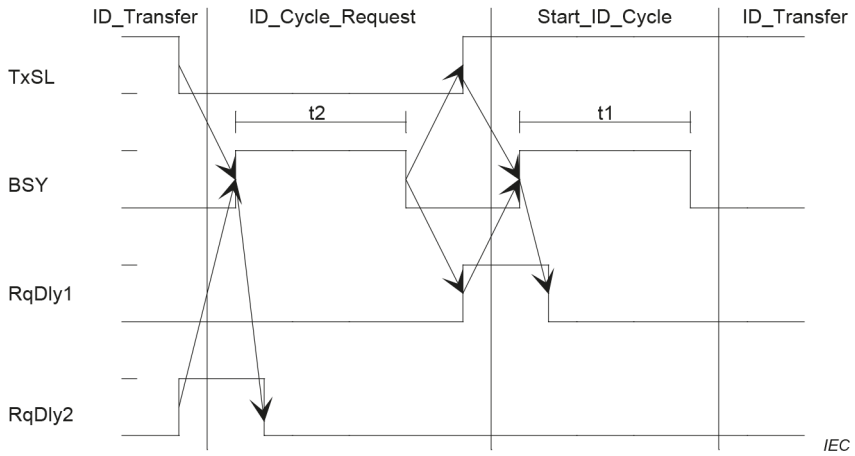


**Figure 32 – MIS-MDS interface: identification cycle request service**

NOTE 2 The identification cycle request service is an asynchronous service and is not related to TxC.

#### 8.4.4.3 Data cycle request service

Figure 33 describes this service with the three states marked in grey and their transitions.

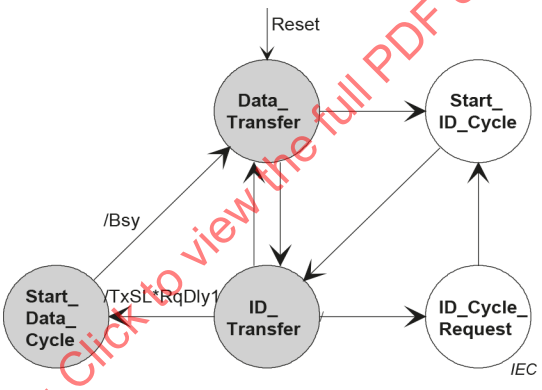


**Figure 33 – State transitions with the data cycle request service**

NOTE 1 Transitions not shown in Figure 33 are used for other services; see Figure 30 and Figure 35 for the states and transitions.

**The data cycle was preceded by an identification cycle:**

ID_Transfer state:
The MIS initiates a data cycle request service by changing the TxSL signal from logical 1 to logical 0 and at the same time the RqDly1 signal from logical 0 to logical 1.

Start_Data_Cycle state:
After that, the MDS transmits the corresponding status PhPDU, starts a timer with the duration t1 and sets the BSY signal from logical 0 to logical 1. The MIS resets the RqDly1 signal to logical 0.

After the time t1 has elapsed, the MDS sets the BSY signal to logical 0 and terminates the data cycle request service. The MIS communicates this to the DLL by means of a PH-DATA confirm primitive and assumes the Data_Transfer state.

Figure 34 shows the corresponding signal forms at the MIS-MDS interface for a data cycle request service after a preceding identification cycle.

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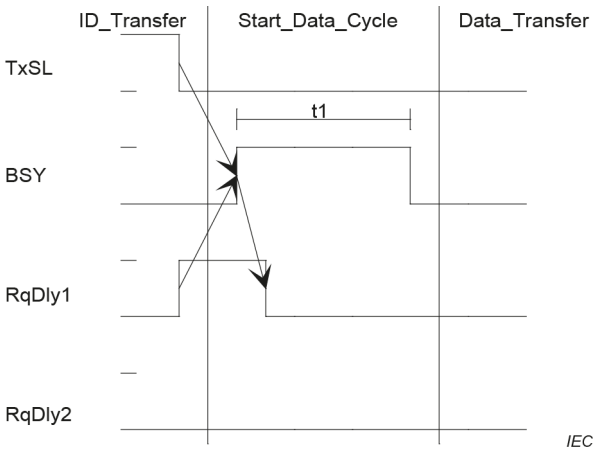


**Figure 34 – MIS-MDS interface: data cycle request service**

**The data cycle was preceded by a data cycle:**

If the DLL requests the beginning of a data cycle with a PH-DATA request primitive (PhICI=start_data_cycle), and the DLL did not request the beginning of an identification cycle by means of an PH-DATA request primitive (PhICI=start_ID_cycle) before, the MIS communicates to the DLL the end of the data cycle request service with a PH-DATA confirm primitive. The status of the signals TxSL, RqDly1 and RqDly2 remains unchanged.

NOTE 2 The data cycle request service is an asynchronous service and is not related to TxC.

#### 8.4.4.4 Data sequence classification service

Figure 35describes this service with the two states marked in grey and their transitions.

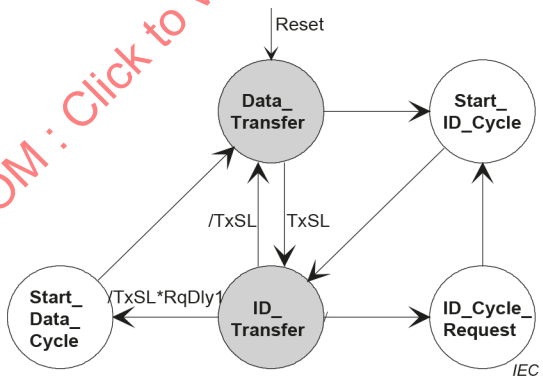


**Figure 35 – State transitions with the data sequence classification service**

NOTE 1 Transitions not shown in Figure 35 are used for other services; see Figure 30 and Figure 33 for the states and transitions.

**Data_Transfer** state:
The MIS initiates an identification cycle (transmission of identification and control data in the PhPDU) by changing the TxSL signal from logical 0 to logical 1.

**ID_Transfer** state
The MIS initiates a data cycle (transmission of user data in PhPDU) by changing the signal from logical 1 to logical 0.

NOTE 2 The data sequence classification service is an asynchronous service and is not related to TxC.

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#### 8.4.4.5 Message transmission service

Figure 36 describes this service with the six states and their transitions.

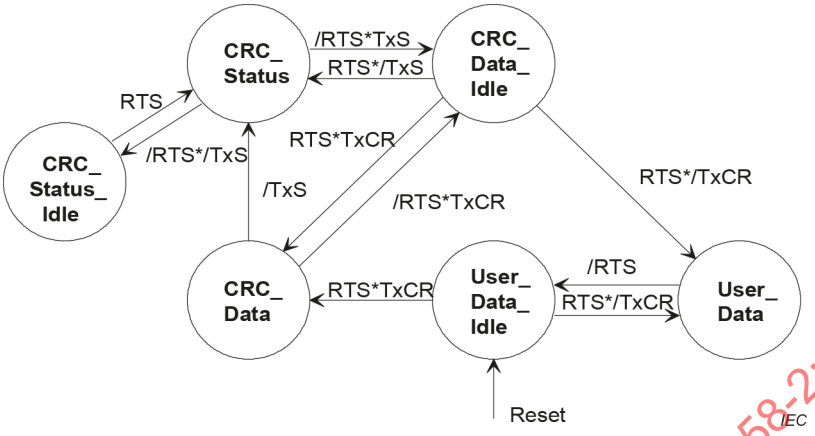


**Figure 36 – Protocol machine for the message transmission service**

NOTE 1 A data bit sequence is transmitted in multiples of octets. After the MIS has set its RTS interface signal from logical 1 to logical 0, it waits for a falling edge of the active low CTS signal from the MDS. The MIS communicates this to the DLL by means of a PH-DATA confirm primitive (mandatory for the master only).

**CRC_Data_Idle** state:
The MIS initiates a message transmission service by setting the RTS signal to logical 1 during the rising edge of TxC, at the same time setting the TxCR signal to logical 0, and transmitting with the TxD signal the first data bit within an octet to the MDS.

NOTE 2 Instead of initiating a message transmission service the MIS can start to transmit the checksum status by setting the RTS signal to logical 1 during the following rising edge of TxC, at the same time setting the TxS signal to logical 0 and transmitting the first bit of the checksum status with the TxD signal to the MDS.

**User_Data** state:
The MIS shall continue data transmission by transmitting the next data bit within an octet with the TxD signal to the MDS during each rising edge of TxC. The MIS completes the data transmission by setting the RTS signal to logical 0 after the last bit has been transmitted and before the next falling edge of TxC.

NOTE 3 The MIS continues data transmission by setting the RTS signal to logical 1 during the rising edge of TxC and at the same time transmitting with the TxD signal the first bit within an octet to the MDS.

**User_Data_Idle** state:
The MIS starts the check sequence by setting the RTS signal to logical 1 during the rising edge of TxC, at the same time setting the TxCR signal to logical 1, and transmitting the first bit of the checksum (CRC data) with the TxD signal to the MDS.

NOTE 4 Instead of the check sequence the MIS can initiate a new message transmission service by setting the RTS signal to logical 1 during the rising edge of TxC, and at the same time transmitting with the TxD signal the first data bit to the MDS. This is equivalent to a continuation of the message transmission service.

**CRC_Data** state:
The MIS shall continue to transmit the checksum data by transmitting the next data bit within an octet with the TxD signal to the MDS during each rising edge of TxC.

After the transmission of checksum data has been completed, the MIS starts the transmission of the checksum status (CRC status) by transmitting the TxS signal to logical 0 during the rising edge of TxC and at the same time transmitting with the TxD signal the first bit of the checksum status to the MDS.

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NOTE 5 The MIS continues the transmission of the checksum by setting the RTS signal to logical 1 before the falling edge of TxC and at the same time transmitting with the TXD signal the first bit of the next octet of the checksum to the MDS.

NOTE 6 The MIS starts with the transmission of the checksum status by setting the RTS signal to logical 1 during the rising edge of TxC, at the same time setting the TxS signal to logical 0, and transmitting the first bit of the checksum status to the MDS.

**CRC_Status** state:
The MIS shall continue checksum status transmission by transmitting the next bit within an octet with the TxD signal to the MDS during each rising edge of TxC. The MIS terminates the transmission of the checksum status by setting the RTS signal to logical 0 and the TxS signal to logical 1 before the falling edge of TxC and after the last bit of the octet to be transmitted.

**CRC_Status_Idle** state:
The MIS continues the transmission of the checksum status by setting the RTS signal to logical 1 during the rising edge of TxC, and at the same time transmitting with the TxD signal the first bit of the next octet to the MDS.

#### 8.4.4.6 Data sequence identification service

Figure 37 describes this service with the two states and their transitions.

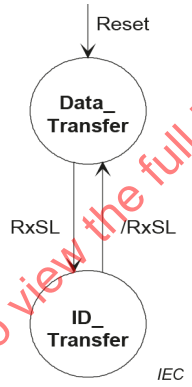


**Figure 37 – Protocol machine for the data sequence identification service**

**Data_Transfer** state:
The beginning of an identification cycle (transmission of identification data or control data in the received PhPDU) is indicated to the MIS by a change of the RxSL signal from logical 1 to logical 0.

**ID_Transfer** state:
The beginning of a data cycle (transmission of user data in the received PhPDU) is indicated to the MIS by a change of the RxSL signal from logical 1 to logical 0.

NOTE The data sequence identification service is an asynchronous service and not related to RxC.

#### 8.4.4.7 Message receipt service

Figure 38 describes this service with the six states and their transitions.

NOTE Data is received in multiples of octets.

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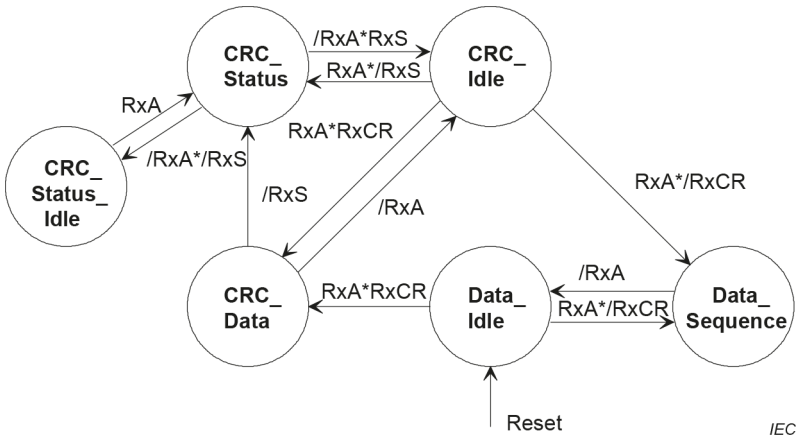


**Figure 38 – Protocol machine for the message receipt service**

**CRC_Idle** state:
If the MDS recognises the beginning of a data sequence PhPDU, it initiates the message receipt service by adapting the time pulses transmitted with the RxC signal to the received ones and at the same time during the rising edge of the RxC signal setting the RxA signal to logical 1, the RxCR signal to logical 0, as well as transmitting the first decoded data bit of an octet with the RxD signal to the MIS.

If the MDS recognises the beginning of a checksum status in a check sequence PhPDU instead of the beginning of a data sequence PhPDU, it sets the RxA signal to logical 1, at the same time the RxS signal to logical 0, and transmits the first decoded bit with the RxD signal to the MIS.

As long as the MDS recognises the CRC_Idle state it shall retain the RxA signal at logical 0 and the RxCR signal at logical 1.

**Data_Sequence** state:
The MDS shall continue to transmit the received and decoded data with the RxD signal to the MIS, and at the same time adapt the transmitted time pulses to the received ones with the RxC signal. If the MDS recognises the Data_Idle state after it has received the last data bit within an octet, it shall set the RxA signal to logical 0 during the falling edge of RxC.

**Data_Idle** state:
As long as the MDS recognises the Data_Idle state, it shall retain the RxA signal at logical 0 and the RxCR signal at logical 0.

If the MDS recognises the beginning of a check sequence PhPDU, it adapts the time pulses transmitted with the RxC signal to the received ones, sets the RxA signal to logical 1 during the rising edge of RxC, at the same time sets the RxCR signal to logical 1 and transmits with the RxD signal the decoded first received bit of the checksum (CRC data) to the MIS.

If the MDS recognises the first bit within an octet of a data sequence PhPDU instead of the beginning of a check sequence, it continues to receive the data sequence by adapting the transmitted time pulses to the received ones with the RxC signal and at the same time setting the RxA signal to logical 1 during the rising edge of RxC and transmitting the received and decoded data bit with the RxD signal to the MIS.

**CRC_Data** state:
The MDS shall continue to transmit the received and decoded checksum data with the RxD signal to the MIS and to adapt with the RxC signal the transmitted time pulses to the received ones.

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If the MDS recognises the first bit of the checksum status after it has received the checksum data completely, it shall adapt the time pulses transmitted with the RxC signal, set the RxS signal during the rising edge of RxC to logical 0, and at the same time transmit the received and decoded bit of the checksum status with the RxD signal to the MIS.

If the MDS recognises the CRC_Idle state after it has received the last bit within an octet it shall set the RxA signal to logical 0 during the falling edge of RxC.

If the MDS recognises the first bit within an octet of the checksum data, it shall continue to receive the checksum data by adapting the time transmitted pulses to the received ones with the RxC signal, setting the RxA signal during the rising edge of RxC to logical 1 and at the same time transmitting with the RxD signal the received and decoded checksum bit to the MIS.

**CRC_Status** state:
The MDS shall continue to transmit the received and decoded checksum status with the RxD signal to the MIS and, at the same time adapt the transmitted time pulses to the received ones with the RxC signal. After it has completely received the checksum status, the MDS sets the RxA signal to logical 0 during the falling edge of RxC and at the same time sets the RxS signal to logical 1.

If the MDS recognises the CRC_Idle state after it has received the last bit within an octet it shall set the RxA signal to logical 0 during the falling edge of RxC.

**CRC_Status_Idle** state:
If the MDS recognises the first bit within an octet of the checksum data, it shall continue to receive the checksum status by adapting the time pulses transmitted with the RxC signal to the received ones, setting the RxA signal during the rising edge of RxC to logical 1 and at the same time transmitting with the RxD signal the received and decoded bit of the checksum status to the MIS.

#### 8.4.4.8 Reset service

This service is sent from the MIS to the MDS by setting the RO signal. The receipt of a reset is passed from the MDS to the MIS with the RI signal. Value ranges: short, long

### 8.5 Type 12: DTE – DCE interface

The DTE-DCE interface is not exposed for Type 12 transmission.

### 8.6 Type 28: DTE – DCE interface and MIS Specific function

#### 8.6.1 General

The PhE is partitioned into DTE component containing the DIS, and Data Communication Equipment (DCE) component containing the MDS and lower sublayers. The DTE-DCE interface connects these two physical components, and is itself within the MIS.

It is not mandatory for the DTE-DCE interface, or any other interface, to be exposed.

#### 8.6.2 MIS Specific function

##### 8.6.2.1 General

The MIS function includes the processing of specific physical resources in the DCE according to the set working mode.

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#### 8.6.2.2 PhL resource

##### 8.6.2.2.1 Signal frame

In the Type 28 network, the data frame sent by DLL is converted into code block (CB) that could be processed by the PhL through DLL-PhL interface. The CB should be encoded by Reed-Solomon (RS) coding and convolution coding. After QAM mapping in PhL, the CB is matched to the physical resource defined by OFDM symbol and subcarrier, and modulated by IFFT. Then the PhL signal frame (SF) is formed and transmitted to the cable. The receiver recovers the digital signal and stream in reverse.

The sampling interval in time domain $T_S$ is given by Formula (1).

$$T_S = \frac{1}{24\,000 \times 4\,096} \tag{1}$$

That is 10,17 nanoseconds. The sampling interval is fixed in different transmit modes (TM).

The basic unit of PhL signal is SF, and 64 OFDM symbols form one SF. Each OFDM symbol is divided into upper sideband and lower sideband in the frequency domain subcarrier. The high frequency subcarrier (16,896 MHz to 32,256 MHz) is named upper sideband and the low frequency subcarrier (1,536 MHz to 16,896 MHz) is named lower sideband. The upper sideband and lower sideband can be allocated to different MN or TNs.

Figure 39 shows the structure of SF and OFDM symbol.

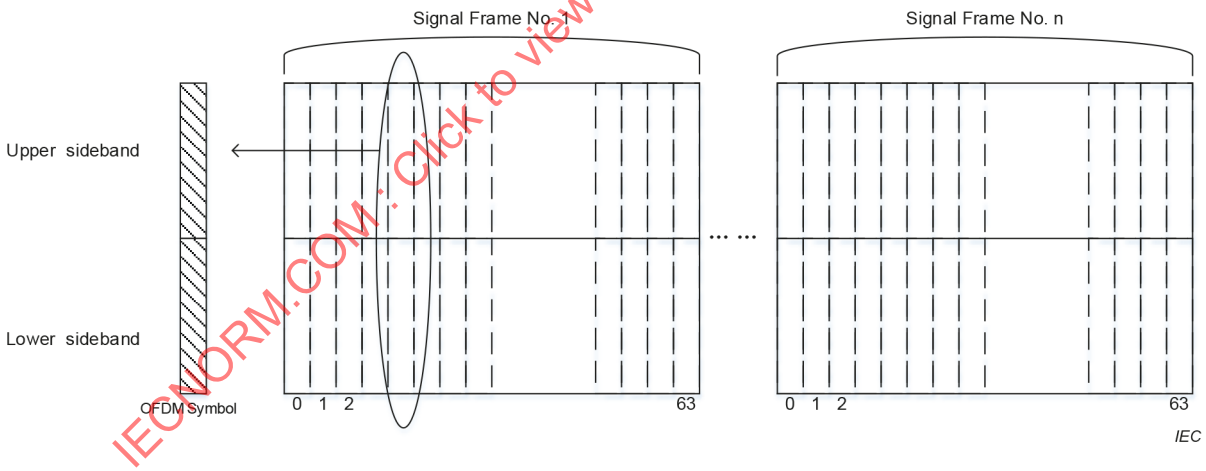


**Figure 39 – SF and OFDM symbol**

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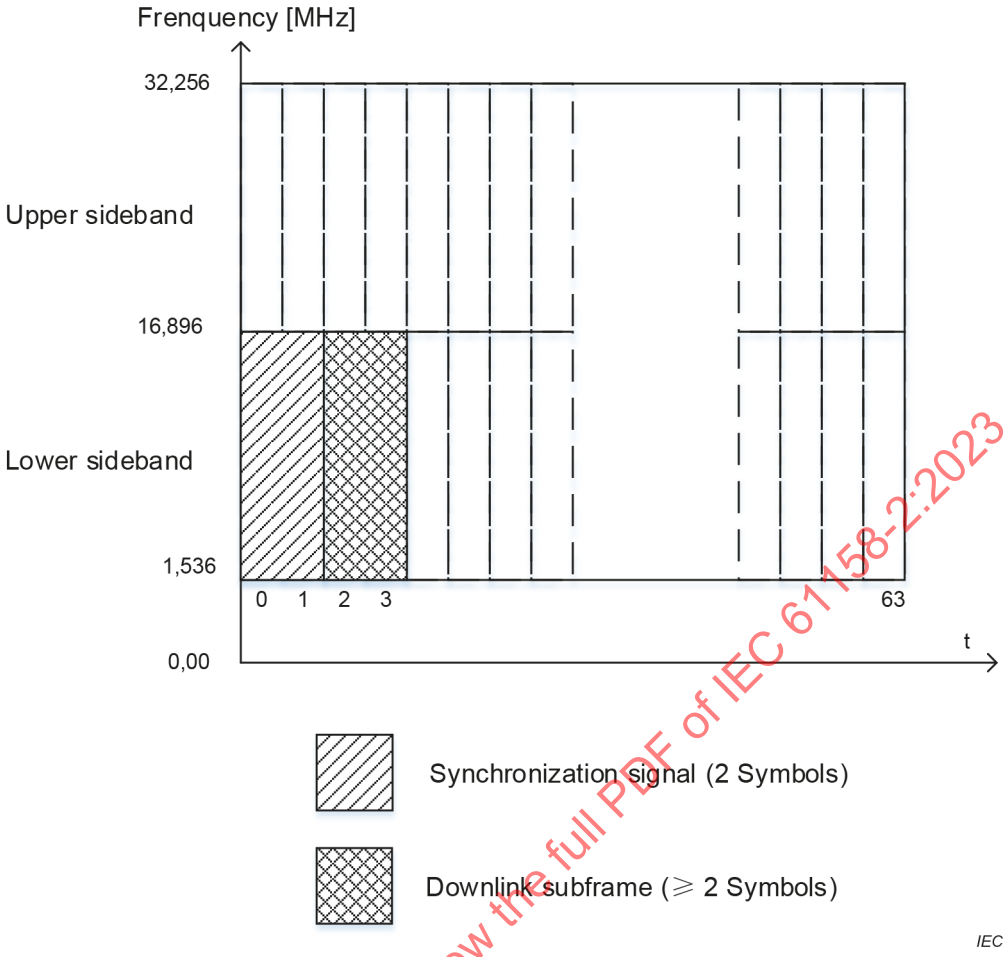


**Figure 40 – SF structure**

Figure 40 shows the block diagram of the SF. The SF should be decomposed by the following elements: synchronization signal (SynS), downlink subframe and data subframe.

– **Synchronization signal (SynS)** is used to identify the start of a SF. SynS has the function of SF synchronization and frame header positioning. The SynS is fixed to the lower sideband of the first and the second OFDM symbol of each SF (see Figure 40).
– **Downlink subframe** is used to send data and information from MN to TNs. It contains channel information, bandwidth allocation result, system maintenance status, etc. Downlink subframe contains the lower sideband which is greater than or equal to 2 OFDM Symbols (see Figure 41).
– **Data subframe** refers to allocable PhL communication resources. The minimum allocation unit is half sideband of one OFDM symbol (see carrier mode A) or half sideband of two OFDM symbols (see carrier mode B). In Figure 40, all blank parts are data subframe. The MN and TNs should request or configure the corresponding data subframe according to their requirement for data transmission.

#### 8.6.2.2.2 Data subframe

After PhS user allocates the data subframe to the MN or each TN., pilot signals should be inserted into the data subframe according to a specific form in order to enable the receiver to decode information quickly and accurately, and such pilot is named symbol pilot. The symbol pilot of data subframe supports discrete pilot and continuous pilot.

According to the difference between inserting symbol pilot mode and the data carrier structure of data subframe, the data subframe supports two kinds of carrier modes: carrier mode A and carrier mode B. They are defined as follows:

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– **Carrier mode A:** Both data signal and symbol pilot signal are transmitted through a single OFDM half sideband using continuous pilot, in which the ratio of occupied subcarrier between the symbol pilot signal and the data signal is 1:8.

– **Carrier mode B:** Symbol pilot signal are transmitted through the first OFDM half sideband of the data subframe obtained previously, and data signals are transmitted by the subsequent OFDM symbols.

Figure 41 shows the difference between carrier mode A and carrier mode B.

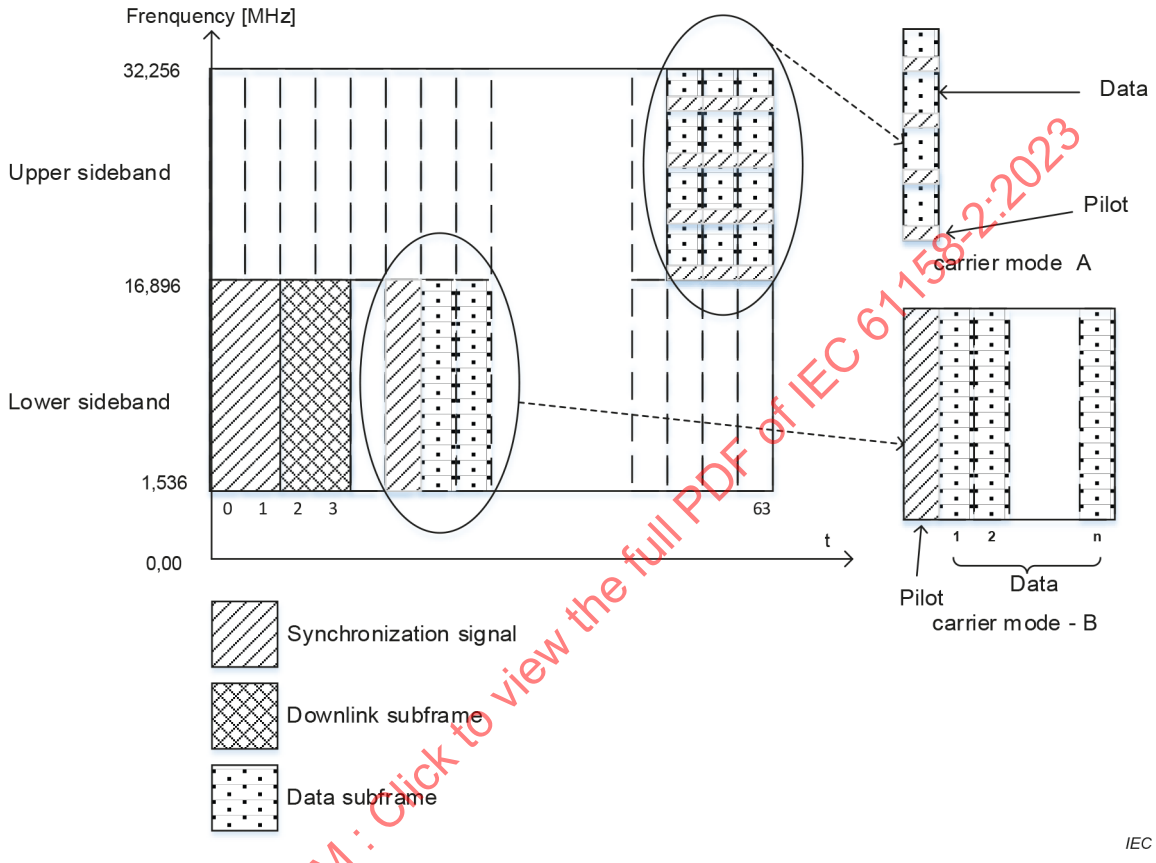


**Figure 41 – carrier mode A and carrier mode B of data subframe**

Carrier mode A is generally used for periodic cyclic data transmission. The data subframe supports up to 8 intervals if the carrier mode A is used. Carrier mode A also supports the application and use of equal allocation of interval resources for multi-users.

Carrier mode B is used both for cyclic fixed rate data transmission and variable rate data transmission.

NOTE Fixed rate data transmission means that the transmitted data is transmitted in a fixed cycle on the bus, and the data size transmitted per cycle is fixed. Variable rate data transmission means that the transmitted data is not processed on the bus in a fixed cycle, and the size of the data being processed is not fixed.

See Annex V for the distinction and choice of carrier mode A or carrier mode B.

#### 8.6.2.2.3 OFDM symbol

Each OFDM symbol in the PhL has its maintenance information as shown in Figure 42 to maintain the availability of OFDM symbols.

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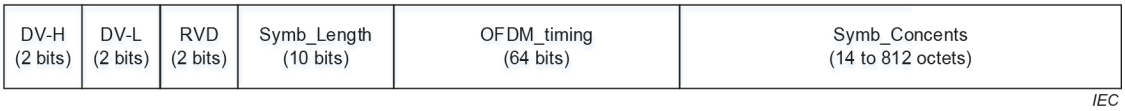


**Figure 42 – OFDM symbol structure of PhL**

– **DV-H** refers to the availability of the upper sideband and carrier mode of the OFDM symbol. 0b00 means unable. 0b01 is carrier mode A. 0b10 is carrier mode B, and 0b11 is reserved.

– **DV-L** refers to the availability of the lower sideband and carrier mode of the OFDM symbol, 0b00 means unable. 0b01 is carrier mode A, 0b10 is carrier mode B, and 0b11 is reserved.

– **RVD** refers to reserved bits.

– **Symb_Length** is the number of valid data octets loaded by this OFDM symbol.

– **OFDM_timing** is the time information contained in this OFDM symbol.

– **Symb_Contents** is the data loaded by this OFDM symbol and consists of 1 or 2 CBs (see 8.6.2.2.4).

Figure 43 shows OFDM timing structure. The structure has 64 bits and is the basis for clock synchronization between nodes.

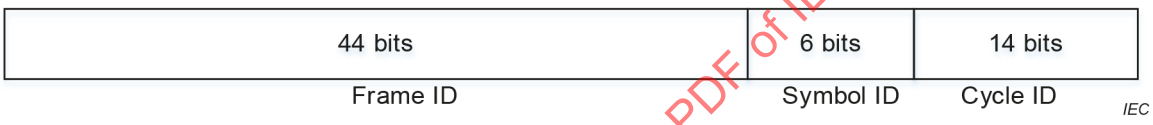


**Figure 43 – OFDM timing structure**

– **Frame ID** is the frame number of the current OFDM symbol, which counts from 0 when the MN is working normally. The valid value range is 0 to ($2^{44}$ − 1). When the count is equal to ($2^{44}$ − 1), it starts from 0 again.

– **Symbol ID** indicates the position of the current OFDM symbol in a SF. The valid value range is 0 to 63. The counting of symbol index starts when receiving a SynS of one SF.

– **Cycle ID** is the current sampling subcarrier number. The valid value range is 0 to 4 095. The counting of cycle id starts when receiving an OFDM symbol.

#### 8.6.2.2.4 Code Block

The basic unit of data interaction between the PhL and the DLL is code block (CB). The CB is composed of a certain number of octet sequences, which have the following characteristics:

– The number of octets of one CB is fixed corresponding to the different working modes of PhL (see 8.6.2.2.6). 1 to 2 CBs can be processed on each OFDM symbol half sideband.

– A DLPDU can be placed in one or more CBs after being serialized by octets. A CB can store octet sequence information for more than one DLPDU. Figure 44 shows the relationship between DLPDU and CB.

– The PhL entity automatically adds CRC check codes with the length of four octets for each CB before starting to process the CB.

– If the CB contains invalid octet sequence, the value of octets is set to 0 by default.

– The MSB in the code block stores the octet sequence information corresponding to the MSB data of DLPDU, and the LSB stores the octet sequence information corresponding to the LSB data of DLPDU.

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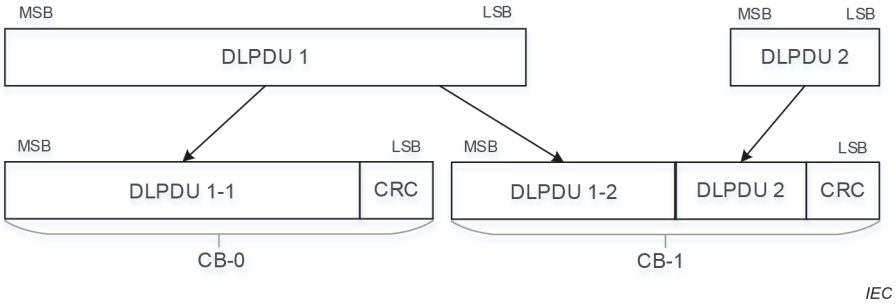


**Figure 44 – DLPDU and CB**

#### 8.6.2.2.5 Resource element

The transmission signal of each SF is defined as the resource grid with $N_{SD}$ subcarriers and $N_{SYM}$ OFDM symbols, where $N_{SD}$ is determined by the transmit mode. The configuration value is shown in Figure 45, and $N_{SYM}$ is 64. Figure 45 shows resource grid structure. Each element in the resource grid is called a resource element, and each resource element is uniquely defined by $(k,l)$, where $k = 0,\dots,N_{SD}-1$ and $l = 0,\dots,N_{SYM}-1$. $k$ represents the frequency domain and $l$ represents the time domain. Resource element $(k,l)$ corresponds to complex value $a_{k,l}$. The corresponding resource $a_{k,l}$ is set to 0 if it is not used for the transmission of physical signals.

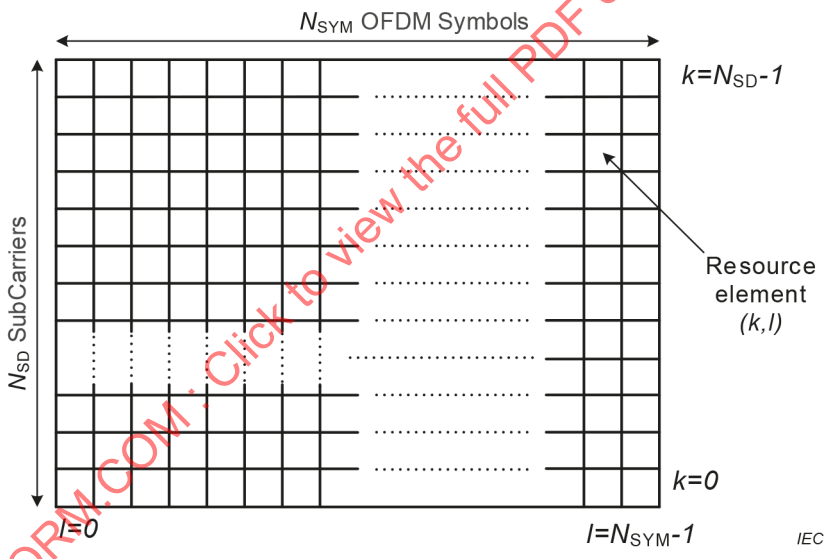


**Figure 45 – Resource element schematic diagram**

#### 8.6.2.2.6 Working mode

The PhL adopts OFDM technology and supports both time division multiplexing (TDM) and frequency division multiplexing (FDM). The PhL provides four different Transmit Modes (TM 0 / 1 / 2 / 3) in frequency domain. PhS users should select the TM according to the actual signal-to-noise ratio (SNR) of the application environment. An OFDM symbol time length should be configured as 64 µs, 32 µs, 16 µs or 8 µs corresponding to different TMs, The SF period varies from 500 µs to 4,0 ms. Table 50 shows the corresponding parameters in different TMs of the PhL.

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**Table 50 – TMs and corresponding parameters**

| Parameters | Transmit Mode | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Frequency Range [MHz] | 1,536 to 32,256 | 1,536 to 32,256 | 1,536 to 32,256 | 1,536 to 32,256 |
| Lower sideband Frequency Range [MHz] | 1,536 to 16,896 | 1,536 to 16,896 | 1,536 to 16,896 | 1,536 to 16,896 |
| Upper sideband Frequency Range [MHz] | 16,896 to 32,256 | 16,896 to 32,256 | 16,896 to 32,256 | 16,896 to 32,256 |
| Frequency Bandwidth [MHz] | 30,72 | 30,72 | 30,72 | 30,72 |
| Subcarrier Spacing, *B* [KHz] | 24 | 48 | 96 | 192 |
| Number of Subcarriers $N_{SD}$ | 1 280 | 640 | 320 | 160 |
| FFT Size [K = 1 024] | 4K | 2K | 1K | 0,5K |
| Subcarrier modulation scheme | 16QAM, 64QAM, 256QAM | 16QAM, 64QAM, 256QAM | 16QAM, 64QAM, 256QAM | 16QAM, 64QAM, 256QAM |
| Useful Symbol length [µs] | 41,666 7 | 20,833 3 | 10,416 7 | 5,208 3 |
| Cyclic Prefix length [µs] | 20,833 3 | 10,416 7 | 5,208 3 | 2,604 2 |
| Symbol length [µs] | 62,5 | 31,25 | 15,625 | 7,812 5 |
| Sampling Interval [ns] | 10,17 | 10,17 | 10,17 | 10,17 |
| Frame length [ms] | 4,0 | 2,0 | 1,0 | 0,5 |
| OFDM Symbols per frame $N_{SYM}$ | 64 | 64 | 64 | 64 |
| Available Channel per Symbol | 1 or 2 | 1 or 2 | 1 or 2 | 1 or 2 |

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The PhL has multiple working modes to carry DLL data. Different working modes adapt to different channel environments and data transmission requirements. In each working mode, the allocation of physical resources and the efficiency of data carry are varied with the selection of TM, frame format and modulation coding strategy (MCS).

After the configuration is completed, MN should broadcast the working mode to each TN in the network. If the network configuration is successful, the network works in this mode and implements the communication between nodes until MN reconfigures the working mode.

CB is the basic unit of data processing in the PhL. The valid octet number carried by an OFDM symbol is an integer multiple of the number of valid octets of a CB. The PhL supports a total of 22 working modes, of which carrier mode A supports 10 working modes and carrier mode B supports 12 working modes. Parameter configuration and the equivalent available bandwidth in each mode are shown in Table 51 and Table 52.

**Table 51 – Working mode under carrier mode A**

| Working mode | Transmit mode | FFT Points | Valid data in CB (octets) | Valid data of an OFDM symbol (octets) | Valid $N_{SD}$ of OFDM symbol | Equivalent available bandwidth (Mbit/s) |
|---|---|---|---|---|---|---|
| A0 | 0 | 1 024 | 173 | 346 | 1 280 | 44,288 |
| A1 | 0 | 1 024 | 103 | 412 | 1 280 | 52,736 |
| A2 | 0 | 1 024 | 173 | 692 | 1 280 | 88,576 |
| A3 | 1 | 512 | 84 | 168 | 640 | 43,008 |
| A4 | 1 | 512 | 103 | 206 | 640 | 52,736 |
| A5 | 1 | 512 | 173 | 346 | 640 | 88,576 |
| A6 | 2 | 256 | 57 | 114 | 320 | 58,368 |
| A7 | 2 | 256 | 84 | 168 | 320 | 86,016 |
| A8 | 3 | 128 | 22 | 44 | 160 | 45,056 |
| A9 | 3 | 128 | 39 | 78 | 160 | 79,872 |

**Table 52 – Working mode under carrier mode B**

| Working mode | Transmit mode | FFT Points | Valid data in CB (octets) | Valid data of an OFDM symbol (octets) | Valid $N_{SD}$ of OFDM symbol | Equivalent available bandwidth (Mbit/s) |
|---|---|---|---|---|---|---|
| B0 | 0 | 1 024 | 123 | 246 | 1 280 | 31,488 |
| B1 | 0 | 1 024 | 203 | 406 | 1 280 | 51,968 |
| B2 | 0 | 1 024 | 123 | 492 | 1 280 | 62,976 |
| B3 | 0 | 1 024 | 203 | 812 | 1 280 | 103,936 |
| B4 | 1 | 512 | 59 | 118 | 640 | 30,208 |
| B5 | 1 | 512 | 99 | 198 | 640 | 50,688 |
| B6 | 1 | 512 | 123 | 246 | 640 | 62,976 |
| B7 | 1 | 512 | 203 | 406 | 640 | 103,936 |
| B8 | 2 | 256 | 59 | 118 | 320 | 60,416 |
| B9 | 2 | 256 | 99 | 198 | 320 | 101,376 |
| B10 | 3 | 128 | 27 | 54 | 160 | 55,296 |
| B11 | 3 | 128 | 47 | 94 | 160 | 96,256 |

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### 8.6.3 DTE – DCE interface

#### 8.6.3.1 General

When the data is serialized in the DIS, DCE should be informed to transmit data through this interface. After completing the data signal receiving and processing, the DTE should be notified to perform data serialization processing. The PhL DTE-DCE interface realizes the services by a set of defined interface signal interactions.

#### 8.6.3.2 Interface signal

##### 8.6.3.2.1 Synchronization Request (SyR)

SyR signal is a continuous timing signal provided by DCE to DTE. The basic unit of the timing signal is one OFDM symbol period. The DCE informs DTE to implement SF synchronization and

continue processing the physical SF based on the SynS signal. The synchronization request signal is fixed to 2 symbol period, and every 64 OFDM symbol period process a SF synchronization.

#### 8.6.3.2.2 Synchronization Confirm (SyC)

DTE transmits SyC signal to DCE to implement synchronization confirming, at the same time, DTE should transmit synchronization information to DLL entity and upper user for further processing.

#### 8.6.3.2.3 Transmit Request (TxR)

DCE prepares for data transmission according to the SyC signal transmitted by DTE. DCE should be ready to receive TxD signal from DTE after the relevant parameters of transmitting are confirmed. If there is an error in transmitted data, the DTE should notify DCE through this signal, and not confirm whether this signal has been processed by DCE.

#### 8.6.3.2.4 Transmit Data (TxD)

DTE notifies DCE to transmit data by sending TxD signal. DCE performs scrambling, encoding, interleaving, modulating and mapping processing on the CB to generate a physical signal based on the determined CB and parameter information, and transmits the physical signal over medium.

#### 8.6.3.2.5 Receive Request (RxR)

DTE prepares for data receiving according to the RxR signal transmitted by DCE. DTE should be ready to receive RxD signal from DCE after the relevant parameters of receiving are confirmed. If there is an error in received data, DCE should notify DTE through this signal, and not confirm whether this signal has been processed by DTE.

#### 8.6.3.2.6 Receive data (RxD)

DCE notifies DTE to receive data by sending RxD signal. After receiving the signal, DTE obtains the valid data from the determined CB and implements the conversion from the serialized data to the interface data unit, and informs the DLL entity for further processing.

### 8.6.3.3 Signal process

The trigger time of DTE-DCE interface signal in the PhL is confirmed according to the configuration of bus cycle time related parameters. The basic unit of the interface signal trigger period is one OFDM symbol period. Figure 46 shows the process of DTE-DCE interface signal on the device.

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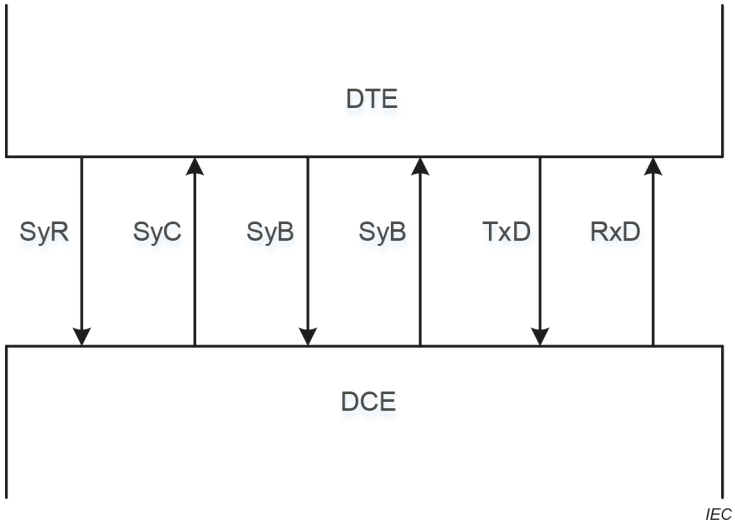


**Figure 46 – DTE-DCE interface signal process**

# 9 Medium dependent sublayer (MDS)

## 9.1 General

The medium dependent sublayer (MDS) is part of the data communication equipment (DCE). (See Figure 1.) It exchanges information across the DTE-DCE interface specified in Clause 8 and it communicates encoded Ph-symbols across the MDS-MAU interface specified in Clause 10. The MDS functions are logical encoding and decoding for transmission and reception respectively and the addition/removal of preamble and delimiters together with timing and synchronization functions.

NOTE A number of different MDS sublayer entities are specified, based on industry practice.

## 9.2 Type 1: MDS: Wire and optical media

### 9.2.1 PhPDU

The MDS shall produce the PhPDU shown in Figure 47 by adding preamble and delimiters to frame the serial sequence of PhSDUs (bits) transferred from the DIS across the DTE-DCE interface. Transmission sequence shall be from left to right as shown in Figure 47, i.e. preamble first, followed by start delimiter, PhSDU sequence and finally end delimiter.

| PREAMBLE | START DELIMITER | PhSDU SEQUENCE | END DELIMITER |
|---|---|---|---|

**Figure 47 – Protocol data unit (PhPDU)**

Conversely, the MDS shall remove preamble and delimiters from a received PhPDU to produce a corresponding serial sequence of PhSDUs. If a non-binary data unit is detected in the received PhSDU sequence, the MDS shall immediately stop transferring PhSDUs to the DIS, the MDS shall report an error, and the MDS shall indicate the end of activity to the DIS when it happens.

### 9.2.2 Encoding and decoding

Data units shall be encoded by the MDS for application to the MAU using the code shown in Figure 48(Manchester Biphase L). The encoding rules are formally given in Figure 49 and Table 53.

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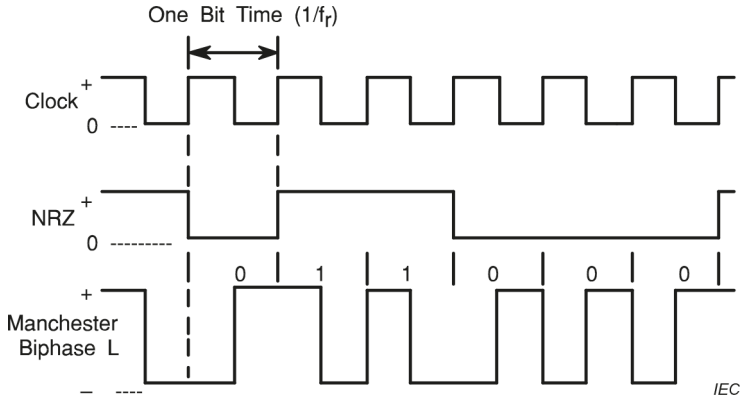


**Figure 48 – PhSDU encoding and decoding**

NOTE Figure 48 is included for explanatory purposes and does not imply a specific implementation.

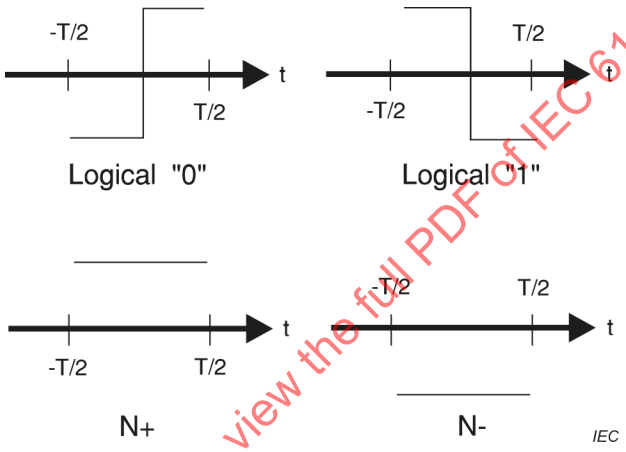


**Figure 49 – Manchester encoding rules**

**Table 53 – Manchester encoding rules**

| Symbols | Encoding |
|---|---|
| 1 (ONE) | Hi-Lo transition (mid-bit) |
| 0 (ZERO) | Lo-Hi transition (mid-bit) |
| N+ (NON-DATA PLUS) | Hi (No transition) |
| N- (NON-DATA MINUS) | Lo (No transition) |
| NOTE It can be seen that data symbols (1 and 0, conveyed by PhSDUs) are encoded to always contain a mid-bit transition. Non-data symbols (N+ and N-) are encoded so that they never have a mid-bit transition. Frame delimiters (see 9.2.4 and 9.2.5) are constructed so that non-data symbols are conveyed in pairs of opposite polarity. | |

Decoding shall normally be the opposite of encoding. At reception, the MDS shall verify that each symbol is encoded in accordance with Figure 49 and Table 53 and shall detect the following errors:

a) invalid Manchester code;

b) half-bit-slip errors.

Any of these errors shall be reported as PH-DATA indication (PhIDU, error).

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### 9.2.3 Polarity detection

The option of automatic polarity detection of the received Manchester encoded signal shall be required where it is specified in the relevant MAU.

### 9.2.4 Start of frame delimiter

The following sequence of symbols, shown from left to right in order of transmission, shall immediately precede the PhSDU sequence to delimit the start of a frame:

1, N+, N-, 1, 0, N-, N+, 0.

(shown as a waveform in Figure 50)

The MDS shall only accept a received signal burst as a PhPDU after verifying this sequence and shall remove this sequence before transferring the PhSDU sequence to the DIS.

### 9.2.5 End of frame delimiter

The following sequence of symbols, shown from left to right in order of transmission, shall immediately follow the PhSDU sequence to delimit the end of a frame:

1, N+, N-, N+, N-, 1, 0, 1.

(shown as a waveform in Figure 50)

The MDS shall remove this sequence from the PhPDU before transferring the PhSDU sequence to the DIS. The MDS shall report to the corresponding DLL entity any frames received via the medium which do not include this sequence within 300 octets of start of frame (from beginning of start delimiter) as PH-DATA indication (PhIDU, frame_too_long). The MDS shall report to the corresponding DLL entity, via the corresponding DIS, any frames received via the medium that have an end delimiter which is not located at an octet boundary as PH-DATA indication (PhIDU, received_timing_error).

### 9.2.6 Preamble

In order to synchronize bit times a preamble shall be transmitted at the beginning of each PhPDU consisting of the following sequence of bits, shown from left to right in order of transmission:

1, 0, 1, 0, 1, 0, 1, 0.

(shown as a waveform in Figure 50)

NOTE 1 It is possible that the received preamble contains as few as four bits due to loss of one bit through each of four repeaters (as specified in the MAU Network Configuration Rules).

The period may be extended, but not reduced, by Systems management as given in Table 13. A preamble extension sequence as listed in Table 13 shall be defined as the following sequence of bits, shown from left to right in order of transmission:

1, 0, 1, 0, 1, 0, 1, 0.

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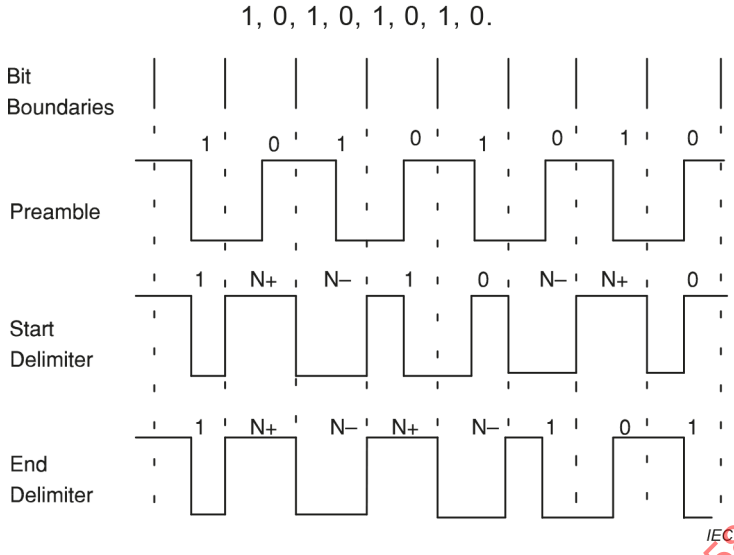


**Figure 50 – Preamble and delimiters**

NOTE 2 These waveforms do not extend the frequency range outside the band required for transmission of binary PhSDUs (conveying data symbols) in accordance with Figure 49 and Table 53.

### 9.2.7 Synchronization

After the reception of the fourth bit of the frame and until end of frame or frame termination the receiver shall detect and report half-bit-slip errors.

NOTE 1 This synchronization specification allows the loss of 4 bits of the preamble.

After the preamble, half-bit-slip errors shall be reported as PH-DATA indication (PhIDU, error).

NOTE 2 Half-bit-slip errors can be detected as excessive bit cell jitter and/or excessive variation in bit period.

### 9.2.8 Post-transmission gap

After transmission of a PhPDU there shall be a minimum period during which a subsequent transmission shall not commence. For the same minimum period after reception of a PhPDU the receiving PhL entity shall ignore all received signaling. An MDS entity shall set a minimum post transmission period of four nominal bit times. The period may be extended, but not reduced, by Systems management as given in Table 13 or by an associated MAU entity. A gap extension sequence as listed in Table 13 shall be defined as four nominal bit times.

NOTE The MAU transmit enable/disable time can reduce the duration of silence between frames.

### 9.2.9 Inter-channel signal skew

If the device is configured (by Systems management) to receive concurrently on more than one channel, then the maximum accepted differential delay between any two active channels, as measured from the first PhPDU of a start delimiter, shall not exceed five nominal bit times. This period may be extended, but not reduced, by Systems management as given in Table 13. A gap extension sequence as listed in Table 13 shall be defined as four nominal bit times. The value of post-transmission gap shall be greater than the value of inter-channel skew.

## 9.3 Void

NOTE Subclause 9.3 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

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## 9.4 Type 2: MDS: Wire and optical media

### 9.4.1 General

NOTE The Medium Dependent Sublayer (MDS) is part of the Data Communication Equipment (DCE). It communicates encoded bits across the MDS-MAU interface specified in 10.4.

### 9.4.2 Clock accuracy

The timing specifications for PhL Signaling shall be as defined in Table 54.

**Table 54 – MDS timing characteristics**

| Specification | Limits / characteristics | Comments |
|---|---|---|
| Bit Rate | 5 Mbit/s with a tolerance of ± CA | Also called M-symbol rate, *data 'zero' or 'one'* |
| Bit Time | 200 ns with a tolerance of ± CA | Also called M-symbol time, *data 'zero' or 'one'* |
| PhL symbol time | 100 ns with a tolerance of ± CA | Also called Ph-symbol time, see data encoding rules |
| Clock Accuracy (CA) | ± 150 µHz/Hz max. | Including temperature, long term and short term stability |

### 9.4.3 Data recovery

The signals at the DLL to PhL interface shall be synchronized to the local bit rate as shown in Table 54. Each PhL implementation shall provide a data recovery mechanism that recovers or reconstructs the data received from the appropriate medium to meet the timing requirements shown in Table 54. When data synchronization has been attained by the MDS, PH-LOCK indication shall be true.

A portion of the received data frame can be lost or discarded in the process of attaining data synchronization. The specification for data timing shown in Table 54 shall be achieved prior to the beginning of the start delimiter (see IEC 61158-4-2).

### 9.4.4 Data encoding rules

The M_symbols present at the DLL to PhL interface shall be encoded into the appropriate Ph-symbols as shown in Table 55 and Figure 51. The M_0 and M_1 symbols shall be encoded into Ph-symbols that represent Manchester Biphase L data encoding rules as shown in Table 55. The M_ND symbols shall be used to create unique data patterns used for start and end delimiters. The signal voltage waveform (from the MAU) is shown in an idealized form in Figure 51 to provide an example of the data encoding rules shown in Table 55.

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**Table 55 – MDS data encoding rules**

| Data bits (common name) | M_symbol representation | Ph-symbol encoding | Manchester encoded |
|---|---|---|---|
| data 'zero' | M_0 or {0} | {L,H} | 0 |
| data 'one' | M_1 or {1} | {H,L} | 1 |
| 'non_data+' | M_ND+ or {+} | {H,H} | no data |
| 'non_data-' | M_ND- or {-} | {L,L} | no data |

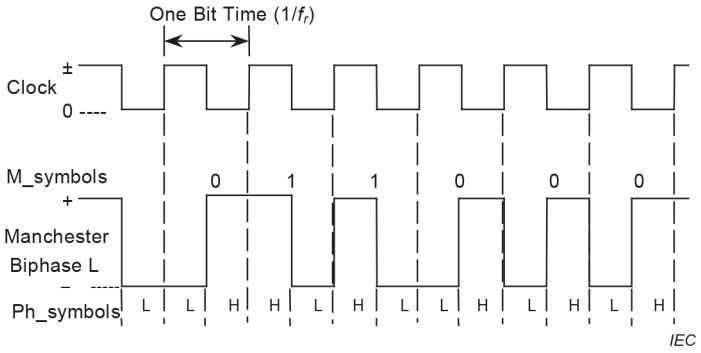


**Figure 51 – Manchester coded symbols**

## 9.5 Type 3: MDS: Wire and optical media

### 9.5.1 Synchronous transmission

The Medium Dependent Sublayer (MDS) specified for Type 1 shall be used (see 9.2).

### 9.5.2 Asynchronous transmission

There is no Medium Dependent Sublayer (MDS) for asynchronous transmission.

## 9.6 Type 4: MDS: Wire medium

### 9.6.1 Half-duplex

#### 9.6.1.1 Overview

NOTE 1 The PhL entity is partitioned into a Data Terminal Equipment (DTE) component containing the MDS, and a Data Communication Equipment (DCE) component containing the MAU.

NOTE 2 The functionality of the MDS is similar to the functionality of what is commonly known as a UART. In addition, the half duplex MDS has some timing functionality. The functionality of the MAU is similar to the functionality of what is commonly known as a driver circuitry.

The half-duplex MDS shall sequence the transmission of the PhID as a sequence of bits. Similarly, the MDS shall form the PhID to be reported to the DLL from the sequence of received bits. Bits are sent and received in NRZ code (non-return-to-zero).

The PhID shall be converted to a sequence of bits for serial transmission in PhPDUs. Within each PhPDU, a bit representing a more significant bit shall be transmitted before a bit representing a less significant bit. On reception, each sequence of bits shall be converted to PhID such that, in the absence of errors, the PhID indicated to the receiving DLL entity is unchanged from the PhID whose transmission was requested by the originating DLL entity.

The MDS receives a single PhID or a sequence of PhID octets from the DLE. The first octet is received from the DLE by one of the services START-OF-ACTIVITY-**11** or START-OF-ACTIVITY-**2**. The remaining octets are received from the DLE by the service DATA. End of transmission is indicated by the service END-OF-ACTIVITY. From each PhID octet the MDS shall form a PhPDU and transmit the formed PhPDU as a sequence of bits to the MAU. Each PhPDU shall consist of 1 start bit, 8 data bit, 1 address/data bit, and finally 1 stop-bit. This is indicated in Figure 52.

| Start | Data8 … Data1 | Address/data | Stop |
|---|---|---|---|
| 0 | X….X | 1 for first octet, 0 for remaining | 1 |

**Figure 52 – PhPDU format, half duplex**

The MDS shall report when the signal level on the attached medium has been idle for 30, 35 and 40 or more bit periods, by **LINK-IDLE** indications to the DLE.

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The transmitted bit rate shall be that of the selected baud rate, with a tolerance of ± 0,2 %.

#### 9.6.1.2 Transmission

##### 9.6.1.2.1 START-OF-ACTIVITY-11

The following shall be performed as a result of the DLE issuing a START-OF-ACTIVITY**-11** PH-DATA request:

a) wait for Idle counter equal to or higher than 11;
b) form first PhPDU with Address/data bit = "1" and data = data parameter of START-OF-ACTIVITY**-11** request;
c) confirm reception to DLE to enable the DLE to issue the next transmission request;
d) activate Transmit Enable (TxE);
e) start transmitting the PhPDU to the MAU.

##### 9.6.1.2.2 START-OF-ACTIVITY-2

The following shall be performed as a result of the DLE issuing a START-OF-ACTIVITY**-2** PH-DATA request:

a) wait for Idle counter modulus 10 equal to or higher than 2;
b) form first PhPDU with Address/data bit = "1" and data = data parameter of START-OF-ACTIVITY**-2** request;
c) confirm reception to DLE to enable the DLE to issue the next transmission request;
d) activate Transmit Enable (TxE);
e) start transmitting the PhPDU to the MAU.

##### 9.6.1.2.3 DATA

The following shall be performed as a result of the DLE issuing a DATA PH-DATA request:

a) wait till transmission of former PhPDUs has finished;
b) form a new PhPDU with Address/data bit = "0" and data = data parameter of DATA request;
c) confirm reception to DLE to enable the DLE to issue the next transmission request;
d) start transmitting the PhPDU to the MAU.

It shall be ensured that there are no idle periods between transmissions of PhPDUs. The DLE should issue the next transmission request within 11 bit periods after confirmation of the former.

##### 9.6.1.2.4 END-OF-ACTIVITY

The following shall be performed as a result of the DLE issuing an END-OF-ACTIVITY PH-DATA request:

a) wait till transmission of former PhPDU has finished;
b) wait for minimum 3, maximum 10 bit periods;
c) deactivate Transmit Enable (TxE).

#### 9.6.1.3 Reception

##### 9.6.1.3.1 START-OF-ACTIVITY

As a result of receiving a frame from the MAU with address/data bit = "1", or receiving a frame when the value of the Idle counter is higher than or equal to 11, the MDS shall issue a PH-DATA indication of class START-OF-ACTIVITY. The associated data parameter shall hold the received data. The value of the associated status parameter shall be set according to the following:

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a) receiving a frame with address/data bit = "1" and stop bit = "1", when the value of the Idle counter is higher than or equal to 11 shall result in an associated status parameter indicating SUCCESS;

b) receiving a frame with stop bit = "0", shall result in an associated status parameter indicating FRAMING_ERROR;

c) receiving a frame with address/data bit = "1", but when the value of the Idle counter is lower than 11 shall result in an associated status parameter indicating IDLE_ERROR;

d) receiving a frame with address/data bit = "0", but when the value of the Idle counter is higher than or equal to 11 shall result in an associated status parameter indicating ADDRESS_DATA_ERROR.

#### 9.6.1.3.2 DATA

As a result of receiving a frame from the MAU with address/data bit = "0", when the value of the Idle counter is lower than 11, the MDS shall issue a PH-DATA indication of class DATA. The associated data parameter shall hold the received data. The value of the associated status parameter shall be set according to the following:

a) receiving a frame with stop bit = "1" from the MAU shall result in an associated status parameter indicating SUCCESS;

b) receiving a frame with stop bit = "0", shall result in an associated status parameter indicating FRAMING_ERROR.

### 9.6.1.4 Idle counter

The MDS holds an idle counter. This counter is incremented by one for each bit period, and is cleared each time a bit with value "0" is sent to or received from the MAU. When the Idle counter reaches 30, the MDS shall report this with a PH-DATA indication of class LINK-IDLE, and associated status indicating 30 bit periods. 5 bit periods later, if the Link is still idle, the PhE reports this with another PH-DATA indication of class LINK-IDLE, and associated status indicating 35 bit periods. 5 bit periods later, if the Link is still idle, the PhE reports this with another PH-DATA indication of class LINK-IDLE, and associated status indicating 40 or more bit periods. This goes on for each 10 bit periods with indications specifying 40 or more bit periods. The speed of the idle counter shall be that of the selected baud rate, with a tolerance of ± 0,2 %.

## 9.6.2 Full-duplex

### 9.6.2.1 Overview

NOTE 1 The PhL entity is partitioned into a Data Terminal Equipment (DTE) component containing the MDS, and a Data Communication Equipment (DCE) component containing the MAU.

NOTE 2 The functionality of the MDS is similar to the functionality of what is commonly known as a UART. In addition, the full duplex MDS has some "byte stuffing" functionality. The functionality of the MAU is similar to the functionality of what is commonly known as a driver circuitry.

The full duplex MDS shall sequence the transmission of the PhID as a sequence of bits. Similarly, the MDS shall form the PhID to be reported to the DLL from the sequence of received bits. Bits are sent and received in NRZ code (non-return-to-zero).

The PhID shall be converted to a sequence of bits for serial transmission in PhPDUs. Within each PhPDU, a bit representing a more significant bit shall be transmitted before a bit representing a less significant bit. On reception, each sequence of bits shall be converted to PhID such that, in the absence of errors, the PhID indicated to the receiving DLL entity is unchanged from the PhID whose transmission was requested by the originating DLL entity.

The MDS receives a single PhID or a sequence of PhID octets from the DLE. The first octet is received from the DLE by the service START-OF-ACTIVITY**-2**. The remaining octets are received from the DLE by the service DATA. End of transmission is indicated by the service END-OF-ACTIVITY. From each PhID octet the MDS shall form a PhPDU and transmit the formed PhPDU

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as a sequence of bits to the MAU. Each PhPDU shall consist of 1 start bit, 8 data bit, and finally 1 stop-bit. This is indicated in Figure 53.

| Start | Data8 ... Data1 | Stop |
|---|---|---|
| 0 | X....X | 1 |

**Figure 53 – PhPDU format, full duplex**

#### 9.6.2.2 Transmission

##### 9.6.2.2.1 START-OF-ACTIVITY-2

The following shall be performed as a result of the DLE issuing a START-OF-ACTIVITY**-2** PH-DATA request:

a) form first PhPDU with data = $D7 (hex);
b) form second PhPDU with data = data parameter of START-OF-ACTIVITY**-2** request;
c) confirm reception to DLE to enable the DLE to issue the next transmission request;
d) activate request-to-send signal (RTS);
e) wait for clear-to-send signal (CTS) to be activated;
f) start transmitting the formed PhPDUs to the MAU.

##### 9.6.2.2.2 DATA

The following shall be performed as a result of the DLE issuing a DATA PH-DATA request:

a) wait till transmission of former PhPDUs is finished;
b) wait for clear-to-send signal (CTS) to be active;
c) form new PhPDU(s) with data according to the following:
d) if the value of data parameter of DATA request = $D7 (hex), form a PhPDU with the data value $D9 (hex), followed by an additional PhPDU with the data value $00;
e) if the value of data parameter of DATA request = $D9 (hex), form a PhPDU with the data value $D9 (hex), followed by an additional PhPDU with the data value $01;
f) if the value of data parameter of DATA request is different from $D7 (hex) and $D9 (hex), form a PhPDU with the data value = data parameter of DATA request;
g) confirm reception to DLE to enable the DLE to issue the next transmission service;
h) start transmitting the PhPDU(s) to the MAU.

##### 9.6.2.2.3 END-OF-ACTIVITY

The following shall be performed as a result of the DLE issuing an END-OF-ACTIVITY PH-DATA request:

a) wait till transmission of former PhPDUs has finished;
b) deactivate request-to-send (RTS) signal.

#### 9.6.2.3 Reception

##### 9.6.2.3.1 START-OF-ACTIVITY

As a result of receiving a PhPDU from the MAU with a data value of $D7 (hex), the MDS shall wait for the following PhPDU, and when this PhPDU is received issue a PH-DATA indication of class START-OF-ACTIVITY. The associated data parameter shall hold the received data from the PhPDU following $D7 (hex). The value of the associated status parameter shall be set according to the following:

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a) receiving a PhPDU with stop bit = "1" shall result in an associated status parameter indicating SUCCESS;

b) receiving a PhPDU with stop bit = "0", shall result in an associated status parameter indicating FRAMING_ERROR.

#### 9.6.2.3.2 DATA

Receiving a PhPDU from the MAU with a data value different from $D7 (hex) shall result in the following:

receiving a PhPDU with stop bit = "1" and a data value = $D9 (hex), shall result in the MDS waiting for the following PhPDU from the MAU. The result of receiving the following PhPDU shall be:

a) if the data value of the following PhPDU is $00 (hex), and the stop bit is = "1", issue a PH-DATA indication of class DATA. The associated data parameter shall hold the value $D7. The value of the associated status parameter shall indicate SUCCESS.

b) if the data value of the following PhPDU is $01 (hex), and the stop bit is = "1", issue a PH-DATA indication of class DATA. The associated data parameter shall hold the value $D9. The value of the associated status parameter shall indicate SUCCESS.

c) if the data value of the following PhPDU is different from $00 (hex) and from $01 (hex), and the stop bit is = "1", issue a PH-DATA indication of class DATA. The associated data parameter shall hold the received data value. The value of the associated status parameter shall indicate BYTE_STUFFING_ERROR.

d) if the stop bit is "0", issue a PH-DATA indication of class DATA. The associated data parameter shall hold the received value. The value of the associated status parameter shall indicate FRAMING_ERROR.

e) receiving a PhPDU with stop bit = "1" and a data value different from $D9 (hex), shall result in the MDS issuing a PH-DATA indication of class DATA. The associated data parameter shall hold the received value. The value of the associated status parameter shall indicate SUCCESS;

f) receiving a PhPDU with stop bit = "0" shall result in the MIS issuing a PH-DATA indication of class DATA. The associated data parameter shall hold the received value. The value of the associated status parameter shall indicate FRAMING_ERROR.

### 9.6.3 Full-duplex UDP

#### 9.6.3.1 Overview

The PhID shall be sent in accordance with ISO/IEC/IEEE 8802-3:2021.

The MDS receives a single PhID or a sequence of PhID octets from the DLE. The first octet is received from the DLE by the service START-OF-ACTIVITY**-2**. The remaining octets are received from the DLE by the service DATA. End of transmission is indicated by the service END-OF-ACTIVITY.

#### 9.6.3.2 Transmission

##### 9.6.3.2.1 START-OF-ACTIVITY-2

The following shall be performed as a result of the DLE issuing a START-OF-ACTIVITY**-2** PH-DATA request:

a) reserve MAC sublayer packet;

b) form PhPDU with data = data parameter of START-OF-ACTIVITY**-2** request;

c) insert the formed PhPDU at the first location in the reserved packet;

d) confirm reception to DLE to enable the DLE to issue the next transmission request;

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The following shall be performed as a result of the DLE issuing a DATA PH-DATA request:

a) form PhPDU with data = data parameter of the DATA request;

b) insert the formed PhPDU at the next location in the reserved packet;

c) confirm reception to DLE to enable the DLE to issue the next transmission service.

#### 9.6.3.2.2 END-OF-ACTIVITY

The following shall be performed as a result of the DLE issuing an END-OF-ACTIVITY PH-DATA request:

a) transfer the reserved packet to the MAC sublayer.

### 9.6.3.3 Reception

#### 9.6.3.3.1 START-OF-ACTIVITY

As a result of receiving a packet from the MAC sublayer, issue a PH-DATA indication of class START-OF-ACTIVITY. The associated data parameter shall hold the first octet of the received packet. The value of the associated status parameter shall be set to SUCCESS.

#### 9.6.3.3.2 DATA

The following data in the received packet shall result in the MDS issuing PH-DATA indications of class DATA. The associated data parameters shall hold the received values. The value of the associated status parameters shall indicate SUCCESS.

## 9.7 Void

NOTE Subclause 9.7 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

## 9.8 Type 8: MDS: Wire and optical media

### 9.8.1 Function

The medium-dependent sublayer (MDS) exchanges PhSDU sequences via the MIS-MDS interface, as described in 6.5, and transmits the PhPDU via the MDS-MAU interface as described in Clause 9. The MDS encodes and decodes the PhSDU, adds and removes the transmission frame (header and stop bit) for the PhSDU subsequences to be transmitted and received, synchronises the MIS-MDS interface and the MDS-MAU interface and the PhPDUs, time functions, and directly transmits a PhPDU between MAUs via the MDS-MAU interface (MAU coupling).

The MDS may consist of several channels. The PhPDU shall generate one channel of the MDS corresponding to the PhSDU sequences transmitted via the MIS-MDS interface and encode the PhSDU sequence accordingly. Conversely, this channel shall recognise the format of the received PhPDU and transmit the decoded PhSDU sequence via the MIS-MDS interface to the MIS. All other channels are used to directly transfer a PhPDU between two MAUs.

The channel of the MDS of a slave, which has an interface to the MIS shall have the following relation between the send and receive direction: If the MIS-MDS interface signal RTS is 0, the contents of DI is transmitted on the MDS-MAU interface signal DO with a delay time of exactly one bit time. If RTS is 1, DO is coupled to TxD (only applicable when there is no MDS coupling).

In the MDS of a master it is possible that a sequence of 8 PhSDUs is first buffered and then a corresponding data sequence or check sequence PhPDU is generated.

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### 9.8.2 PhPDU formats

#### 9.8.2.1 General

The MDS can recognise and generate the following PhPDU formats: **data sequence PhPDU**, **check sequence PhPDU**, **status PhPDU** and **reset PhPDU**.

#### 9.8.2.2 Data sequence PhPDU

The MDS generates data sequence PhPDU by adding a start bit, header, and stop bit to the data unit. The data unit itself consists of eight PhSDUs that, as a PhSDU sequence, have been transmitted as a part of the data sequence DLPDU via the MIS-MDS interface with the message transmission service. Figure 54 shows the structure of the data sequence PhPDU.

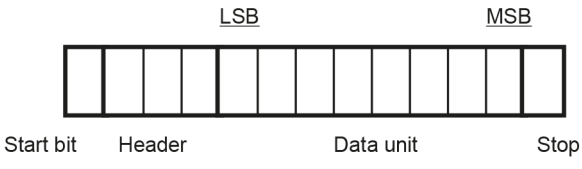


**Figure 54 – Data sequence PhPDU**

The data sequence PhPDU thus generated is transmitted from left to right via the MDS-MAU interface in the following order: start bit, header, data unit, stop bit. The PhSDUs of the data unit are transmitted via the MDS-MAU interface in the order in which they have been transmitted through the MIS-MDS interface.

According to Figure 54, a data sequence PhPDU is received from left to right and in the order: start bit, header, data unit, stop bit. The MDS removes start bit, stop bit and header and transmits the PhSDU sequence contained in the data unit with the message receipt service as a part of a data sequence DLPDU through the MIS-MDS interface to the MIS. The transmission begins with the first PhSDU that follows the header and ends with the last PhSDU before the stop bit.

NOTE 1 Each data sequence PhPDU begins with a start bit and ends with a stop bit.

NOTE 2 A data sequence DLPDU is transmitted by a sequence of data sequence PhPDUs.

The header in a data sequence PhPDU is structured as shown in Figure 55.

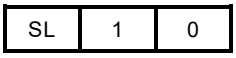


**Figure 55 – Structure of the header in a data sequence PhPDU**

The header of the data sequence PhPDU is transmitted and received from left to right via the MDS-MAU interface, beginning with the SL bit.

For a data sequence PhPDU to be sent, the logical symbol which is transferred in the SL bit is equivalent to the negated logical state of the TxSL signal of the MIS-MDS interface at the time at which the data sequence PhPDU is to be transmitted via the MDS-MAU interface to the MAU (see Table 56):

**Table 56 – SL bit and TxSL signal assignment**

| TxSL signal | SL bit |
|---|---|
| Logical 1 | 0 |
| Logical 0 | 1 |

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For a received data sequence PhPDU the logical state of the RxSL signal of the MIS-MDS interface is equivalent to the negated logical symbol that is transmitted in the SL bit (see Table 57).

**Table 57 – SL bit and RxSL signal assignment**

| SL bit | RxSL signal |
|---|---|
| 0 | Logical 1 |
| 1 | Logical 0 |

#### 9.8.2.3 Check sequence PhPDU

The MDS generates the check sequence PhPDU by adding a start bit, header and stop bit to the data unit. The data unit itself consists of eight PhSDUs that have been transmitted as a PhSDU sequence with a message transmission service as a part of a check sequence DLPDU via the MIS-MDS interface. Figure 56 shows the structure of the check sequence PhPDU.

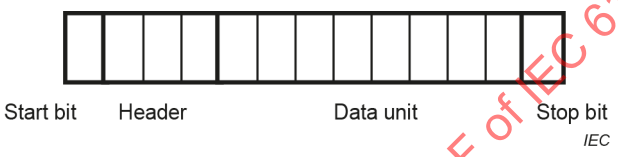


**Figure 56 – Check sequence PhPDU**

A check sequence PhPDU thus generated is transmitted from left to right via the MDS-MAU interface in the following order: start bit, header, data unit, stop bit. The PhSDUs of the data unit are transmitted via the MDS-MAU interface in the order in which they have been transmitted through the MIS-MDS interface.

A check sequence PhPDU is received, according to Figure 56, from left to right and in the order: start bit, header, data unit, stop bit. The MDS removes start bit, stop bit and header and transmits the PhSDU sequence contained in the data unit with the message receipt service as a part of a check sequence DLPDU via the MIS-MDS interface to the MIS. The transmission starts with the first PhSDU that follows the header and ends with the last PhSDU before the stop bit.

NOTE 1 Each check sequence PhPDU begins with a start bit and ends with a stop bit.

NOTE 2 A check sequence DLPDU is transmitted with a series of four check sequence PhPDUs.

The header in a check sequence PhPDU is structured according to Figure 57.

| | | |
|---|---|---|
| SL | 0 | 0 |

**Figure 57 – Structure of a header in a check sequence PhPDU**

The header of the check sequence PhPDU is transmitted and received from left to right via the MDS-MAU interface, beginning with the SL bit.

For a check sequence PhPDU to be sent, the logical symbol to be transferred in the SL bit is equivalent to the negated logical state of the TxSL signal of the MIS-MDS interface at the time at which the check sequence PhPDU is to be transmitted via the MDS-MAU interface to the MAU (see Table 58).

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**Table 58 – SL bit and TxSL signal assignment**

| TxSL signal | SL bit |
|---|---|
| Logical 1 | 0 |
| Logical 0 | 1 |

For a received check sequence PhPDU the logical state of the RxSL signal of the MIS-MDS interface is equivalent to the negated logical symbol that is transmitted in the SL bit (see Table 59).

**Table 59 – SL bit and RxSL signal assignment**

| SL bit | RxSL signal |
|---|---|
| 0 | Logical 1 |
| 1 | Logical 0 |

#### 9.8.2.4 Status PhPDU

The status PhPDU which is formed by the MDS consists of a start bit, the header, and a stop bit. The status PhPDU is structured as shown in Figure 58.

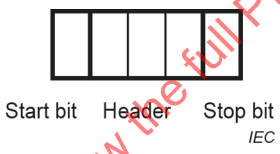


**Figure 58 – Structure of the status PhPDU**

The status PhPDU is transmitted and received via the MDS-MAU interface from left to right beginning with the stop bit, followed by the header and ending with the stop bit.

The header in a status PhPDU is structured according to Figure 59.

| SL | 0/1 | 1 |
|---|---|---|

**Figure 59 – Structure of the header in a status PhPDU**

According to Figure 59 the header is transmitted and received from left to right via the MDS-MAU interface, starting with the SL bit. The state of the bit which comes after the SL bit is not defined and can assume the values "0" or "1".

For a status PhPDU to be sent the logical symbol to be transmitted in the SL bit is equivalent to the negated logical state of the TxSL signals of the MIS-MDS interface at the time at which the status PhPDU is to be transmitted through the MDS-MAU interface to the MAU (see Table 60).

**Table 60 – SL bit and TxSL signal assignment**

| TxSL signal | SL bit |
|---|---|
| Logical 1 | 0 |
| Logical 0 | 1 |

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For a received status PhPDU the logical state of the RxSL signal of the MIS-MDS interface is equivalent to the negated logical symbol that is transmitted in the SL bit (see Table 61).

**Table 61 – SL bit and RxSL signal assignment**

| SL bit | RxSL signal |
|---|---|
| 0 | Logical 1 |
| 1 | Logical 0 |

Each status PhPDU begins with a start bit and ends with a stop bit.

If no sequences of PhSDUs are transmitted to the MDS via the MIS-MDS interface, the MDS automatically begins to transmit successive status PhPDUs. Idle states can be generated between two successive status PhPDUs. The transmission of status PhPDUs is terminated synchronously to the message as soon as the first PhSDU of a data sequence or check sequence PhPDU was transmitted from MIS to the MDS.

The status PhPDUs are transmitted after a reset PhPDU, if no check sequence PhPDU or data sequence PhPDU is to be transmitted.

NOTE Receipt of a status PhPDU does not change the logical state of the RxCR signal of the MIS-MDS interface.

#### 9.8.2.5 Medium activity status PhPDU

The medium activity status PhPDU that is formed by the MDS consists of a start bit, the header, and a stop bit. The medium activity status PhPDU is structured as shown in Figure 60.

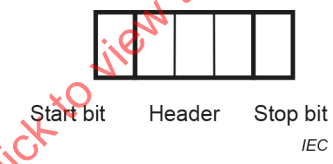


**Figure 60 – Structure of the medium activity status PhPDU**

The header in a medium activity status PhPDU is structured according to Figure 61.

**Figure 61 – Structure of the header in a medium activity status PhPDU**

According to Figure 61the header is transmitted and received from left to right via the MDS-MAU interface. The medium activity status PhPDU is only transmitted via an outgoing passive MAU (loopback mode = disable) when the systems management set the variable data select = enable.

#### 9.8.2.6 Coding and decoding

Coding and decoding is done in accordance with the rules in Table 62.

**Table 62 – Coding and decoding rules**

| Logical symbol bit | Coding DO, DI |
|---|---|
| 1 | High level |
| 0 | Low level |

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The high and low levels shall each be taken from the beginning of a bit for the duration of one bit time.

NOTE 1 For the coding, the logical symbols are converted to the corresponding state of the DO signal of the MDS-MAU interface.

NOTE 2 For the decoding, the status of the DI signal of the MDS-MAU interface is converted to the corresponding logical symbol.

#### 9.8.2.7 Start bit

The start bit corresponds to the logical symbol "1".

The MDS shall synchronise its receive clock with the beginning of the start bits (low-high transitions).

#### 9.8.2.8 Stop bit

The stop bit corresponds to the logical symbol "0".

NOTE The MDS can synchronise its receive clock to a newly arriving start bit only after a stop bit (low-high transition).

### 9.8.3 Idle states

The sender of the bus master can generate idle states during the transitions of status PhPDUs to data sequence PhPDUs or check sequence PhPDUs. Idle states have always a low level on DO. The maximum length of the idle states shall not exceed 26 bit times. The decoding rules for idle states recognised on the medium are given in Table 63.

**Table 63 – Decoding rules for the idle states**

| Idle state | State RxCR | Decoding DI |
|---|---|---|
| Data_Idle | Logical 0 | Low level |
| CRC_Idle | Logical 1 | Low level |
| CRC_Status_Idle | Logical 1 | Low level |

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### 9.8.4 Reset PhPDU

#### 9.8.4.1 Structure of the Reset PhPDU

The reset PhPDU transmits the logical symbols "short reset" or "long reset". Figure 62 shows the structure of the reset PhPDU.

**Figure 62 – Reset PhPDU**

NOTE The symbols "short reset" and "long reset" only differ in the time during which the signals DO or DI of the MDS-MAU interface transmit a low level.

#### 9.8.4.2 Coding and decoding

The coding rules for the reset PhPDU are given in Table 64 and Table 65.

**Table 64 – Coding rules for the reset PhPDU**

| Logical symbol | Time interval | Coding DO |
|---|---|---|
| Short bus reset | 2 ms ≤ $T_{Rst}$ < 25,6 ms | Low level |
| Long bus reset | $T_{Rst}$ ≥ 25,6 ms | Low level |

**Table 65 – Decoding rules of the reset PhPDU**

| DI | Time interval | Logical symbol |
|---|---|---|
| Low level | 2 ms ≤ $T_{Rst}$ < 25,6 ms | Short bus reset |
| Low level | $T_{Rst}$ ≥ 25,6 ms | Long bus reset |

NOTE 1 A reset PhPDU is terminated with the start bit of a data sequence PhPDU, a check sequence PhPDU or a status PhPDU.

NOTE 2 During the coding, the logical symbols are converted to the corresponding state of the DO signal of the MDS-MAU interface during the time $T_{Rst}$.

NOTE 3 During the decoding, in the time $T_{Rst}$ the state of the DI signal of the MDS-MAU interface is converted to the corresponding logical symbol.

The times given in Table 64 and Table 65 do not apply to the sender of the master. For the sender of the bus master the corresponding reset PhPDU shall be generated upon request of the RO service in accordance with the definitions specified in the PhL variables *short bus reset time* and *long bus reset time*.

NOTE 4 The encoding rules for the reset PhPDU apply only to a MDS coupling in the MIS.

### 9.8.5 MAU coupling

When MAUs of the same type are coupled pairs, each PhPDU and all idle states are transmitted unchanged between two MAUs. Figure 63, Figure 64 and Figure 65 show possible configurations for the bus devices when the 2-wire medium is used.

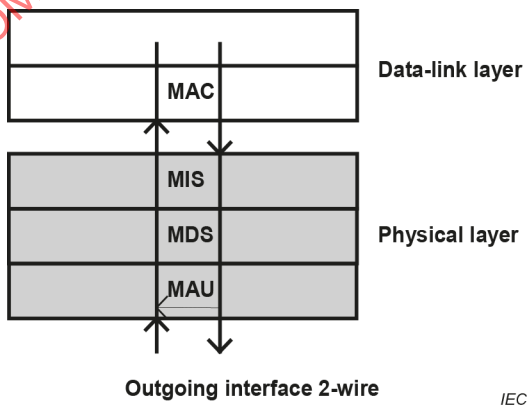


**Figure 63 – Configuration of a master**

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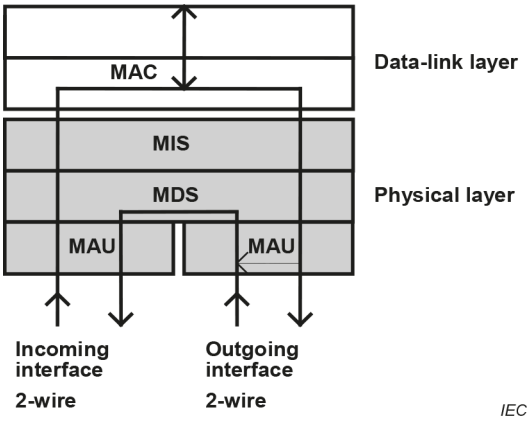


**Figure 64 – Configuration of a slave**

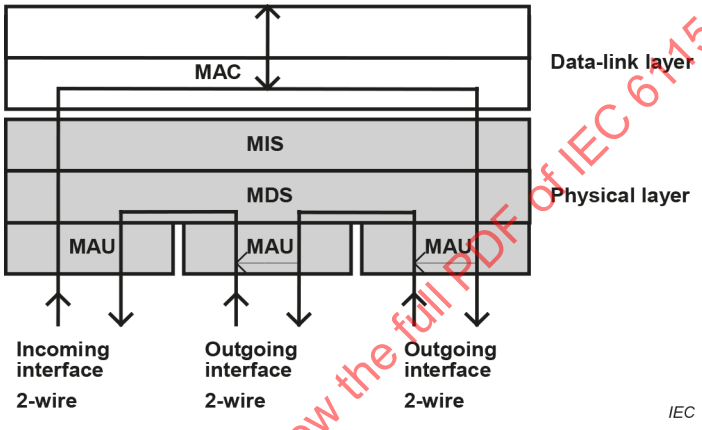


**Figure 65 – Configuration of a bus coupler**

When two MAUs are directly coupled, code-transparent repeaters may be used for the time regeneration.

### 9.9 Type 12: MDS: Wire media

This sublayer conforms to the PHY sublayer of 100BASE-TX described in ISO/IEC/IEEE 8802-3:2021, Clause 25.

### 9.10 Type 16: MDS: Optical media

#### 9.10.1 Data encoding rules

Signals on the transmission lines shall be NRZI-coded. Signal changes are only allowed to take place in synchronization with the transmitting clock. Every time a 0 is transmitted, the signal shall change its status in synchronization with the transmitting clock, whereas the signal shall remain unchanged when a 1 is transmitted.

By a suitable method (i.e., bit-stuffing), the transmitter shall ensure that enough zeros occur in the transmitted bit stream. This generates additional signal changes. In this way, conditions are created which make it possible to retrieve a receiving clock from the received signal. The retrieved receiving clock shall also have a fixed phase position with respect to the clock of the transmitter. The clock shall be retrievable by means of a digital phase locked loop (DPLL) which shall be synchronized to the signal change of the received signal transformed to an electrical signal. Figure 66 d) is an example of a NRZI-coded signal. Therefore, the transmitting clock provides the pattern for the system timing via the signal transitions.

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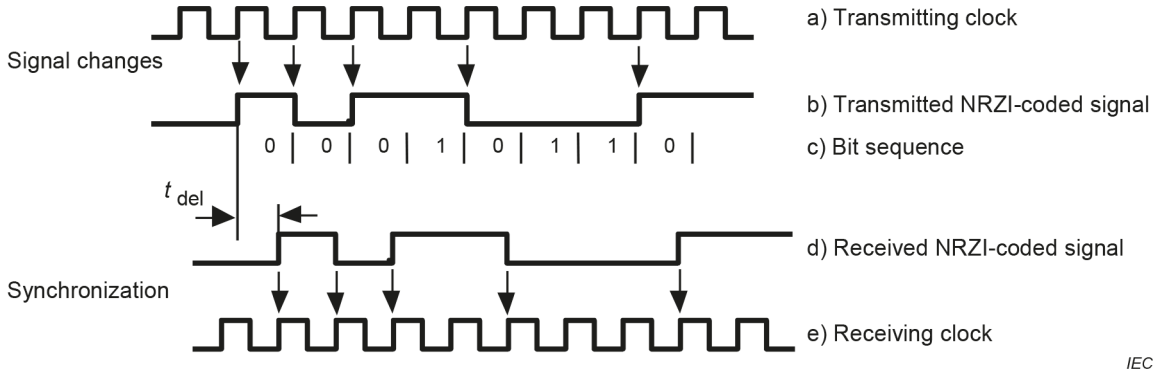


**Figure 66 – Example of an NRZI-coded signal**

### 9.10.2 Telegrams and fill characters

On the physical level, it is sufficient to know that a telegram shall start and end with the bit sequence 0111 1110. This bit sequence is also known as a delimiter. Due to bit-stuffing, this bit sequence is prevented from occurring inside the telegram.

Other fields of the telegram belong to higher protocol layers and are discussed elsewhere.

If a unit does not place its own telegram on the network, two possibilities arise:

a) the master shall transmit a so-called fill signal (fill bits) between its own telegrams. It shall consist of a sequence of one binary 0 and seven binary 1's (i.e., 0111 1111). This generates a symmetric fill signal with 16 times the period of the transmitting clock, due to NRZI-coding (see Figure 67);

b) between its own telegrams, a slave shall transmit with its synchronized local clock the physically regenerated, received signals (repeater mode).

During the transition from telegram to fill signal (master) or from telegram to repeater mode (slave), signal changes shall follow the pattern of the current clock.

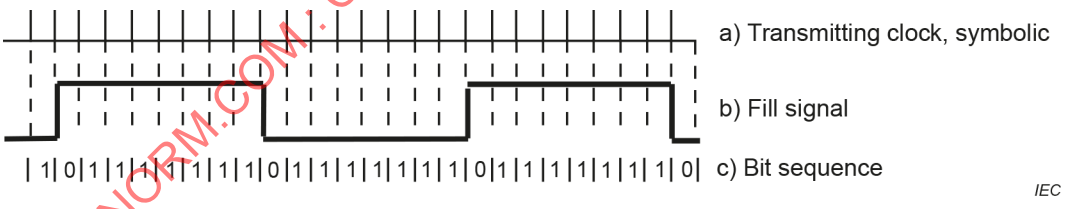


**Figure 67 – Fill signal**

NOTE Due to bit-stuffing and a), the slave physically located first in the network is able to derive its local clock from its received signal at any time. Because of b), this is also the case for all subsequent units, all the way to the receiver of the master. In this way, digital phase locked loops, which are eventually used to obtain the local clock, remain locked on, preventing time-consuming synchronization before the start of the actual telegram.

## 9.11 Type 18: MDS: Wire media

### 9.11.1 Overview

The Type 18 MDS shall be able to sense the initiation and subsequent termination of data reception, the means of which are beyond the scope of this specification.

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### 9.11.2 Transmission

Data transmission is started upon receipt of a PH-DATA (START-OF-ACTIVITY) request from the DL-user. This is translated by the MDS into a TRANSMIT-ENABLE signal assertion with the value specified in the DATA field being transmitted on the TRANSMIT-SIGNAL.

The MDS shall issue a PH-DATA (SUCCESS) confirmation and shall receive the next PH-DATA (DATA) request before the expiration of the MDS baud rate bit timer. It is not until this request is acted upon that the subsequent PH-DATA (SUCCESS) confirmation is produced. In this way, the MDS baud rate timer regulates the flow rate of data.

Upon receipt of a PH-DATA (END-OF-ACTIVITY) request from the DL-user, the MDS completes the transmission in process and concludes with a TRANSMIT-ENABLE signal deassert.

### 9.11.3 Reception

Upon receipt of data activity, the MDS issues a PH-DATA (START-OF-ACTIVITY) indication with the DATA value received. Each subsequent datum received results in a PH-DATA (DATA) indication with the DATA value received. Upon completion of the data reception, the MDS issues a PH-DATA (END-OF-ACTIVITY) indication to the DL-user.

## 9.12 Type 24: MDS: Twisted-pair wire

### 9.12.1 General

The Medium Dependent Sublayer (MDS) is part of the Data Communication Equipment (DCE). It communicates encoded bits across the MDS-MAU interface specified in 10.8.

### 9.12.2 Clock accuracy

The timing specifications for PhL Signaling shall be as defined in Table 66, Table 67 and Table 68.

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**Table 66 – Type 24-1 MDS timing characteristics**

| Specification | Limits / characteristics | Comments |
|---|---|---|
| Bit Rate | 10 Mbit/s with a tolerance of ± CA | Also called DL-symbol rate, data 'zero' or 'one' |
| Bit Time | 100 ns with a tolerance of ± CA | Also called DL-symbol time, data 'zero' or 'one' |
| PhL symbol time | 50 ns with a tolerance of ± CA | Also called Ph-symbol time, see data encoding rules |
| Clock Accuracy (CA) | ± 100 µHz/Hz max. | Including temperature, long term and short term stability |

**Table 67 – Type 24-3 Manchester coding MDS timing characteristics**

| Specification | Limits / characteristics | | Comments |
|---|---|---|---|
| Bit Rate | 4 Mbit/s with a tolerance of ± CA | 8 Mbit/s with a tolerance of ± CA | Also called DL-symbol rate, data 'zero' or 'one' |
| Bit Time | 250 ns with a tolerance of ± CA | 125 ns with a tolerance of ± CA | Also called DL-symbol time, data 'zero' or 'one' |
| PhL symbol time | 125 ns with a tolerance of ± CA | 62,5 ns with a tolerance of ± CA | Also called Ph-symbol time, see data encoding rules |
| Clock Accuracy (CA) | ± 100 ppm max. | | Including temperature, long term and short term stability |

**Table 68 – Type 24-3 NRZI coding MDS timing characteristics**

| Specification | Limits / characteristics | | | Comments |
|---|---|---|---|---|
| Bit Rate | 16 Mbit/s with a tolerance of ± CA | 24 Mbit/s with a tolerance of ± CA | 32 Mbit/s with a tolerance of ± CA | Also called DL-symbol rate, data 'zero' or 'one' |
| Bit Time | 62.5 ns with a tolerance of ± CA | 41,66 ns with a tolerance of ± CA | 31,25 ns with a tolerance of ± CA | Also called DL-symbol time, data 'zero' or 'one' |
| PhL symbol time | 62.5 ns with a tolerance of ± CA | 41,66 ns with a tolerance of ± CA | 31,25 ns with a tolerance of ± CA | Also called Ph-symbol time, see data encoding rules |
| Clock Accuracy (CA) | ± 100 ppm max. | | | Including temperature, long term and short term stability |

### 9.12.3 Data recovery

Depending on the Type used and the data encoding, the signals at the DLL to PhL interface shall be synchronized to the local bit rate as shown in Table 66, Table 67 or Table 68. Each PhL implementation shall provide a data recovery mechanism that recovers or reconstructs the data received from the appropriate medium to meet the timing requirements shown in Table 66, Table 67 or Table 68. When data synchronization has been attained by the MDS, PH-LOCK indication shall be true.

A portion of the received data frame can be lost or discarded in the process of attaining data synchronization. The specification for data timing shown in Table 66, Table 67 or Table 68 shall be achieved prior to the beginning of the start flag.

### 9.12.4 Data encoding rules

The DL_symbols present at the DLL to PhL interface shall be encoded into the appropriate Ph-symbols as shown in Table 69, Figure 68, and Table 70, Figure 69. The ZERO and ONE symbols shall be encoded into Ph-symbols that represent Manchester Biphase L data encoding rules as shown in Table 69. The signal voltage waveform (from the MAU) is shown in an idealized form in Figure 68 to provide an example of the data encoding rules shown in Table 69.

**Table 69 – MDS data encoding rules of Manchester coding**

| Data bits (common name) | DL_symbol representation | Ph-symbol encoding | Manchester encoded |
|---|---|---|---|
| data 'zero' | ZERO or {0} | {L,H} | 0 |
| data 'one' | ONE or {1} | {H,L} | 1 |

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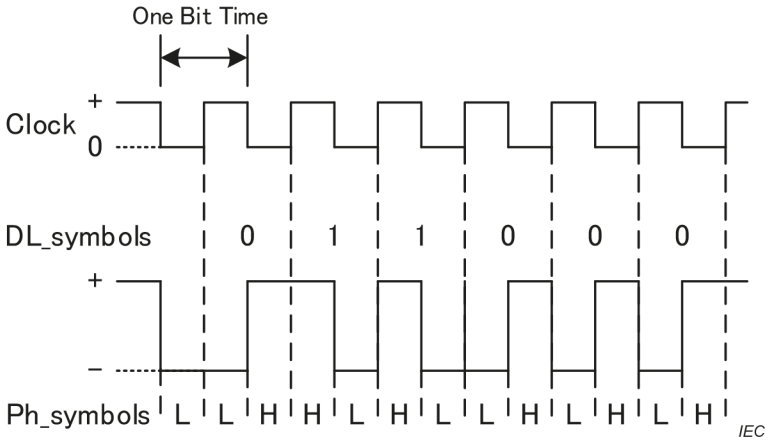


**Figure 68 – Manchester coded symbols**

**Table 70 – MDS data encoding rules of NRZI coding**

| Data bits (common name) | DL_symbol representation | Ph-symbol encoding | NRZI encoded |
|---|---|---|---|
| data 'zero' | ZERO or {0} | invert previous bit symbol level | 0 |
| data 'one' | ONE or {1} | keep previous bit symbol level | 1 |

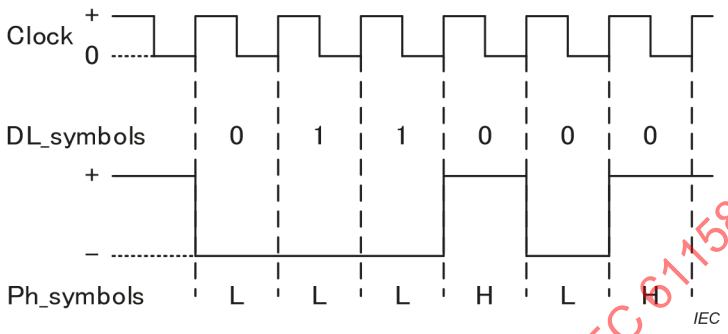


**Figure 69 – NRZI coded symbols**

## 9.13 Type 28: MDS: Twisted-pair wire and coaxial media

### 9.13.1 General

MDS is a part of the DCE. It exchanges PhSDU through the DTE-DCE interface, and it transmits the mapped symbols to the MAU through the MDS-MAU interface. The signal is received at peer MDS after demodulating and decoding. The PhSDU should be recovered and transmitted to DIS by the DTE-DCE interface for further processing.

The MDS of PhL specifies the physical channel process of DCE, including scrambling, encoding, decoding, interleaving, mapping, modulation and demodulation.

### 9.13.2 MDS specification

#### 9.13.2.1 Physical channel process

Figure 70 shows the PhL channel process of transmission and receiving. During the transmission process, data streams are interleaved after scrambling, RS encoding and convolution encoding respectively, then modulated by 16QAM, 64QAM or 256QAM (see 9.13.2.5) to form an OFDM signal. According to different TMs, the data is combined into SFs and then transmitted over the cable line. The receiving system conducts inverse process of the transmission system which is used to recover the data flow correctly from the encoded physical signal.

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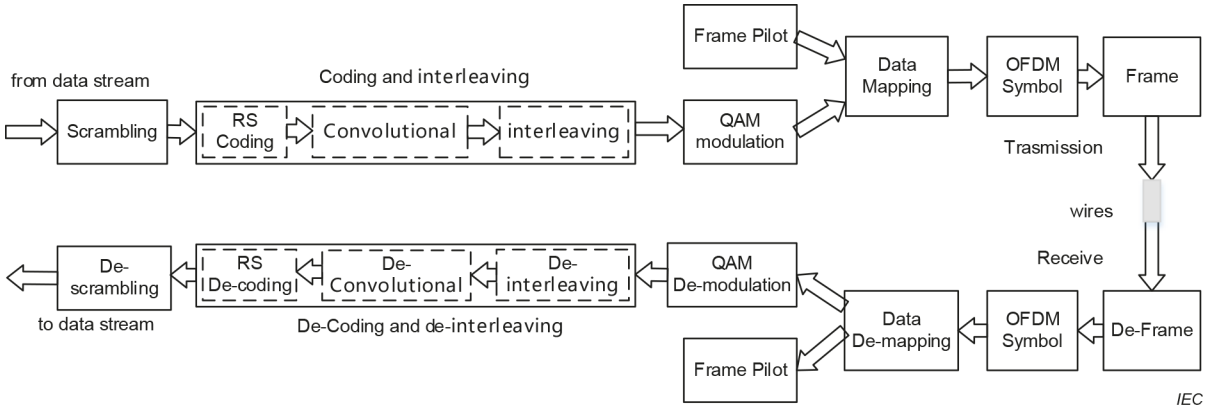


**Figure 70 – PhL channel process**

### 9.13.2.2 System parameter configuration

The PhL signal is transmitted by OFDM modulation. The core process of generating OFDM signal is IFFT (Inverse Fast Fourier Transform), and the recovery process of OFDM signal is based on FFT (Fast Fourier transform). On the basis of given bandwidth and sampling interval condition, different FFT/IFFT sampling points should get different subcarrier interval and OFDM symbol length. The system supports 0, 1, 2 and 3, in total four different TMs, corresponding to 4 096, 2 048, 1 024 and 512 sampling points respectively. See Table 50 for specific parameter configuration.

### 9.13.2.3 Scrambling

In order to avoid the long "0" or "1" sequences, CB to be transmitted should be scrambled before encoding. The scrambling sequence is an m sequence with length 11, and the generating polynomial is $x^{11} + x^2 + 1$.

The initialization phase is 0b11111111111. The scrambling sequence generator is reinitialized as each CB begins processing. Figure 71 shows the scrambling sequence generation process. The "enable" indicates the control switch, and the "data" is the input octet sequence to be scrambled. The "output" is the scrambled octet sequence.

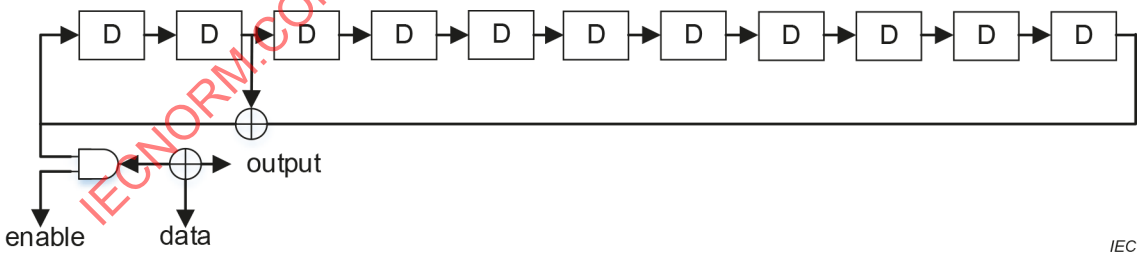


**Figure 71 – Scrambling sequence generation**

### 9.13.2.4 Encoding and interleaving

#### 9.13.2.4.1 General

RS code uses the shorter code of original RS (255, 247), RS (255, 239) and RS (255, 223) system code. Original RS code length is 255 octets. The check length is 8, 16 or 32 octets, which is the cyclic code based on finite domain GF(256). The generating polynomial within domain is given by Formula (2).

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$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \tag{2}$$

The RS code generating polynomial is given by Formula (3).

$$g(x) = \sum_{i=0}^{i=L-1} g_i x^i \tag{3}$$

where

$L$ is check bit length.

The input information sequence polynomial is given by Formula (4).

$$m(x) = \sum_{i=0}^{i=K-1} m_i x^i \tag{4}$$

where

$K$ is information bit length.

The system code output polynomial is given by Formula (5).

$$C(x) = \sum_{i=0}^{i=N-1} c_i x^i = x^{N-K} m(x) + r(x) \tag{5}$$

where

$r(x)$ is defined by Formula (6).

$$r(x) = \frac{x^{N-K} m(x)}{g(x)} \tag{6}$$

The details about RS (255, 247), RS (255, 239), RS (255, 223) generating polynomial $g^0(x)$, $g^1(x)$, $g^2(x)$ are given by Annex W.

The RS code mode used is shown in Table 71.

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**Table 71 – RS code mode**

| RS code mode | RS code |
|---|---|
| 0 | (239, 207) |
| 1 | (159, 127) |
| 2 | (119, 103) |
| 3 | (79, 63) |
| 4 | (59, 51) |
| 5 | (39, 31) |
| 6 | (109, 177) |
| 7 | (139, 107) |
| 8 | (104, 88) |
| 9 | (69, 61) |
| 10 | (51, 43) |
| 11 | (34, 26) |

#### 9.13.2.4.2 Convolutional encoding

Each octet of the transmission data encoded by RS is mapped into 8-bit stream according to the principle of high-bit priority transmission, and sent into convolutional code encoder. The bits are coded with a rate 1/2, 2/3 and 3/4 respectively, as shown in Table 72.

**Table 72 – Convolutional code mode**

| Convolutional code | Convolutional code rate |
|---|---|
| 0 | 1/2 |
| 1 | 2/3 |
| 2 | 3/4 |

The constraint length of convolutional encoder is 7 and code rate is 1/2. Generation polynomial is $G_1 = 171_8$ and $G_0 = 133_8$. Figure 72 shows a convolutional encoder with a code rate of 1/2.

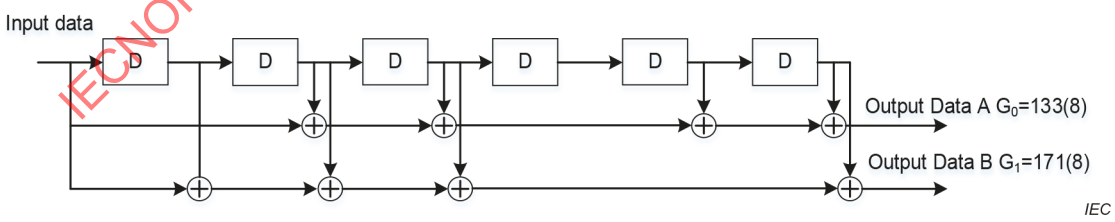


**Figure 72 – Convolutional encoder with a code rate of 1/2**

The initial value of the shift registers is set to the corresponding value of the last 6 bits in the input stream so that the initial and final states of the shift register are the same. According to Figure 72, the coded bit streams are output in order A and order B. By deleting the encoding bits, the convolutional code with the code rates 2/3 and 3/4 could be obtained. The process of deleting bit is shown in Figure 73.

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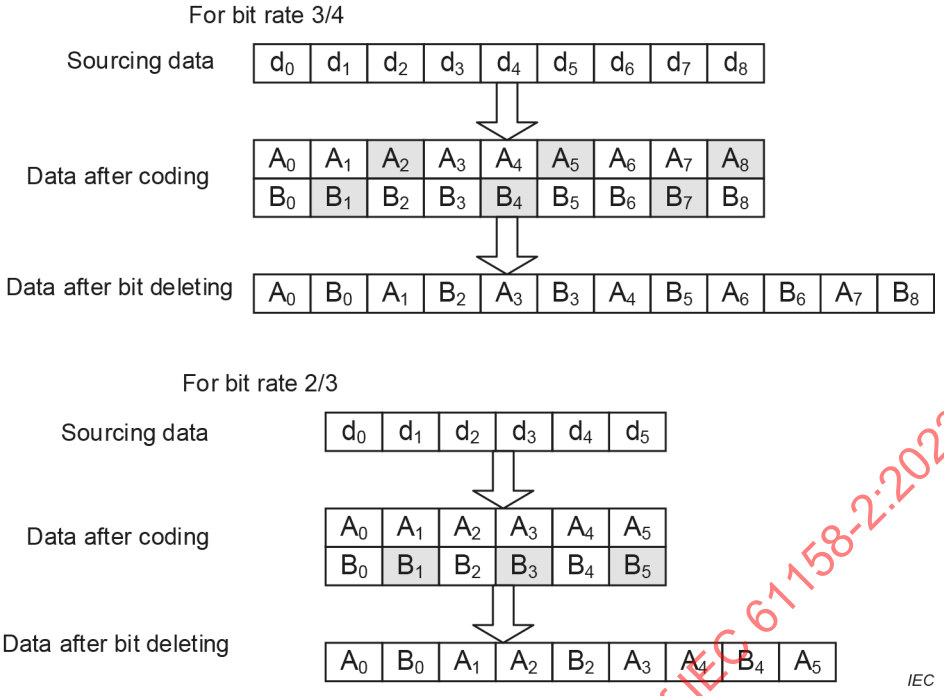


**Figure 73 – Bit deletion process with code rates 2/3 and 3/4**

#### 9.13.2.4.3 Bit interleaving

The coded bit stream need be interleaved by grouping a bit stream with $N_{CBIB}$ as an interleaving block. All coded data bits are interleaved within a resource block of an OFDM symbol. Interleaving is partitioned into two steps: firstly, adjacent coding bits are mapped to non-adjacent subcarriers; secondly, adjacent coding bits are alternately mapped to high and low significant bits of the constellation. The specific interleaving rules are:

The first permutation is given by Formula (7):

$$i = \left(\frac{N_{CBIB}}{N_{COL}}\right)(k \bmod N_{COL}) + floor\left(\frac{k}{N_{COL}}\right) \tag{7}$$

where

$N_{CBIB}$ is interleaved block length;

$k$ is the coded bit sequence number before the first permutation;

$i$ is the coded bit sequence number after the first permutation.

The second permutation is given by Formula (8):

$$j = s \times floor\left(\frac{i}{s}\right) + \left[i + N_{CBIB} - floor\left(i \times \frac{N_{COL}}{N_{CBIB}}\right)\right] \bmod s \tag{8}$$

where

$i$ = 0,1, …$N_{CBIB}$

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$$s = \max\left(\frac{N_{BPS}}{2,1}\right)$$

$j$ is the coded bit sequence number after the second permutation;

$N_{BPS}$ is the number of bits corresponding to a modulation symbol.

Table 73 shows the bit interleaving parameters. Carrier mode A should use interleaving modes 3 and 4. Carrier mode B should use interleaving modes 0, 1, 2.

**Table 73 – Bit interleaving parameters**

| Interleaving mode | Modulation mode | Symbol bit number ($N_{BPS}$) | Column number ($N_{COL}$) | Interleaving block length ($N_{CBIB}$) |
|---|---|---|---|---|
| 0 | 16QAM | 4 | 16 | 320 |
| 1 | 64QAM | 6 | 16 | 480 |
| 2 | 256QAM | 8 | 16 | 640 |
| 3 | 64QAM | 6 | 14 | 420 |
| 4 | 256QAM | 8 | 14 | 560 |

### 9.13.2.5 QAM mapping

Modulation mapper uses the binary number 0, 1 as input to generate complex modulation output symbol x. The modulation mapping scheme is 16QAM, 64QAM and 256QAM. The constellation point z is obtained from binary number according to the modulation mode, then it is normalized to obtain the correct complex modulation symbol.

### 9.13.2.6 Resource mapping

A reference signal is derived from m sequence with a generating polynomial of $x^{11} + x^8 + x^5 + x^2 + 1$. Figure 74 shows the generation circuit of m sequence.

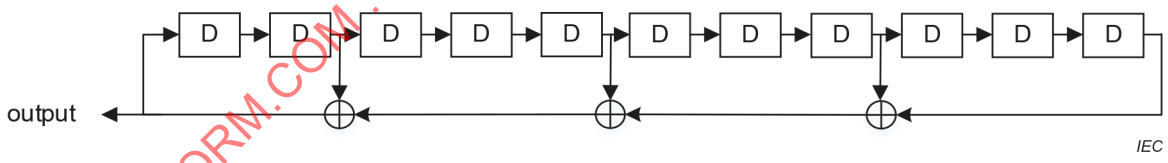


**Figure 74 – Generation of m sequence**

The m sequence in Figure 74 is modulated by BPSK to get the reference signal generation sequence $r(m)$. For pilot physical resource mapping, the reference signal $r(m)$ should be mapped to OFDM symbol resource. The SynS pilot is mapped to the 0th, 1st OFDM symbol of the SF and for the pilot symbol 0, only the even subcarriers. The scattered pilot should be mapped to the upper sideband or lower sideband of one OFDM symbol, and the contiguous pilot should be mapped to a partial subcarrier in the specified OFDM symbol half sideband. For the physical resource mapping, the modulated complex symbol block should be mapped to the corresponding OFDM symbol half sideband resource, and the subcarrier resource equal interval distribution is implemented in the frequency domain.

### 9.13.2.7 OFDM signal generation

The time continuous signal of the OFDM symbol $l$ of a SF is defined by Formula (9).

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$$s_l(t) = \left[ \sum_{k=N_S}^{N_S+N_{SD}-1} a_{k^{(-)},l} \times e^{j2\pi k\Delta f\left(t-N_{CP,l}T_s\right)} \right] \quad (9)$$

where

$k^{(-)} = k - N_s$

Table 74 shows OFDM configuration parameters.

**Table 74 – OFDM configuration parameters**

| | $\Delta f$ | $N$ | $N_{SD}$ | $N_{CP}$ | $N_S$ |
|---|---|---|---|---|---|
| **Transmit mode** | **Subcarrier interval, kHz** | **FFT number** | **Valid subcarrier number** | **Cyclic prefix length** | **Starting subcarrier number** |
| 0 | 24 | 4 096 | 1 280 | 2 048 | 64 |
| 1 | 48 | 2 048 | 640 | 1 024 | 32 |
| 2 | 96 | 1 024 | 320 | 512 | 16 |
| 3 | 192 | 512 | 160 | 256 | 8 |

Using the real function from the above formula, the transmission function can be obtained as shown in Formula (10).

$$S_l(t) = \mathrm{Re}\left[ s_l(t) \right] \quad (10)$$

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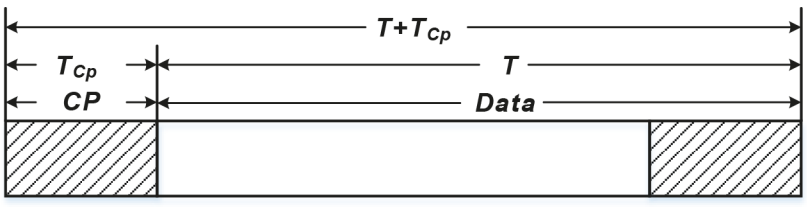
#### 9.13.2.8 Framing

For each symbol in the SF, there is a structure shown in Figure 75, and 64 symbols form a SF.

The signal is given by Formula (11).

$$S(t) = \sum_{l=0}^{63} S_l(t - T_l) \quad (11)$$




***CP*** : Cyclic Prefix ***Data*** : Data $T_{CP}$: Cyclic Prefix Time ***T*** : Data Time

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**Figure 75 – OFDM symbol structure diagram**

#### 9.13.2.9 Modulation Coding Scheme (MCS)

PhL supports a variety of encoding modulation modes, and the MCS under carrier mode A and carrier mode B is shown in Table 75 and Table 76.

**Table 75 – Modulation Coding Scheme in carrier mode A**

| Working mode | Transmit mode | RS coding | Convolutional encoding | modulation mode |
|---|---|---|---|---|
| A0 | 0 | (209, 177) | 1/2 | 64QAM |
| A1 | 0 | (139, 107) | 2/3 | 64QAM |
| A2 | 0 | (209, 177) | 3/4 | 256QAM |
| A3 | 1 | (104, 88) | 1/2 | 64QAM |
| A4 | 1 | (139, 107) | 2/3 | 64QAM |
| A5 | 1 | (209, 177) | 3/4 | 256QAM |
| A6 | 2 | (69, 61) | 2/3 | 64QAM |
| A7 | 2 | (104, 88) | 3/4 | 256QAM |
| A8 | 3 | (34, 26) | 2/3 | 64QAM |
| A9 | 3 | (51, 43) | 3/4 | 256QAM |

**Table 76 – Modulation Coding Scheme in carrier mode B**

| Working mode | Transmit mode | RS coding | Convolutional encoding | Modulation mode |
|---|---|---|---|---|
| B0 | 0 | (159, 127) | 1/2 | 16QAM |
| B1 | 0 | (239, 207) | 1/2 | 64QAM |
| B2 | 0 | (159, 127) | 2/3 | 64QAM |
| B3 | 0 | (239, 207) | 3/4 | 256QAM |
| B4 | 1 | (79, 63) | 1/2 | 16QAM |
| B5 | 1 | (119, 103) | 1/2 | 64QAM |
| B6 | 1 | (159, 127) | 2/3 | 64QAM |
| B7 | 1 | (239, 207) | 3/4 | 256QAM |
| B10 | 2 | (79, 63) | 2/3 | 64QAM |
| B11 | 2 | (119, 103) | 3/4 | 256QAM |
| B14 | 3 | (39, 31) | 2/3 | 64QAM |
| B15 | 3 | (59, 51) | 3/4 | 256QAM |

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## 10 MDS – MAU interface

### 10.1 General

The medium attachment unit (MAU) is an optionally separate part of a communication element that connects to the medium directly or via passive components (see Figure 1). For electrical signaling variants the MAU is the transceiver, which provides level shifting and wave shaping for transmitted and received signals. The MDS-MAU interface links the MAU to the MDS. The services are defined as physical signals to facilitate this interface optionally being exposed. The following subclauses list for each Type specifies the minimum set of required services at the MDS-MAU interface. See Clause 6 for management services.

NOTE A number of different MDS-MAU interfaces are specified, based on industry practice.

## 10.2 Type 1: MDS – MAU interface: Wire and optical media

### 10.2.1 Services

If the MDS-MAU interface is exposed, it shall support at least the set of required services given in Table 77 and specified in 10.2.2.

**Table 77 – Minimum services at MDS-MAU interface**

| Service | Abbreviation | Direction |
|---|---|---|
| **Required:** | | |
| Transmit Signal | TxS | To MAU |
| Receive Signal | RxS | From MAU |
| Transmit Enable | TxE | To MAU |
| **Optional:** | | |
| Loopback enable | LbE | To MAU |

### 10.2.2 Service specifications

#### 10.2.2.1 Transmit signal (TxS)

The Transmit Signal service (TxS) shall transfer the encoded PhPDU signal sequence across the MDS-MAU interface to the MAU, where the sequence shall be transmitted on to the medium if the Transmit Enable (TxE) is set to logic 1 (high level).

#### 10.2.2.2 Receive signal (RxS)

The Receive Signal service (RxS) shall transfer the encoded PhPDU signal sequence or silence across the MAU-MDS interface to the MDS. The RxS shall echo the signal transmitted via TxS by simultaneously receiving the transmissions from the medium.

#### 10.2.2.3 Transmit enable (TxE)

The Transmit Enable service (TxE) shall provide the MDS with the facility to enable the MAU to transmit. The TxE shall be set to logic 1 (high level) at the commencement of preamble transmission and then set to logic 0 (low level) after the last bit of the end delimiter has been transmitted.

If redundant media are in use and the method of implementing redundancy is to receive on all channels but transmit on only one, then the channel (cable) that is currently used for transmission shall be selected by setting its TxE to logic 1 (high level). All channels that are not currently in use for transmission shall be disabled by setting the TxE to logic 0 (low level).

#### 10.2.2.4 Loopback enable (LbE)

If the optional Loopback Enable (LbE) service shown in Table 77 is used it shall disable the final output stage of the MAU transmit circuit, connect the output of the previous stage of the MAU transmit circuit to the MAU receive circuit and disconnect the MAU receive circuit from the medium. The state of the Loopback Enable shall not change while the MAU is transmitting or receiving.

NOTE This confirmation service is of local significance only and provides a device with the facility to test the integrity and functionality of the PhL circuitry, excluding the medium.

### 10.2.3 Signal characteristics

Timing characteristics shall be compatible with those specified in the requirements of this document for the relevant MDS.

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If the MDS-MAU interface is exposed, it shall operate with digital signal levels as shown in Table 78. Both sides of the interface shall operate with the same value of $V_{DD}$.

**Table 78 – Signal levels for an exposed MDS-MAU interface**

| Symbol | Parameter | Conditions | Limits | Units | Remarks |
|---|---|---|---|---|---|
| VOL | Maximum low-level output voltage | $I_{out}$ = ±100 µA | 0,1 | V | See Note 1 |
| | | $I_{out}$ = +1,6 mA | 0,4 | V | |
| VOH | Min.high-level output voltage | $I_{out}$ = ±100 µA | $V_{DD}$ - 0,1 | V | See Note 1 |
| | | $I_{out}$ = −0,8 mA | $V_{DD}$ - 0,8 | V | See Note 2 |
| VIL | Max.low-level input voltage | | 0,2 $V_{DD}$ | V | |
| VIH | Min.high-level input voltage | | 0,7 $V_{DD}$ | V | See Note 3 |

NOTE 1 Provides the capability to drive two typical CMOS loads.

NOTE 2 CMOS input compatibility with TTL output requires a "pull-up" resistor from signal input to VDD.

NOTE 3 Compatible with CMOS output for 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. Compatibility with TTL output (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) requires a "pull-up" resistor from signal input to $V_{DD}$.

### 10.2.4 Communication mode

The communication mode at this interface shall allow simultaneous transmission and reception.

### 10.2.5 Timing characteristics

The MDS-MAU interface shall function correctly with a PhSDU bit rate of between 1 kbit/s and 1,1 times the highest stated MAU bit rate.

NOTE The bit rates available in an implementation are stated in the Protocol Implementation Conformance Statement (PICS).

## 10.3 Void

NOTE Subclause 10.3 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the subclause numbering of the prior edition.

## 10.4 Type 2: MDS – MAU interface: Wire and optical media

### 10.4.1 MDS – MAU interface: general

#### 10.4.1.1 Conformance

A node may include any (or more than one) PhL variant but the appropriate medium interface shall be provided for each PhL variant implemented.

The MDS-MAU interface need not be exposed in the implementation of any PhL variant. This interface may be internal to the node and may be internal to a semiconductor device. If, however, conformance to the MDS-MAU interface is claimed, the implementation shall conform to the requirements of 10.4.

#### 10.4.1.2 Delay from medium to MDS – MAU interface

For all implementations conformant to the MDS-MAU interface, the receive delay from the medium to the MDS-MAU interface shall be less than 200 ns and the transmit delay from the MDS-MAU interface to the medium shall be less than 200 ns.

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### 10.4.2 MDS – MAU interface: 5 Mbit/s, voltage-mode, coaxial wire

#### 10.4.2.1 Signal definitions

Subclause 10.4.2 lists the signals defined for the 5 Mbit/s, voltage-mode, coaxial wire medium MDS-MAU interface, as shown in Table 79.

**Table 79 – MDS-MAU interface definitions: 5 Mbit/s, voltage-mode, coaxial wire**

| TxDataOut | TxDataBar | NetEnable | RxData | RxCarrier | Ph-symbol |
|---|---|---|---|---|---|
| x | x | 0 | undefined | 0 | No transmission<br>MAU_FRAME_REQUEST = false |
| 0 | 0 | 1 | undefined | 0 | No transmission<br>MAU_FRAME_REQUEST = false |
| 1 | 0 | 1 | 1 | 1 | H |
| 0 | 1 | 1 | 0 | 0 | L |
| 1 | 1 | 1 | - | - | Not allowed, transmitter damage could occur |

#### 10.4.2.2 TxDataOut

TxDataOut shall be true to represent H from the MAU, and shall be false to represent L as shown in Table 79. TxDataOut shall be false when no Ph-symbol data is to be transmitted (MAU_frame_request = false).

#### 10.4.2.3 TxDataBar

TxDataBar shall be true to represent L from the MAU, and shall be false to represent H as shown in Table 79. TxDataBar shall be false when no Ph-symbol data is to be transmitted (MAU_frame_request = false).

#### 10.4.2.4 NetEnable

NetEnable shall be true to enable the MAU for transmission of TxDataOut and TxDataBar Ph-symbol data on the coaxial wire medium. NetEnable false shall prevent transmission of TxDataOut and TxDataBar Ph-symbol data as shown in Table 79.

#### 10.4.2.5 RxData

RxData shall represent the raw, distorted, unsynchronised Ph-symbols (H or L) as recovered from the coaxial wire medium. This signal shall be true or false based on the requirements shown in Table 121. After data recovery and resynchronisation to meet the MDS timing requirements (from Table 54), these Ph-symbols shall be decoded into the appropriate MDS M_symbols as shown in Table 55.

#### 10.4.2.6 RxCarrier

RxCarrier shall be true when the signal level on the coaxial wire medium exceeds the carrier detection threshold voltage as shown in Table 122; otherwise, it shall be false. This signal shall be used to create the Ph-Carrier indication at the DLL-PhL interface as defined in 5.3.5.

### 10.4.3 MDS – MAU interface 5 Mbit/s, optical medium

#### 10.4.3.1 Signal definitions

Subclause 10.4.3 lists the signals defined for the 5 Mbit/s, optical fiber medium MDS-MAU interface, as shown in Table 80.

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**Table 80 – MDS-MAU interface 5 Mbit/s, optical fiber medium**

| TxDataOut | NetEnable | RxData | RxCarrier | Ph-symbol |
|---|---|---|---|---|
| Don't care | 0 | 0 | 0 | L or 'light off' |
| 1 | 1 | 1 | 1 | H or 'light on' |
| 0 | 1 | 0 | 0 | L or 'light off' |

#### 10.4.3.2 TxDataOut

TxDataOut shall be true to represent H from the MAU, and shall be false to represent L as shown in Table 129. A true signal shall be represented on the fiber medium as 'light on'. A false signal shall be represented on the fiber medium as 'light off'. The fiber transmit level requirements that define 'light on' (or Coupled Power, PT on) and 'light off' (or Coupled Power, PT off) shall be as defined in 19.6.

#### 10.4.3.3 NetEnable

NetEnable shall be true to indicate the MDS sublayer has valid Ph-symbols to be transmitted onto the fiber medium. NetEnable shall enable the MAU for transmission of TxDataOut light levels on the fiber medium. NetEnable false shall prevent transmission of TxDataOut signals, as shown in Table 80.

#### 10.4.3.4 RxData

RxData shall represent the raw, distorted, unsynchronised Ph-symbols (H or L) as recovered from the fiber medium. This signal shall be true when the light level on the medium meets the 'light on' requirements defined in 19.6, otherwise this signal shall be false. After data recovery and resynchronisation to meet the MDS timing requirements (from Table 54), these Ph-symbols shall be decoded into the appropriate PLS_DATA_INDICATION M_symbols as shown in Table 55. RxData shall report false if the medium is broken, missing or power is removed from the transmitting end of the fiber.

#### 10.4.3.5 RxCarrier

RxCarrier shall be true when the light level on the medium meets the 'light on' requirements defined in 19.6, otherwise this signal shall be false. This signal shall be used directly to create the PLS_CARRIER_INDICATION at the DLL-PhL interface. If the fiber transceiver does not support a carrier indication mechanism, this interface signal shall be connected to the RxData interface signal. The RxCarrier shall report false if the medium is broken, missing or power removed from the transmitting end of the fiber.

### 10.4.4 MDS – MAU interface Network Access Port (NAP)

The following signals shall be required for the NAP MDS-MAU interface:

a) /TxPTC shall be false to represent H transmit data from the MAU, and shall be true to represent L;

b) /RxPTC shall be false to represent H receive data from the MDS, and shall be true to represent L. This signal shall be true if the NAP medium is removed, broken, short-circuited or the source transmitter is disabled.

## 10.5 Type 3: MDS – MAU interface: Wire and optical media

### 10.5.1 Synchronous transmission

The MDS-MAU interface specified for Type 1 shall be used (see 10.2).

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### 10.5.2 Asynchronous transmission

Instead of the MDS-MAU interface as described in 10.2 the DL-Ph interface for asynchronous transmission shall be used (see 5.1 and 5.4.2).

## 10.6 Type 8: MDS – MAU interface: Wire and optical media

### 10.6.1 Overview of the services

The MDS-MAU interface makes services available to connect the MDS with a corresponding MAU. The services are defined as logical signals that the MAU sublayer directly converts into physical signals (see Table 81).

**Table 81 – Services of the MDS-MAU interface**

| Service | Mnemonic | Direction |
|---|---|---|
| Data Out | DO | From MDS |
| Data In | DI | From MAU |
| Bus Connector | BC | From MAU |
| Loopback Enable | LbE | From MDS |
| Data Select | DS | From MDS |
| Medium Activity | MA | From MDS |
| NOTE The Bus Connector, Loopback Enable, Data Select and Medium Activity services are only supported by the MAU of an outgoing interface. | | |

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### 10.6.2 Description of the services

#### 10.6.2.1 Data-out (DO)

This service transmits the PhPDU from the MDS to the MAU.

#### 10.6.2.2 Data-in (DI)

This service transmits the PhPDU from the MAU to the MDS.

#### 10.6.2.3 Bus connector (BC)

This service indicates to a MDS whether the transmission medium is connected to the MAU of an outgoing interface. If the transmission medium is not connected to the MAU of an outgoing interface, the systems management shall, for this MAU, disconnect the receive circuit from the medium with the Loopback Enable (LbE) service and connect the send circuit with the receive circuit.

NOTE 1 The Bus Connector service is only supported by the MAU of an outgoing interface. It is not related to the other services of the MDS-MAU interface.

NOTE 2 This service is a local management service that indicates whether another bus device is connected to the outgoing interface of the MAU, which allows the systems management to close or open the transmission ring with the Loopback Enable service.

NOTE 3 The detection of another connected bus device is caused by a signal that is led through a bridge in the connector of the outgoing cable (see cable definition).

#### 10.6.2.4 Loopback enable (LbE)

This service allows the systems management to decouple the receive circuit from the transmission medium for a MAU of an outgoing interface, and to connect the send circuit with the input circuit.

NOTE 1 The Loopback Enable service is only supported by the MAU of an outgoing interface and is not related to the other services of the MDS-MAU interface.

NOTE 2 This service is a local management service that allows the systems management to close the transmission ring if no other bus slave is connected to the MAU of an outgoing interface.

#### 10.6.2.5 Medium activity (MA)

This service transmits a special status PhPDU from the MDS to the MAU if the active ring was decoupled from the medium and the send and receive circuit were connected but controlled activity is to be generated on the medium.

NOTE 1 This service is used by a slave only.

NOTE 2 The Medium Activity service is only supported by MAU of an outgoing interface and has no time relation to the other services of the MDS-MAU interface.

#### 10.6.2.6 Data select (DS)

The systems management uses this service to transmit on the decoupled medium of an outgoing MAU either a reset PhPDU or with the Medium Activity service certain status PhPDUs.

NOTE 1 This service is used by a slave only.

NOTE 2 The Data Select service is only supported by MAU of an outgoing interface and is not related to the other services of the MDS-MAU interface.

### 10.6.3 Time response

The MDS shall be able to correctly decode a bit with bit jitter specified in Figure 76. The variation for the sample clock shall be within the range of ± 0,1 %.

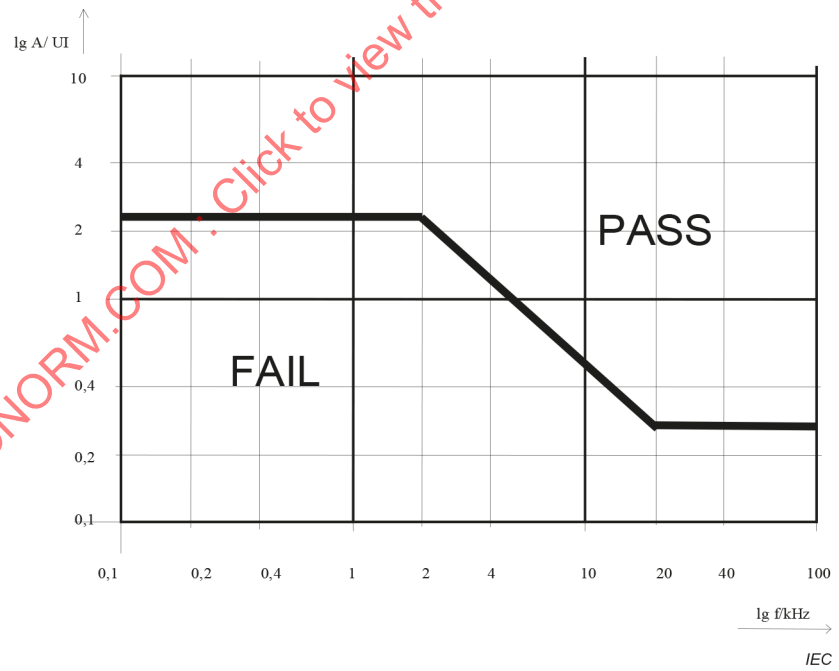


**Figure 76 – Jitter tolerance**

### 10.6.4 Transmission mode

The MDS-MAU interface shall allow a simultaneous, independent sending and receiving.

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## 10.7 Type 18: MDS – MAU interface: Wire media

### 10.7.1 General

The granularity of PhPDU exchanged at the MAU interface is one bit.

### 10.7.2 Services

If the MAU interface is exposed, it shall support at least the set of required services given in Table 82 and specified in 10.7.3.

**Table 82 – Minimum services at MAU interface**

| Service | Abbreviation | Direction |
|---|---|---|
| Transmit Signal | TxS | To MAU |
| Receive Signal | RxS | From MAU |
| Transmit Enable | TxE | To MAU |

### 10.7.3 Service specifications

#### 10.7.3.1 Transmit Signal (TxS)

The Transmit Signal service (TxS) shall transfer the encoded PhPDU signal sequence across the interface to the MAU, where the sequence shall be transmitted on to the medium if the Transmit Enable (TxE) is set to logic one (high level).

#### 10.7.3.2 Receive Signal (RxS)

The Receive Signal service (RxS) shall transfer the encoded PhPDU signal sequence or silence across the interface to the MDS. The RxS shall echo the signal transmitted via TxS by simultaneously receiving the transmissions from the medium.

#### 10.7.3.3 Transmit Enable (TxE)

The Transmit Enable service (TxE) shall provide the facility to enable the MAU to transmit. The TxE shall be set to logic one (high level) at the commencement of preamble transmission and then set to logic zero (low level) after the last bit of the end delimiter has been transmitted.

### 10.7.4 Signal characteristics

If the MAU interface is exposed, it shall operate with digital signal levels as shown in Table 83. Both sides of the interface shall operate with the same value of $V_{DD}$.

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**Table 83 – Signal levels for an exposed MAU interface**

| Symbol | Parameter | Conditions | Limits | Units | Remarks |
|---|---|---|---|---|---|
| $V_{OL}$ | Maximum low-level output voltage | $I_{out}$ = ±100 µA | 0,1 | V | See Note 1 |
| | | $I_{out}$ = +1,6 mA | 0,4 | V | |
| $V_{OH}$ | Minimum high-level output voltage | $I_{out}$ = ±100 µA | $V_{DD}$ - 0,1 | V | See Note 1 |
| | | $I_{out}$ = −0,8 mA | $V_{DD}$ - 0,8 | V | See Note 2 |
| $V_{IL}$ | Maximum low-level input voltage | | 0,2 $V_{DD}$ | V | |
| $V_{IH}$ | Minimum high-level input voltage | | 0,7 $V_{DD}$ | V | See Note 3 |

NOTE 1 Provides the capability to drive two typical CMOS loads.

NOTE 2 CMOS input compatibility with TTL output requires a "pull-up" resistor from signal input to $V_{DD}$.

NOTE 3 Compatible with CMOS output for 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. Compatibility with TTL output (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) requires a "pull-up" resistor from signal input to $V_{DD}$.

### 10.7.5 Communication mode

The communication mode at this interface shall allow simultaneous transmission and reception.

### 10.7.6 Timing characteristics

The MAU shall function correctly with a PhSDU bit rate of between 1 kbit/s and 1,1 times the highest stated MAU bit rate. The clocking frequency shall be implemented accurate to within 150 µHz/Hz of the specified rate.

## 10.8 Type 24: MDS – MAU interface: Twisted-pair wire medium

### 10.8.1 Overview of service

If the MDS-MAU interface is exposed, it shall support at least the set of required services given in Table 84 and specified in 10.8.2.

**Table 84 – Minimum services of the MDS-MAU interface**

| Signal name | Mnemonic | Direction |
|---|---|---|
| Transmit Signal | TxS | To MAU |
| Transmit Enable | TxE | To MAU |
| Receive Signal | RxS | From MAU |

### 10.8.2 Description of the services

#### 10.8.2.1 Transmit signal (TxS)

This service transmits the PhPDU from the MDS to the MAU, where it shall be transmitted on to the medium if Transmit Enable (TxE) is set to logic 1 (high level).

#### 10.8.2.2 Transmit enable (TxE)

The Transmit Enable service (TxE) shall provide the MDS with the facility to enable the MAU to transmit. TxE shall be set to logic 1 (high level) by the MDS immediately before the transmission begins, and to logic 0 (low level) after transmission ends.

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#### 10.8.2.3 Receive signal (RxS)

This service transmits the PhPDU from the MAU to the MDS.

#### 10.8.2.4 Signal characteristics

If the MDS-MAU interface is exposed, it shall operate with digital signal levels as shown in Table 85. Both sides of the interface shall operate with the same value of $V_{DD}$.

**Table 85 – Signal levels for an exposed MDS-MAU interface ($V_{DD}$=5 V)**

| Symbol | Parameter | Conditions | Limits | Units | Remarks |
|---|---|---|---|---|---|
| $V_{OL}$ | Maximum low-level output voltage | $I_{out}$ = ±100 µA | 0,1 | V | See Note1 |
| $V_{OH}$ | Min.high-level output voltage | $I_{out}$ = ±100 µA<br>$I_{out}$ = −0,8 mA | $V_{DD}$ - 0,1<br>$V_{DD}$ - 0,8 | V | See Note 2 |
| $V_{IL}$ | Max.low-level input voltage | | 0,2 $V_{DD}$ | V | |
| $V_{IH}$ | Min.high-level input voltage | | 0,7 $V_{DD}$ | V | See Note 3 |
| NOTE 1 Provides the capability to drive two typical CMOS loads.<br>NOTE 2 CMOS input compatibility with TTL output requires a "pull-up" resistor from signal input to $V_{DD}$.<br>NOTE 3 Compatible with CMOS output for 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. Compatibility with TTL output (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) requires a "pull-up" resistor from signal input to $V_{DD}$. | | | | | |

#### 10.8.2.5 Timing characteristics

Timing characteristics shall be compatible with those specified in the requirements of this document for the relevant MDS. The MDS-MAU interface shall function correctly with a PhSDU bit rate of up to 32 Mbit/s.

### 10.9 Type 28: MDS – MAU interface: Twisted-pair wire and coaxial media

#### 10.9.1 General

Medium Attachment Unit (MAU) is an optionally separate part of a communication element that connects to the medium directly or via passive components. The MDS-MAU interface of the PhL provides the function of signal conversion and docking. The interface should convert the digital signal output by MDS into analog signal and send it by MAU, or convert the analog signal received from MAU into digital signal that can be processed by MDS.

#### 10.9.2 Services

The PhL MDS-MAU interface supports at least a set of required services given in Table 86 and specified in 10.9.4.

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**Table 86 – Minimum services at MDS-MAU interface**

| Service | Abbreviation | Direction |
|---|---|---|
| **Required:** | | |
| Transmit signal | TxS | To MAU |
| Receive signal | RxS | From MAU |
| Transmit enable | TxE | To MAU |
| **Optional:** | | |
| Loopback enable | LbE | To MAU |

### 10.9.3 Service process

Figure 77 shows the PhL MDS-MAU interface service process.

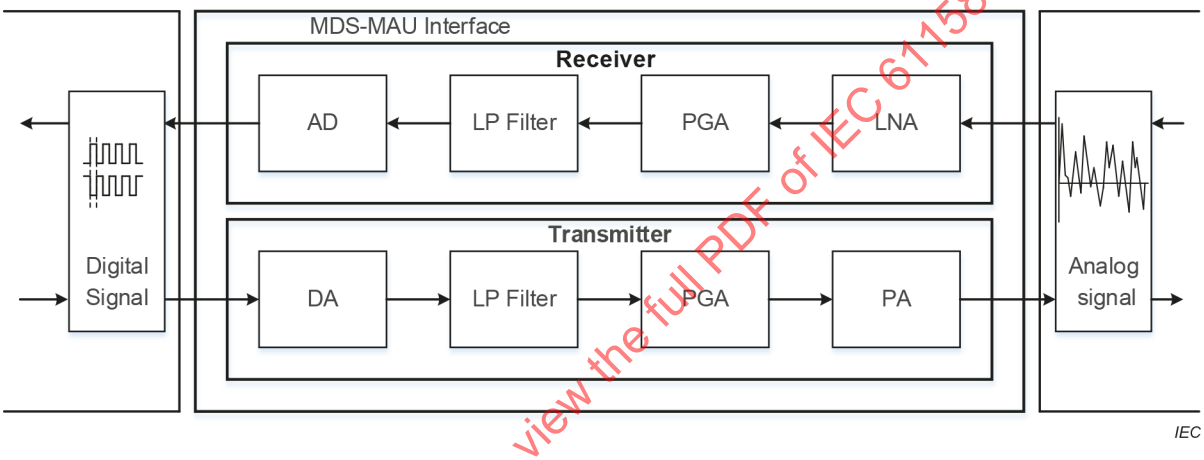


**Figure 77 – MDS-MAU interface service process diagram**

PhL MDS implements encoding and modulation based on OFDM and outputs the digital signal to the MDS-MAU interface to transmit the signal. The interface includes a transmitter and a receiver. At the transmitter, the digital signal is converted to an analog signal by the D/A module. After filtering, gain amplification and power amplification, the analog signal is transmitted to the medium and then sent to the network. At the receiver, the analog signal is recovered to the corresponding digital signal by A/D module after low-noise amplifying, power amplifying and filtering. Then the digital signal is transmitted to MDS for further signal processing like demodulation and decoding.

### 10.9.4 Service specifications

#### 10.9.4.1 Transmit Signal (TxS)

Transmit Signal service (TxS) transfers the encoded PhPDU signal sequence to MAU across the MDS-MAU interface. If the Transmit Enable (TxE) is set to logic 0 (low level), the output analog signal sequence should be sent to the medium.

#### 10.9.4.2 Receive Signal (RxS)

Receive Signal (RxS) transfers the encoded PhPDU signal sequence to MDS across the MDS-MAU interface. The output signal sequence should be a decodable PhPDU. Once PhL runs, the RxS service is always valid by default and does not need to be confirmed to enable. The RxS should echo the signal transmitted via TxS by simultaneously receiving the transmissions from the medium.

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#### 10.9.4.3 Transmit Enable (TxE)

Transmit Enable service (TxE) provides MDS with the facility to enable MAU to transmit. TxE should be set to logic 0 (low level) when at the PhPDU signals sequence is ready to be sent and then set to logic 1 (high level) after MDS-MAU interface processes the sequence and transmits it on to the medium. Once the physical device is powered on, TxE is set to logic 0 (low level) by default, i.e., the user is always allowed to send.

#### 10.9.4.4 Loopback Enable (LbE)

When MDS-MAU interface provides Loopback Enable (LbE) service, the signal sent by the MAU is returned to MAU as a received signal for further processing. LbE returns all signals back to local loopback, which has no effect on the signals received by the MAU from the medium. The service status of LbE should not change when the MAU is transmitting or receiving.

NOTE This confirmation service is valid in local. it provides a device with the facility to test the integrity and functionality of the PhL circuit, excluding the medium.

### 10.9.5 Transmit specifications

#### 10.9.5.1 Transmit level

The PhL specifies that the maximum allowable output power which is 100 mW.

#### 10.9.5.2 Transmit frequency spectrum specification

The transmission frequency range implemented in the PhL MDS-MAU interface is from 1,536 MHz to 32,256 MHz. In order to reduce the out-of-band power of RF signal, the filter should be used to filter the RF signal. Figure 78 shows the signal template for a possible filter implementation under signal bandwidth.

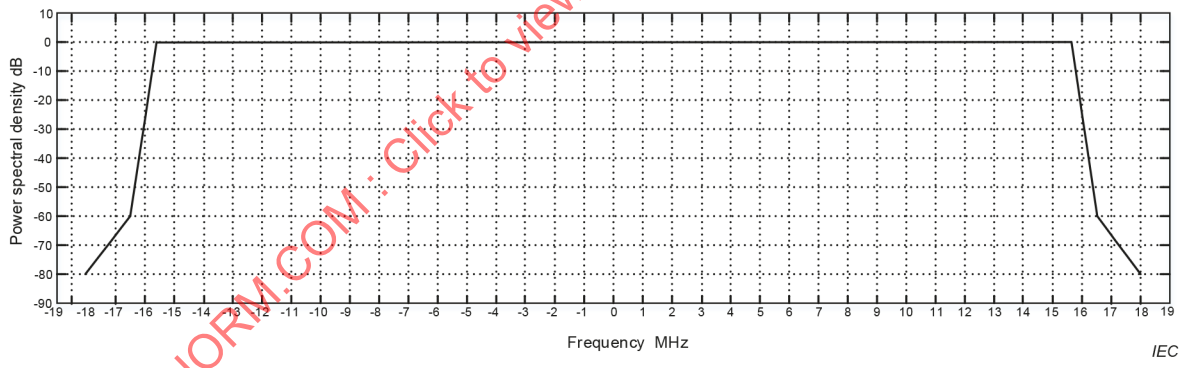


**Figure 78 – Signal spectrum template**

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#### 10.9.5.3 Transmit subcarrier frequency tolerance

The clock frequency range of PhL is required to be 100 MHz with an accuracy of ±150 ppm. During transmitting, the subcarrier frequency is synchronized with the clock frequency.

#### 10.9.5.4 Modulation accuracy

The constellation diagram after averaging subcarrier, OFDM frame and grouping for RMS should comply with Table 87.

**Table 87 – Allowable constellation diagram errors in different modulation modes**

| Modulation mode | Relative constellation error (dB) |
|---|---|
| 16QAM | 45 |
| 64QAM | 45 |
| 256QAM | 45 |

#### 10.9.5.5 System transmission parameters

The maximum transmit power of the system is 20 dBmW, and the minimum receiving sensitivity is −82 dBmW.

The maximum transmission distance is 500 m.

Table 88 shows the parameters specifications for different transmission rates.

**Table 88 – System transmission parameters**

| Parameter | Value | | | Unit |
|---|---|---|---|---|
| Net load bit rate | 14 | 57 | 103 | Mbit/s |
| SNR | 13,4 | 18 | 23 | dB |

## 11 Types 1 and 7: Medium attachment unit, voltage mode, linear-bus-topology 150 Ω twisted-pair wire medium

### 11.1 General

NOTE These MAU requirements are not specifically intended to facilitate the options of power distribution via the signal conductors and suitability for intrinsic safety certification.

The network medium consists of shielded twisted-pair cable. Independent of topology, all attached devices, other than possibly the transmitting device, present a high impedance to prevent significant network loading. Trapezoidal waveforms are used to reduce electromagnetic emissions and signal distortion.

A linear bus topology is supported, as are some branched acyclic topologies. A network contains one trunk cable, terminated at its ends.

### 11.2 Bit-rate-dependent quantities

Six bit rates are defined for the voltage-mode twisted-pair medium attachment unit (MAU). A given MAU shall support at least one of these bit rates.

Table 89 specifies the supported bit rates, and defines symbols for bit-rate-dependent quantities used throughout Clause 11.

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**Table 89 – Bit-rate-dependent quantities of voltage-mode networks**

| Quantity | | Symbol | Unit | Value | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nominal bit rate | | BR | Mbit/s | 0,031 25 | 1 | 2,5 | 5 | 10 | 25 |
| Maximum deviation from BR | | ΔBR | | 0,2 % | 0,01 % | | | | |
| Nominal bit duration | | $T_{bit}$ | µs | 32 | 1,0 | 0,4 | 0,2 | 0,1 | 0,04 |
| Maximum deviation from $T_{bit}$ | | $\Delta T_{bit}$ | - | 0,9 µs | 0,025 % | | | | |
| Signaling frequencies | Nominal for a repeated bit | $f_r$ | MHz | 0,031 25 | 1 | 2,5 | 5 | 10 | 25 |
| | Nominal minimum = 0,25 $f_r$ | $f_{min}$ | MHz | 0,007 8 | 0,25 | 0,625 | 1,25 | 2,5 | 6,25 |
| | Nominal maximum = 1,25 $f_r$ | $f_{max}$ | MHz | 0,039 | 1,25 | 3,125 | 6,25 | 12,5 | 31,25 |
| Maximum number of devices | | $N_{max}$ | | 32 | | | | 16 | |
| Maximum inter-device distance | | $L_{max}$ | m | 4 000 | 750 | 500 | 400 | 200 | 100 |
| Maximum inter-device attenuation | | $A_{max}$ | dB | 15 | 17 | 18 | | | |
| Maximum inter-device attenuation distortion | | $AD_{max}$ | dB | 8 | | 10 | | | |
| Maximum inter-device mismatching distortion | | $MD_{max}$ | dB | 0,2 | | | 0,4 | 0,6 | |
| Maximum signal rise or fall time | | $T_{rf}$ | ns | 8 000 | 200 | 80 | 40 | 20 | 8 |
| Maximum coupler spacing to form a cluster | | $CS_{max}$ | m | 4 | | 2 | 1 | 0,5 | 0,25 |
| Minimum device input impedance | | $Din_{min}$ | kΩ | 8 | | | 4 | 2 | 1 |
| Maximum quiescent transmitter output | | $QTO_{max}$ | mV rms | 1 | 5 | 10 | 20 | 40 | 80 |
| Maximum frequency for $QTO_{max}$ measurement | | $f_{QTOmax}$ | MHz | 0,1 | 4 $f_r$ | | | | |

The average bit rate shall be BR with a tolerance of ± ΔBR, averaged over a frame having a minimum length of 16 octets.

The instantaneous bit time shall be $T_{bit}$ with a tolerance of ± $\Delta T_{bit}$.

## 11.3 Network specifications

### 11.3.1 Components

A voltage-mode MAU operates in a network composed of the following components:

a) twisted-pair wire cable;

b) devices (containing at least one communication element);

c) connectors;

d) couplers;

e) terminators.

### 11.3.2 Topologies

A wire MAU shall operate in a network with an acyclic nominally linear bus topology, consisting of a trunk, terminated at each end as specified in 11.8.5, to which communication elements are connected via couplers. Each communication element shall be connected in parallel with the trunk cable.

NOTE The coupler and communication element are generally integrated in one device.

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Active repeaters may be used to establish branches or to extend the length of the trunk beyond that of a single segment as permitted by the network configuration rules. Branches shall be considered as segments, and can make the bus non-linear. Cycles (closed loops) are never permitted.

### 11.3.3 Network configuration rules

An MAU that claims conformance to Clause 11 shall meet the requirements of Clause 11 when used in a network that complies with these rules.

**Rule 1:** A fieldbus shall be capable of communication between two and $N_{max}$ devices, all operating at the same bit rate.

NOTE 1 This rule does not preclude the use of more than $N_{max}$ devices in an installed system.

**Rule 2:** A fully loaded (maximum number of connected devices) fieldbus segment shall have a total cable length, including branches, between any two devices, of up to $L_{max}$.

NOTE 2 Support of this maximum cable length is a requirement for MAU conformance to Clause 11, but this does not preclude the use of longer lengths in an installed system.

**Rule 3:** The total number of waveform regenerations by repeaters and active couplers between any two devices is repeater implementation dependent.

NOTE 3 Prior editions of this document limited this total number to four.

**Rule 4:** The maximum propagation delay between any two devices shall not exceed 40 $T_{bit}$. For efficiency of the network, that part of the turn-around time of any device on the network caused by a PhE between the end of a received frame and the beginning of the transmitted frame containing an associated immediate response should not exceed 30 bit times, no more than 2 bit times of which should be due to the MAU.

NOTE 4 As it is not mandatory to expose either the DLL-PhL interface or the MDS-MAU interface, that part of the turn-around time of a fieldbus device caused by the PhL or the MAU is not specified and thus not available for conformance tests.

**Rule 5:** The fieldbus shall be capable of continued operation while a device is being connected or disconnected. Data errors induced during connection or disconnection shall be detected.

**Rule 6:** For a fieldbus that is not powered via the signal conductors, a single failure in any one communication element (including a short circuit but excluding jabber) shall not interfere with transactions between other communication elements for more than 1 ms.

**Rule 7:** In polarity sensitive systems, the medium wire pairs shall have distinctly marked conductors that uniquely identify individual conductors. Consistent polarization shall be maintained at all connection points.

**Rule 8:** The degradation of the electrical characteristics of the signal, between any two devices, due to attenuation, attenuation distortion and mismatching distortion shall be limited to the values indicated below.

a) Signal attenuation: The configuration of the bus (trunk length, number of devices, and possible matching devices) shall be such that the attenuation between any two devices at frequency $f_r$ shall not exceed $A_{max}$;

b) Attenuation distortion: The configuration of the bus (trunk and spur lengths and number of devices) shall be such that between any two devices:

c) Mismatching Distortion: Mismatching (due to any effect) on the bus shall be such that, at any point along the trunk, in the frequency band $f_{min}$ to $f_{max}$:

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$0 \leq$ [Attenuation ($f_{max}$) - Attenuation ($f_{min}$)] $\leq$ $AD_{max}$

Attenuation shall be monotonic non-decreasing for all frequencies from $f_{min}$ to $f_{max}$;

$|Z - Z_{f_r}| / |Z + Z_{f_r}| \leq MD_{max}$

where $Z_{f_r}$ is the characteristic impedance of the trunk cable at frequency $f_r$ and Z is the parallel combination of $Z_{f_r}$ and the load impedance at the coupler.

NOTE 5 This rule minimizes restrictions on trunk and spur length, number of devices etc. by specifying only the transmission limitations imposed by combinations of these factors. It is possible to use different combinations depending on the needs of the application.

NOTE 6 The usual cause of a large mismatch is the concentration of several couplers on a short length of the trunk.

If the distance between two consecutive couplers is less than $CS_{max}$, then the propagation delay between them is smaller than $T_{rf}$ and the concentration appears as a single mismatched element inducing large reflections of the signal transitions.

A concentration of couplers where the distance between two consecutive couplers is less than $CS_{max}$ is defined as a cluster. In order to comply with Rule 8c using devices with an input impedance of minimum value $Din_{min}$ and zero-length spurs, it is recommended that a cluster does not include more than 4 couplers.

Using devices with input impedance significantly higher than the minimum value $Din_{min}$ allows clusters with more couplers. Using non-zero-length spurs could require clusters to have fewer than 4 couplers.

NOTE 7 It is possible to reduce the mismatching due to a cluster by the following means:

– using active multiport couplers,

– inserting matching devices (passive attenuators) on each side of the cluster while satisfying Rule 8.

**Rule 9:** The following rules shall apply to systems implemented with redundant media:

a) each channel (cable) shall comply with the network configuration rules;

b) there shall not be a non-redundant segment between two redundant segments;

c) repeaters shall also be redundant;

d) if the devices of the system are configured (by Systems management) to transmit on more than one channel simultaneously then the propagation time difference between any two devices on any two channels shall not exceed five bit times;

   This period may be extended, but not reduced, by Systems management as given in Table 13 (see 6.2.2.2 and 9.2.9).

e) channel numbers and association with the physical transmission media shall be maintained consistently throughout the fieldbus, i.e. channels 1, 2, 3… from Systems management shall always connect to physical channels 1, 2, 3…;

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### 11.3.4 Power distribution rules for network configuration

The cable shield shall not be used as a power conductor.

## 11.4 MAU transmit circuit specification

### 11.4.1 Summary

Table 90 through Table 92 summarise the requirements of the MAU.

**Table 90 – MAU transmit level specification summary**

| Transmit level characteristics, values referred to trunk (but measured using test load as shown in Figure 79) | Limits |
|---|---|
| Output level (peak-to-peak, see Figure 80)<br>With test load (0,5 nominal $Z_o$ of the trunk cable at $f_r$) | 5,5 V to 9,0 V<br>75 Ω ± 1 % |
| Maximum positive and negative amplitude difference (signaling bias) as shown in Figure 81 | ± 0,45 V |
| Output level with one terminator removed (peak-to-peak)<br>with test load (nominal impedance of the trunk cable at $f_r$) | 5,5 V to 11,0 V<br>150 Ω ± 1 % |
| Maximum output level; open circuit (peak-to-peak) | 5,5 V to 30,0 V |
| Maximum output signal distortion; i.e., overvoltage, ringing and droop (see Figure 80) | ±10 % |
| Quiescent transmitter output; i.e. transmitter noise<br>(measured over the frequency band 1 kHz to $f_{QTOmax}$) | ≤ $QTO_{max}$ (RMS.) |

**Table 91 – MAU transmit timing specification summary for 31,25 kbit/s operation**

| Transmit timing characteristics, values referred to trunk (but measured using test load as shown in Figure 79) | Limits |
|---|---|
| Transmitted bit rate | BR ± ΔBR |
| Instantaneous bit time | $T_{bit}$ ± $\Delta T_{bit}$ |
| Rise and fall times (10 % to 90 % of peak-to-peak signal, see Figure 80) | ≤ 25 % $T_{bit}$ |
| Slew rate (at any point from 10 % to 90 % of peak-to-peak signal) | ≤ 0,2 V/µs |
| Maximum transmitted bit cell jitter (zero-crossing point deviation, see Figure 81) | ± 2,5 % $T_{bit}$ |
| Transmit enable/disable time (i.e. time during which the output waveform can meet the transmit requirements, or not) | ≤ 2,0 $T_{bit}$ |

**Table 92 – MAU transmit timing specification summary for ≥ 1 Mbit/s operation**

| Transmit timing characteristics, values referred to trunk (but measured using test load as shown in Figure 79) | Limits |
|---|---|
| Transmitted bit rate | BR ± ΔBR |
| Instantaneous bit time | $T_{bit}$ ± $\Delta T_{bit}$ |
| Rise and fall times (10 % to 90 % of peak-to-peak signal, see Figure 80) | ≤ 20 % $T_{bit}$ |
| Slew rate (at any point from 10 % to 90 % of peak-to-peak signal) | ≤ 100 V/µs × ($f_{r/MHz}$) |
| Maximum transmitted bit cell jitter (zero-crossing point deviation, see Figure 81) | ± 2,5 % $T_{bit}$ |
| Transmit enable/disable time (i.e. time during which the output waveform can meet the transmit requirements, or not) | ≤ 2,0 $T_{bit}$ |

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### 11.4.2 MAU test configuration

Figure 79 shows the configuration that shall be used for testing MAUs, as follows.

- Differential signal voltage: $V_d = V_a - V_b$
- Test load resistance R = 75 Ω (0,5 nominal impedance of the trunk cable at $f_r$) and C = 0,15 µF except where otherwise stated in a specific requirement.
- Data "+" terminal connected to the power "+" terminal and data "-" terminal connected to the power "-" terminal.

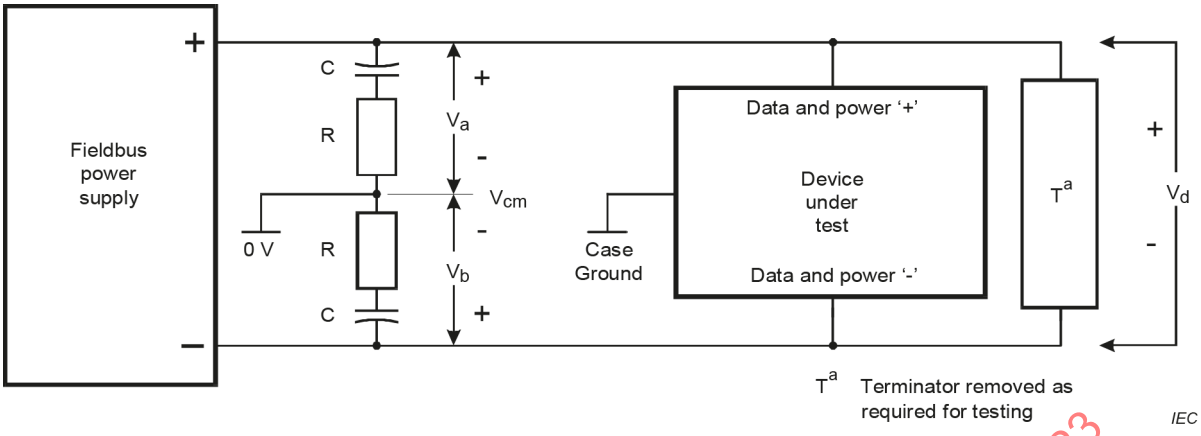


**Figure 79 – Transmit circuit test configuration**

### 11.4.3 MAU output level requirements

Figure 80 describes the output form of the signal for the twisted-pair voltage output level requirements.

NOTE Figure 80 shows an example of the a.c. component of one cycle of a fieldbus waveform, illustrating some key items from the transmit circuit specification. Only signal voltages are shown; this diagram takes no account of power supply voltages.

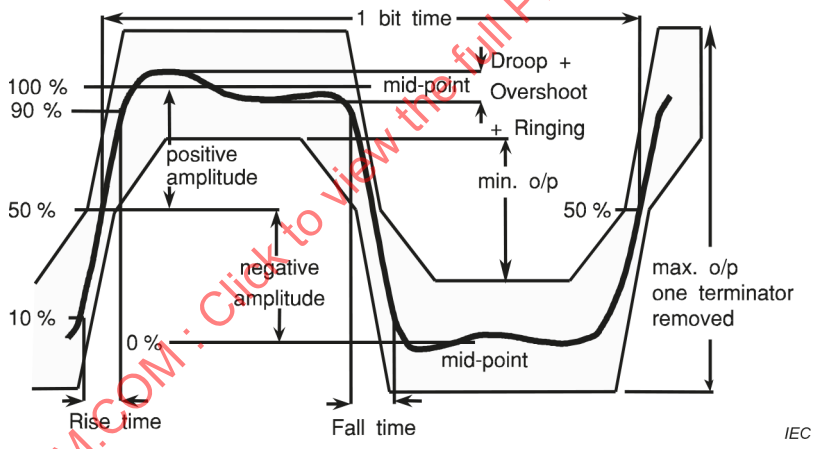


**Figure 80 – Output waveform**

The MAU transmit circuit shall conform to the following output level requirements, all amplitudes being measured at the estimated mid-point between any peaks or troughs in the top and bottom of the waveform ("mid-point" in Figure 80):

a) the output voltage across the test load after transformer step up/down (if applicable) shall be between 5,5 V and 9,0 V peak-to-peak with a load resistance of 75 Ω with a tolerance of ± 1 % ("min. o/p" in Figure 80);

b) the output voltage at the trunk, or at the transmit terminals, with a load resistance of 150 Ω with a tolerance of ± 1 % (i.e. with one trunk terminator removed) shall be between 5,5 V and 11,0 V peak-to-peak ("max. o/p one terminator removed" in Figure 80);

c) the output voltage at the trunk, or at the transmit terminals, with any load including an open circuit shall be between 5,5 V and 30,0 V peak-to-peak. For test purposes open circuit shall be defined as a load of 100 kΩ resistance in parallel with 15 pF capacitance;

d) during transmission a device shall not suffer permanent failure when a load resistance of ≤1 Ω is applied for 1 s;

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e) the difference between positive amplitude and negative amplitude, measured as shown in Figure 80, shall not exceed ±0,45 V peak;

f) the output noise from an MAU which is receiving or not powered shall not exceed $QTO_{max}$ RMS, measured differentially over the frequency band 1 kHz to $f_{QTOmax}$, referred to the trunk;

g) the differential voltage across the test load shall be such that the voltage monotonically changes between 10 % and 90 % of peak-to-peak value. Thereafter, the signal voltage shall not vary more than ±10 % of peak-to-peak value until the next transition occurs. This permitted variation shall include all forms of output signal distortion, i.e. overvoltage, ringing and droop.

### 11.4.4 MAU output timing requirements

#### 11.4.4.1 Common output timing requirements for all data rates

An MAU transmit circuit shall conform to the following output timing requirements:

a) transmitted bit cell jitter shall not exceed $\Delta T_{bit}$ from the ideal zero crossing point, measured with respect to the previous zero crossing (see Figure 81);

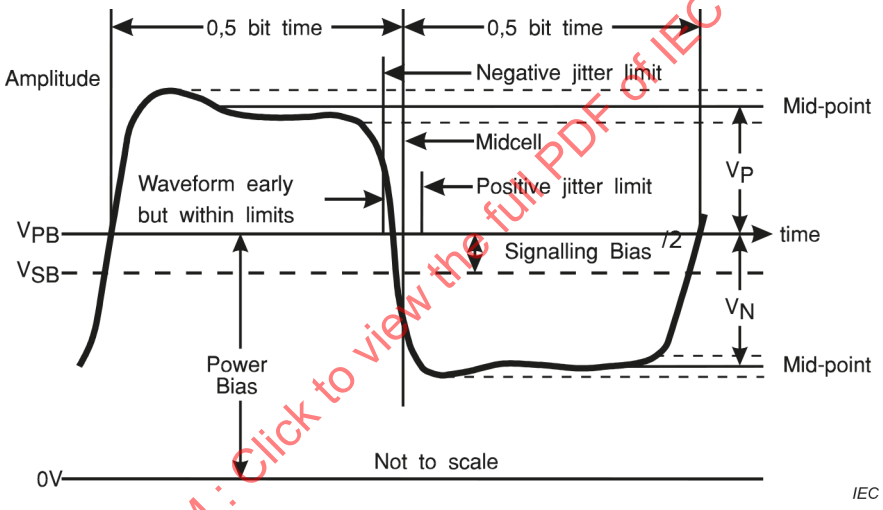


**Figure 81 – Transmitted and received bit cell jitter (zero crossing point deviation)**

b) the transmit circuit shall turn on, i.e. the signal shall rise from below the transmit circuit maximum output noise level as specified in 11.4.3 f) to full output level, in less than 2,0 $T_{bit}$. The waveform corresponding to the third and later bit times shall be as specified in Figure 80;

c) the transmit circuit shall turn off, i.e. the signal shall fall from full output level to below the transmit circuit maximum output noise level as specified in 11.4.3 f), in less than 2,0 $T_{bit}$. The time for the transmit circuit to return to its off-state impedance shall not exceed 4,0 $T_{bit}$. For the purposes of testing, this requirement shall be met with the transmit circuit test configuration of Figure 79 with the equivalent capacitance of a maximum length cable across the DUT terminals.

NOTE This requirement is to ensure that the transition of the transmit circuit from active to passive leaves the line capacitance fully discharged.

#### 11.4.4.2 Additional output timing requirements for 31,25 kbit/s operation

The MAU transmit circuit shall conform to the following additional output timing requirements:

a) rise and fall times, measured from 10 % to 90 % of the peak-to-peak signal amplitude shall not exceed 0,25 $T_{bit}$ (see Figure 80);

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b) slew rate shall not exceed 0,2 V/µs measured at any point in the range 10 % to 90 % of the peak-to-peak signal amplitude (see Figure 80).

NOTE Requirements a) and b) produce a trapezoidal waveform at the transmit circuit output. Requirement b) limits the level of interference emissions that can be coupled to adjacent circuits etc. Requirement b) is calculated from the formula:

$$\text{max. slew rate} = 2 \times \text{min. slew rate} = 2 \times 0{,}8\ V_o / 0{,}25\ T_{bit} = 6{,}4 \times V_o / T_{bit},$$

where $V_o$ is the maximum peak-to-peak output voltage (9,0 V) with a standard load.

#### 11.4.4.3 Additional output timing requirements for ≥ 1 Mbit/s operation

The MAU transmit circuit shall conform to the following additional output timing requirements:

a) rise and fall times, measured from 10 % to 90 % of the peak-to-peak signal amplitude shall not exceed 0,2 $T_{bit}$ (see Figure 80);

b) slew rate shall not exceed 100 V/µs × ($f_{r/MHz}$) measured at any point in the range 10 % to 90 % of the peak-to-peak signal amplitude (see Figure 80).

NOTE Requirements a) and b) produce a trapezoidal waveform at the transmit circuit output. Requirement b) limits the level of interference emissions that can be coupled to adjacent circuits etc. Requirement b) is calculated from the formula:

$$\text{max. slew rate} = 36 \times \text{min. slew rate} = 3 \times 0{,}8\ V_o / 0{,}2\ T_{bit} = 12 \times V_o / T_{bit},$$

where $V_o$ is the maximum peak-to-peak output voltage (9,0 V) with a standard load.

### 11.4.5 Signal polarity

For a bus-powered device, the data "+" terminal shall be connected to the power "+" terminal, and the data "-" terminal shall be connected to the power "-" terminal. See Figure 79.

When transmission is enabled, a high to low transition of the Manchester encoded signal shall result in a high to low transition in $V_d$ on the bus. A low to high transition of the Manchester encoded signal shall result in a low to high transition in $V_d$ on the bus. The signal polarity is defined in Figure 82.

During reception, a high to low transition in $V_d$ on the bus shall result in a high to low transition of the Manchester encoded signal. A low to high transition in $V_d$ on the bus shall result in a low to high transition of the Manchester encoded signal.

NOTE 1 Manchester encoding is defined in 9.2.2.

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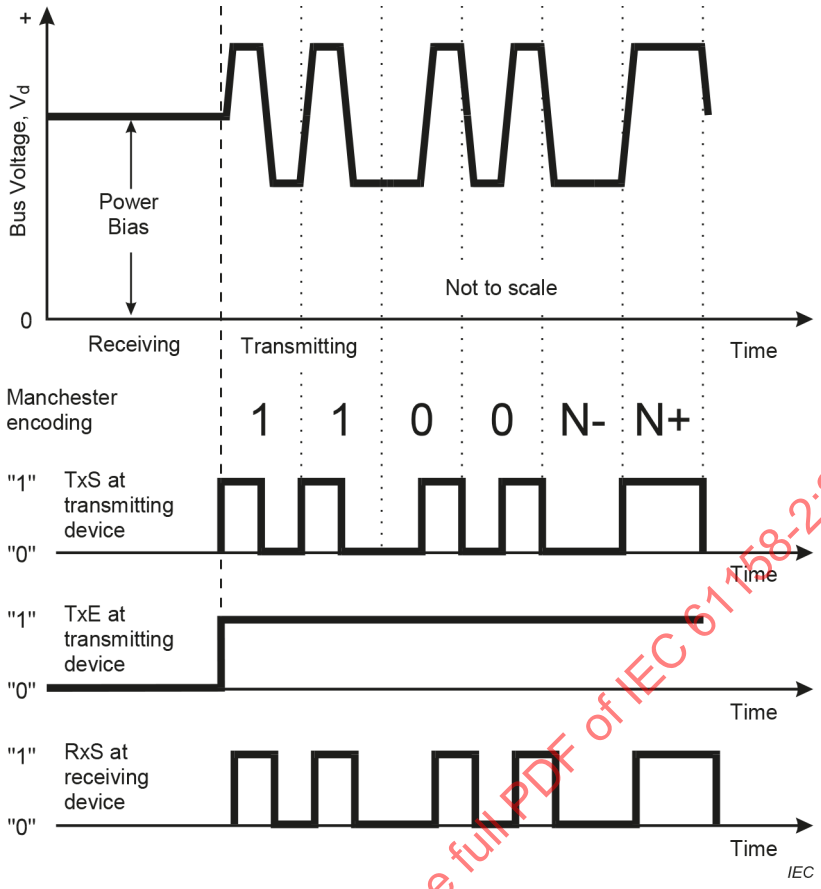


**Figure 82 – Signal polarity**

NOTE 2 The waveform in Figure 82 is shown to provide an example of the "1", "0", "N+", and "N-" symbols. This waveform does not represent an actual PhPDU. See 9.2.2 for the encoding rules.

NOTE 3 The TxS and RxS waveforms in Figure 82 are indeterminate in the time period marked "Receiving".

NOTE 4 The signals at the MDS-MAU interface are defined in Clause 10. The TxS, TxE, and RxS signals shown in Figure 82 are only accessible if the MDS-MAU interface is exposed.

## 11.5 MAU receive circuit specification

### 11.5.1 Summary

Table 93 summarises the specification.

**Table 93 – MAU receive circuit specification summary**

| Receive circuit characteristics (values referred to trunk) | Limits |
|---|---|
| Input impedance, measured over the frequency range $f_{min}$ to $f_{max}$ | ≥8 kΩ |
| Sensitivity; min. peak-to-peak signal required to be accepted (see Figure 83) | 700 mV |
| Noise rejection; max. peak-to-peak noise required to be rejected (see Figure 83) | 280 mV |
| Maximum received bit cell jitter (zero crossing-point deviation (see Figure 81) | ±0,10 $T_{bit}$ |

### 11.5.2 Input impedance

The differential input impedance of an MAU receive circuit shall be no less than $Din_{min}$ over the frequency range $f_{min}$ to $f_{max}$. This requirement shall be met in the power-off and power-on (not transmitting) states and in transition between these states. This impedance shall be measured

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at the communication element terminals using a sine wave with a signal amplitude greater than the receiver sensitivity threshold and lower than 9,0 V peak-to-peak.

NOTE The requirement for ≥$Din_{min}$ input impedance during power-up and power-down can be met by automatic disabling of the transmitter during these periods.

### 11.5.3 Receiver sensitivity and noise rejection

An MAU receive circuit shall be capable of accepting an input signal of amplitude no less than 700 mV peak-to-peak, including overvoltage and oscillation (see "signal level" together with "positive amplitude" and "negative amplitude", all in Figure 83.

An MAU receive circuit shall not respond to an input signal with a peak-to-peak amplitude which does not exceed 280 mV (see "noise rejection" in Figure 83).

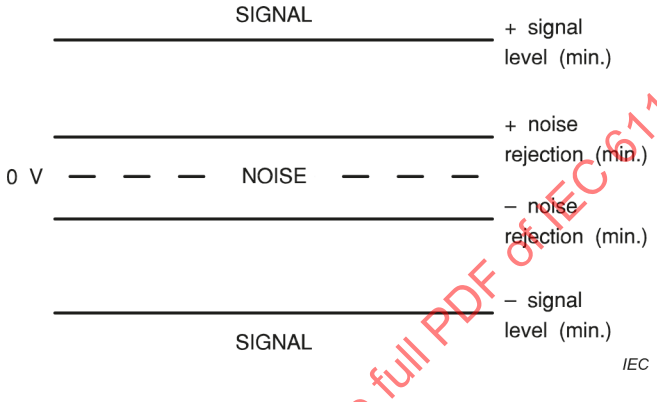


**Figure 83 – Receiver sensitivity and noise rejection**

### 11.5.4 Received bit cell jitter

The receive circuit shall accept a Manchester encoded signal transmitted in accordance with 11.2 and 11.4. In addition, the receiver shall work properly with signals with the time variation between any two adjacent signal transition points (zero crossing) of ±0,10 $T_{bit}$ or less. See Figure 81.

NOTE 1 This specification does not preclude the use of receivers that perform better than this specification.

NOTE 2 Depending on the symbol pattern, the nominal time between zero crossings is 0,5 $T_{bit}$ or 1,0 $T_{bit}$.

NOTE 3 There is no requirement to reject a signal with a specified time variation value. The receiver reports an error when the received bit cell jitter exceeds the receiver's ability to reliably decode signaling.

### 11.5.5 Interference susceptibility and error rates

When a fieldbus is operating in a variety of standard noise environments the probability that an Application Layer User Data Unit contains an undetected error, due to operation of the conveying Physical and DLL entities, should be less than 1 in $10^{12}$ (1 error in 20 years at 1 600 messages/s).

A communication element is regarded as conforming to this theoretical requirement when it meets the following interference susceptibility requirements. These are specified by a detected frame error rate which is derived by using a ratio of detected to undetected errors of $10^6$.

NOTE 1 This is achievable with a 16 bit Frame Check Sequence at the DLL.

A communication element which includes an MAU, operating with frames containing 64 random user data bits, with maximum frame rate and with signals of 1,4 V pk-pk amplitude, shall produce no more than three detected frame errors in 3 × $10^6$ frames during operation in the presence of common-mode voltage or Gaussian noise as follows:

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a) a common-mode sinusoidal signal of any frequency from 63 Hz to 2 $f_r$, with an amplitude of 4 V RMS and from 47 Hz to 63 Hz with an amplitude of 250 V RMS;

b) a common-mode DC signal of ±10 V;

c) white Gaussian additive differential noise in the frequency band 1 kHz to 4 $f_r$, with a noise density of 30 μV/√Hz RMS

NOTE 2 The common-mode voltage and Gaussian noise specifications are for receive circuit conformance testing with balanced loads and are not indicative of system installation practice.

A communication element which includes an MAU, operating with frames containing 64 random user data bits, at an average of 1 600 messages/s, with signals of 1,4 V peak-to-peak amplitude, shall produce no more than six detected frame errors in 100 000 frames during operation in the presence of electromagnetic or electrical interference environments as follows:

1) 10 V/m electromagnetic field as specified in IEC 61000-4-3 at severity level 3;
2) electrical fast transient as specified in IEC 61000-4-4 at severity level 3.

The above error rate specification shall also be satisfied after but not during operation in the following noise environments:

i) 8 kV electrostatic discharge to exposed metalwork as specified in IEC 61000-4-2 at severity level 3. If the device suffers temporary loss of function or performance as a result of this test it shall recover from any such loss without operator intervention within 3 s after the end of the test;

ii) high-frequency disturbance tests as specified in IEC 60255-22-1:1988, Test voltage class III (2,5 kV and 1 kV peak values of first half-cycle in longitudinal and transverse mode respectively). If the device suffers temporary loss of function or performance because of this test, it shall recover from any such loss without operator intervention within 3 s after the end of the test.

### 11.6 Jabber inhibit

The MAU shall contain a self-interrupt capability to inhibit transmitted signals from reaching the medium. Hardware within the MAU (with no external message other than the detection of output signals or leakage via the transmit function) shall provide a window of between 5 000 $T_{bit}$ and 15 000 $T_{bit}$ during which time a normal frame can be transmitted. If the frame length exceeds this duration, the jabber inhibit function shall inhibit further output signals from reaching the medium and shall disable echo on the RxS line (see 10.2.2.2) to indicate jabber detection to the MDS.

For a data rate of 31,25 kbit/s, the MAU shall reset the self-interrupt function after a period of 3 s with a tolerance of ± 50 %.

NOTE 1 This inhibits bus traffic for no more than 8 % (≈ 1/12,5) of the available time.

For a data rate of 1 Mbit/s or greater, the MAU shall reset the self-interrupt function after a period of 500 000 $T_{bit}$ with a tolerance of ± 50 %.

NOTE 2 This inhibits bus traffic for no more than 3 % (≈ 1/32) of the available time.

### 11.7 Power distribution

#### 11.7.1 Overview

Voltage mode MAUs operating at a data rate of ≤ 2,5 Mbit/s can optionally receive power via the signal conductors or be separately powered. Voltage mode MAUs operating at a data rate of > 2,5 Mbit/s are separately powered. A separately powered device can be connected to a powered fieldbus.

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For ease of reference, the requirements of 11.7 for network-powered devices and network power supplies are summarized in Table 94 and Table 95, respectively.

**Table 94 – Network powered device characteristics**

| Network powered device characteristics | Limits | | |
|---|---|---|---|
| | 31,25 kbit/s | 1 Mbit/s | > 1 Mbit/s |
| Maximum rate of change of quiescent current (non-transmitting) | 1 mA/µs | 0,05 mA/µs | 0,1 mA/µs |
| Operating voltage | 9,0 V to 32,0 V d.c. | | |
| Minimum withstand voltage, either polarity, for no damage | 35 V | | |

**Table 95 – Network power supply requirements**

| Network power supply requirements | Limits |
|---|---|
| Output voltage | ≤ 32 VDC |
| Output ripple and noise | See Figure 84 |
| Output impedance, measured over the frequency range $f_{min}$ to $f_{max}$ | ≥ $Din_{min}$ |

### 11.7.2 Supply voltage

A fieldbus device claiming conformance to Clause 11 shall be capable of operating within a voltage range of 9 V to 32 VDC between the two conductors including ripple. The device shall withstand a minimum voltage of ±35 VDC without damage.

A fieldbus device claiming conformance to Clause 11 shall conform to the requirements of Clause 11 when powered by a supply with the following specifications:

a) The output voltage of the power supply shall be 32 VDC maximum including ripple.

   The voltage of the power supply added to the open circuit transmitter output voltage should be less than the limit specified by the local regulatory agency for the particular implementation.

b) The output impedance of the power supply shall be ≥ 8 kΩ over the frequency range $f_{min}$ to $f_{max}$.

c) The breakdown requirements of the isolation of the signal circuit and the power distribution circuit from ground and from each other shall be in accordance with IEC 61131-2.

   The equivalent test voltage is to be applied between independent isolated circuits or between isolated circuits and accessible conducting parts. For circuits with a nominal voltage ≤ 50 VDC or RMS, the equivalent test voltages at sea level are 444 V RMS, 635 VDC and 635 V peak impulse test. For circuits with a nominal voltage between 150 V and 300 V RMS, the equivalent test voltages at sea level are 2 260 V RMS, 3 175 VDC and 3 175 V peak impulse test.

d) When a power supply powers two or more segments, the isolation impedance to each segment shall be split ±10 % between the two signal conductors of the segment.

### 11.7.3 Powered via signal conductors

A fieldbus device claiming conformance to Clause 11 that is powered via the signal conductors shall conform to the requirements of Clause 11 when operating with maximum levels of power supply ripple and noise as follows:

a) 30 mV peak-to-peak over the frequency range $f_{min}$ to $f_{max}$;

b) 2 V peak-to-peak over the frequency range 47 Hz to 63 Hz;

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c) 300 mV peak-to-peak at frequencies greater than 12,5 $f_r$, up to a maximum of 50 MHz;

d) levels at intermediate frequencies generally in accordance with Figure 84, which gives the level and the frequencies for power via signal conductors.

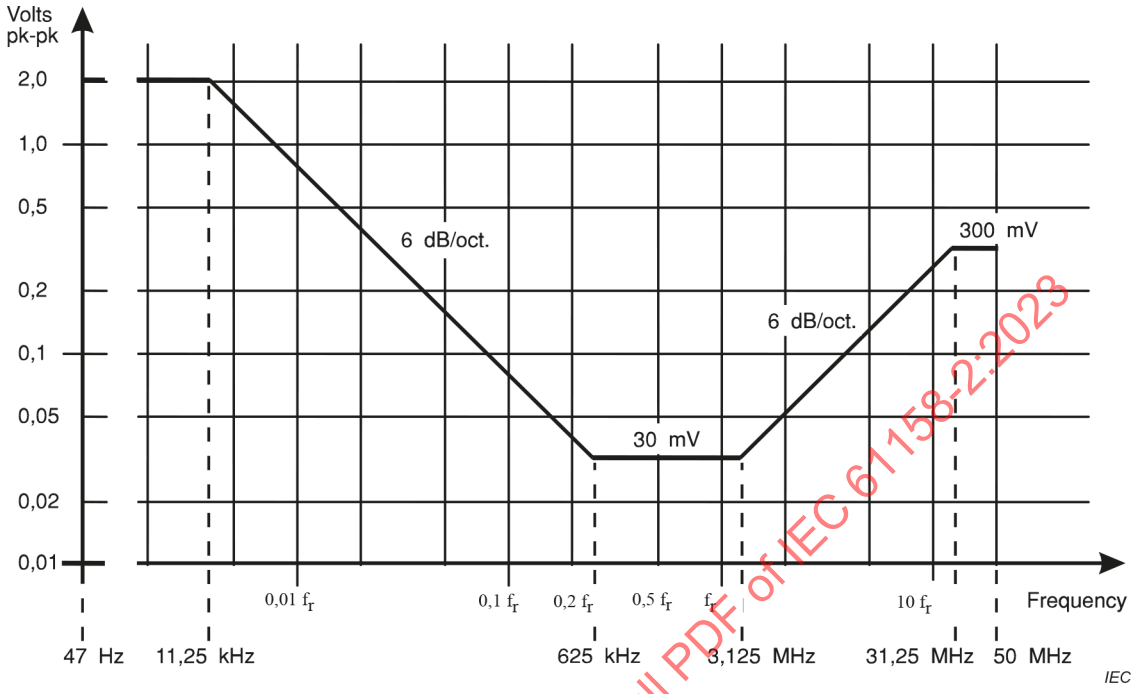


**Figure 84 – Power supply ripple and noise**

The device shall have a maximum rate of change of quiescent current in the non-transmitting condition of 0,1 mA/µs.

NOTE This requirement limits the effect of power transients on the signals.

### 11.7.4 Powered separately from signal conductors

NOTE Power distribution to non-bus-powered fieldbus devices is by separate conductors feeding local power supplies or regulators. It is possible that these conductors are in a separate cable or in the same cable as the signal conductors.

A separately powered fieldbus device claiming conformance to Clause 11 shall draw no more than 100 µA direct current from the signal conductors, nor shall it supply more than 100 µA direct current to the signal conductors when not transmitting.

### 11.7.5 Electrical isolation

All fieldbus devices, whether separately powered or powered via the signal conductors, shall provide low-frequency isolation between ground and the fieldbus trunk cable.

NOTE 1 This is possible by isolation of the entire device from ground or by use of a transformer, opto-coupler or some other isolating component between trunk cable and device.

A combined power supply and communication element shall not require electrical isolation.

For electrical installations providing different grounds, the isolation impedance measured between the shield of the fieldbus cable and the fieldbus device ground shall be greater than 250 kΩ at all frequencies below 63 Hz.

The isolation shall be bypassed at high frequencies by capacitance, such that the impedance measured between the shield of the fieldbus cable and the fieldbus device ground shall be less than 15 Ω between 3 MHz and 100 MHz.

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NOTE 2 The capacitance between ground and trunk cable shield necessary to meet both these requirements can be any value between 3,5 nF and 10,6 nF.

For electrical installations providing a common ground in conformance with IEC 60364-4-41 and IEC 60364-5-54, the shield of the fieldbus cable and the fieldbus device ground may be directly connected.

The maximum unbalanced capacitance to ground from either input terminal of a device shall not exceed 250 pF.

The breakdown requirements of the isolation of the signal circuit and the power distribution circuit from ground and from each other shall be in accordance with IEC 61131-2.

NOTE 3 The equivalent test voltage is applied between independent isolated circuits or between isolated circuits and accessible conducting parts. For circuits which is powered from a supply with rated voltage ≤ 50 VDC or RMS, the equivalent test voltages at sea-level are 444 V RMS, 635 VDC and 635 V peak impulse test. For a device which is powered from a supply with rated voltage between 150 V and 300 V RMS, the equivalent test voltages at sea-level are 2 260 V RMS, 3 175 VDC and 3 175 V peak impulse test.

### 11.8 Medium specifications

#### 11.8.1 Connector

Cable connectors, if used, shall be in accordance with this document (see Annex A). Field termination techniques such as screw or blade terminals and permanent terminations (splices) may also be used.

#### 11.8.2 Standard test cable

The cable used for testing fieldbus devices with a 150 Ω voltage-mode MAU for conformance to the requirements of Clause 11, shall be a single twisted-pair cable with overall shield meeting the following minimum requirements at 25 °C:

a) $Z_o$ = 150 Ω with a tolerance of ± 10 % over the range 0,25 $f_r$ to 1,25 $f_r$;

b) maximum attenuation at 0,25 $f_r$ to 1,25 $f_r$, as specified in Table 96;

c) maximum capacitive unbalance to shield = 1,5 nF/km

d) maximum DC resistance (per conductor) = 57,1 Ω/km;

e) conductor cross-sectional area (wire size) = nominal 0,33 $mm^2$;

f) minimum resistivity between either conductor and shield = 16 GΩ km;

g) minimum shield coverage shall be 95 %.

**Table 96 – Test cable attenuation limits**

| Bit rate | Maximum attenuation at | |
|---|---|---|
| | 0,25 $f_r$ | 1,25 $f_r$ |
| 31,25 kbit/s | 1,5 dB | 3 dB |
| 1 Mbit/s | 6,5 dB | 13 dB |
| 2,5 Mbit/s | 10 B | 20 dB |
| 5 Mbit/s | 13 dB | 26 dB |
| 10 Mbit/s | 17 dB | 37 dB |
| 25 Mbit/s | 26 dB | 60 dB |

The preceding specification is for conformance testing an MAU. Other types of cable may be used in real installations (see Annex B.) Cables with improved specifications may enable increased trunk length or superior interference immunity or may be required to meet

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environmental or installation conditions. Conversely, cables with inferior specifications may be used subject to length limitations for both trunk and spurs, plus possible non-conformance to the RFI/EMI susceptibility requirements.

### 11.8.3 Coupler

The coupler, as shown in Figure 85, shall provide one or several point(s) of connection to the trunk. It is generally integrated with a fieldbus device.

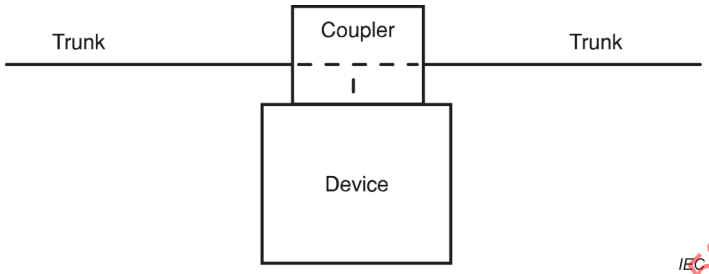


**Figure 85 – Fieldbus coupler**

A passive coupler may contain any or all the optional elements as described below:

a) a transformer, to provide galvanic isolation and impedance transformation between trunk and device;

b) connectors, to provide easy connection to trunk.

Active couplers, which require external power supplies, contain components for signal amplification and re-transmission. The transmit level and timing requirements shall conform to 11.4.

### 11.8.4 Splices

NOTE A splice is any part of the network in which the characteristic impedance of the network cable is not preserved. This is possibly due to separation of the cable conductors, removal of the cable shield, change of wire gauge or type, attachment to terminal strips, etc. A practical definition of a splice is therefore any part of the network that is not a continuous length of the specified medium.

The continuity of all conductors of the cable shall be maintained in a splice.

### 11.8.5 Terminator

A terminator shall be located at both ends of the trunk cable, connected from one signal conductor to the other. No connection shall be made between terminator and cable shield.

For test purposes, using the cable specified in 11.8.2, the terminator shall have an impedance value of 150 Ω with a tolerance of ± 2 % over the overall frequency range 625 kHz to 31,25 MHz.

NOTE In practical implementations this value would be selected to be approximately equal to the average cable characteristic impedance value at the relevant frequencies to minimize transmission line reflections.

The direct current leakage through the terminator shall not exceed 100 µA. The terminator shall be non-polarized.

### 11.8.6 Shielding rules

For full conformance to the noise immunity requirements of 11.5.3 it is necessary to ensure the integrity of shielding throughout the cabling, connectors and couplers by the following means:

a) the coverage of the cable shield shall be greater than 95 % of the full cable length;

b) shielding shall completely cover the electrical circuits in connectors, couplers, and splices.

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NOTE Deviation from these shielding rules can degrade noise immunity.

### 11.8.7 Grounding (earthing) rules

NOTE Grounding (earthing) means permanently connected to earth through sufficiently low impedance and with sufficient current-carrying capability to prevent voltage build-up which might result in undue hazard to connected equipment or persons.

Zero volts (common) lines may be connected to ground where they are galvanically isolated from the fieldbus trunk.

Fieldbus devices shall be required to function to the requirements of Clause 11 with the mid-point of one terminator or one inductive coupler connected directly to ground.

Fieldbus devices shall not connect either conductor of the twisted pair to ground at any point in the network. Signals shall be applied and preserved differentially throughout the network.

It is standard practice for the shield of the fieldbus trunk cable (if applicable) to be effectively grounded at one point along the length of the cable. For this reason fieldbus devices should allow DC isolation of the cable shield from ground.

It is also standard practice to connect the signal conductors to ground in a balanced manner at the same point, e.g. by using the center tap of a terminator or coupling transformer.

For bus-powered systems the grounding of the shield and balanced signal conductors should be close to the power supply unit. Capacitive coupling between the shield or the balanced signal conductors and device local ground for EMI control is permitted.

### 11.8.8 Color coding of cables

Regional practice should be considered in the choice of cable colors.

Within North America, colors of inner cable conductors and outer cable sheath (jacket) should be assigned as specified in Table 97.

**Table 97 – Recommended color coding of cables in North America**

| Color for inner conductors | |
|---|---|
| '+' (positive voltage) inner conductor | Orange, or red/orange/brown end of the spectrum |
| '-' (negative voltage) inner conductor | Blue, or blue/violet end of the spectrum |
| Shield conductor (which may be earthed) | Bare, clear, or green |
| **Color for outer sheath (jacket)** | |
| General purpose construction rules | Orange |
| Non-incendive construction rules | Orange/blue stripe |
| IS construction rules | Blue or blue/orange stripe or blue/black stripe |

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## 12 Types 1 and 3: Medium attachment unit: 31,25 kbit/s, voltage-mode with low-power option, bus- and tree-topology, 100 Ω wire medium

### 12.1 General

NOTE Type 3 uses this MAU only for synchronous transmission.

The 31,25 kbit/s and 100 Ω voltage-mode MAU simultaneously provides access to a communication network and to an optional power distribution network. Devices attached to the network communicate via the medium and can be powered from it, or not. If bus powered, power

is distributed as direct voltage and current, and communication signals are superimposed on the DC power. In intrinsically safe applications, available power can limit the number of devices.

The network medium consists of a one pair cable, usually, but not always, a twisted pair. Independent of topology, all attached devices, other than possibly the transmitting device, present a high impedance to prevent significant network loading. Trapezoidal waveforms are used to reduce electromagnetic emissions.

Bus and tree topologies are supported. In either topology, a network contains one trunk cable, terminated at its ends. In the bus topology, spurs are distributed along the length of the trunk. In the tree topology, spurs are concentrated at one end of the trunk. A spur can connect more than one device to the network, with the maximum number of devices on a spur depending on spur length.

At the power frequency (DC), devices appear to the network as current sinks, with a limited rate of change of the supply current drawn from the medium. This prevents transient changes in load current from interfering with communication signals.

Clause 12 specifies a low-power option that allows devices to reduce their current draw from the network when not transmitting.

To minimize oscillations and ringing on the network, the power supply impedance is specified as a function of the bus terminator impedance such that the total network reactance is minimized over the frequency range 50 Hz to 39 kHz.

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### 12.2 Transmitted bit rate

The average bit rate, BR, shall be 31,25 kbit/s with a tolerance of ± 0,2 %, averaged over a frame having a minimum length of 16 octets. The instantaneous bit time, $T_{bit}$, shall be 32 µs ± 0,9 µs.

### 12.3 Network specifications

#### 12.3.1 Components

An MAU operates in a network composed of the following components:

a) wire cable;
b) devices (containing at least one communication element);
c) couplers;
d) terminators.

The network may optionally include the following components:

a) connectors;
b) power supplies;
c) devices which include power supplies;
d) intrinsic safety barriers.

#### 12.3.2 Topologies

A wire MAU shall operate in a network with an acyclic nominally linear or tree-like bus topology, consisting of a trunk, terminated at each end as specified in 12.8.5, to which communication elements are connected via couplers and spurs. A tree topology with all the communication elements located at the ends of the trunk is regarded as a special case of a bus for the purpose of Clause 12. Each communication element shall be connected in parallel with the trunk cable.

The coupler and communication element may be integrated in one device (i.e. a zero length spur). Several communication elements can be connected to the trunk at one point using a multi-port coupler. An active coupler may be used to extend a spur to a length that requires termination to avoid reflections and distortions. Active repeaters may be used to extend the length of the trunk beyond that of a single segment as permitted by the network configuration rules. Branches shall be considered as segments, and can make the bus non-linear. Cycles (closed loops) are never permitted.

### 12.3.3 Network configuration rules

An MAU that claims conformance to Clause 12 shall meet the requirements of Clause 12 when used in a network that complies with these rules.

**Rule 1:** A fieldbus shall be capable of communication between the following numbers of devices, all operating at the same bit rate:

a) for a non IS fieldbus without power supplied via the signal conductors: between two and 32 devices;

b) for a non IS fieldbus with power supplied via the signal conductors: between two and the number of devices which can be powered via the signal conductors, assuming that a minimum of 120 mA (aggregate) shall be available to devices at the remote end from the power supply, communicating with one device at the power supply end drawing 10 mA;

c) for an IS fieldbus: between two and the number of devices which can be powered via the signal conductors, assuming that a minimum of 40 mA (aggregate) shall be available to devices in the hazardous area.

NOTE 1 This rule does not preclude the use of more than the specified number of devices in an installed system. Since the device power consumption is not specified, the number of bus-powered devices cannot be specified.

Item b) assumes that the minimum power supply voltage is 20 VDC.

Item c) assumes that the IS barrier operates with a 19 VDC output.

**Rule 2:** A fully loaded (maximum number of connected devices) fieldbus segment shall have a total cable length, including spurs, between any two devices, of up to 1 900 m.

NOTE 2 Support of this maximum cable length is a requirement for conformance to Clause 12, but this does not preclude the use of longer lengths in an installed system.

**Rule 3:** The total number of waveform regenerations by repeaters and active couplers between any two devices is repeater implementation dependent.

NOTE 3 Prior editions of this document limited this total number to four.

**Rule 4:** The maximum propagation delay between any two devices shall not exceed 20 $T_{bit}$.

For efficiency of the network, that part of the turn-around time of any device on the network caused by a PhE between the end of a received frame and the beginning of the transmitted frame containing an associated immediate response should not exceed 30 bit times, no more than 2 bit times of which should be due to the MAU.

NOTE 4 As it is not mandatory to expose either the DLL-PhL interface or the MDS-MAU interface, that part of the turn-around time of a fieldbus device caused by the PhL or the MAU is not specified and thus not available for conformance testing.

**Rule 5:** The fieldbus shall be capable of continued operation while a device is being connected or disconnected. Data errors induced during connection or disconnection shall be detected.

**Rule 6:** Failure of any communication element or spur (with the exception of a short circuit, low impedance, or jabber) shall not interfere with transactions between other communication elements for more than 1 ms.

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**Rule 7:** In polarity sensitive systems, the medium wire pairs shall have distinctly marked conductors that uniquely identify individual conductors. Consistent polarization shall be maintained at all connection points.

**Rule 8:** The degradation of the electrical characteristics of the signal, between any two devices, due to attenuation, attenuation distortion and mismatching distortion shall be limited to the values indicated below.

a) Signal attenuation: The configuration of the bus (trunk and spur lengths, number of devices, IS barriers, galvanic isolators, and possible matching devices) shall be such that the attenuation between any two devices at $f_r$ (31,25 kHz) shall not exceed 10,5 dB.

b) Attenuation distortion: The configuration of the bus (trunk and spur lengths and number of devices, IS barriers, and galvanic isolators) shall be such that between any two devices:

   $0 \leq$ [Attenuation (1,25 $f_r$) - Attenuation (0,25 $f_r$)] $\leq$ 6 dB

   Attenuation shall be monotonic non-decreasing for all frequencies from 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz).

c) Mismatching distortion: Mismatching (due to any effect, including one open circuit spur of maximum length) on the bus shall be such that, at any point along the trunk, in the frequency band 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz):

   $|Z - Z_{f_r}| / |Z + Z_{f_r}| \leq 0,2$

   where $Z_{f_r}$ is the impedance of the trunk cable at frequency $f_r$ (31,25 kHz) and Z is the parallel combination of $Z_{f_r}$ and the load impedance at the coupler.

The concentration of couplers shall be less than 15 per 250 m.

NOTE 5 This rule minimizes restrictions on trunk and spur length, number of devices etc. by specifying only the transmission limitations imposed by combinations of these factors. It is possible to use different combinations depending on the needs of the application.

**Rule 9:** The following rules shall apply to systems implemented with redundant media:

a) each channel (cable) shall comply with the network configuration rules;

b) there shall not be a non-redundant segment between two redundant segments;

c) repeaters shall also be redundant;

d) if the devices of the system are configured (by Systems management) to transmit on more than one channel simultaneously then the propagation time difference between any two devices on any two channels shall not exceed five bit times;

   This period may be extended, but not reduced, by Systems management as given in Table 13 (see 6.2.2.2 and 9.2.9).

e) channel numbers and association with the physical transmission media shall be maintained consistently throughout the fieldbus, i.e. channels 1, 2, 3… from Systems management shall always connect to physical channels 1, 2, 3…;

**Rule 10:** For a bus-powered fieldbus segment, the voltage available to all devices, including ripple and the DC component of the voltage drop caused by signaling, shall be within the range of 9,0 V to 32,0 VDC.

NOTE 6 The DC component of the voltage drop caused by signaling is dependent upon the configuration of the network. The DC component is caused by the step change in device current through the network resistance (cable resistance, IS barrier resistance, etc.).

### 12.3.4 Power distribution rules for network configuration

See 11.3.4.

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## 12.4 MAU transmit circuit specification

### 12.4.1 Summary

For ease of reference, the requirements of 12.2 and 12.4 are summarized in Table 98 and Table 99.

**Table 98 – MAU transmit level specification summary**

| Transmit level characteristics, values referred to trunk (but measured using test load as shown in Figure 79 | Limits |
|---|---|
| Output level (peak-to-peak, see Figure 80)<br>With test load (0,5 nominal impedance of the trunk cable at $f_r$ (31,25 kHz)) | 0,75 V to 1 V<br>50 Ω ± 0,5 Ω |
| Maximum positive and negative amplitude difference (signaling bias) as shown in Figure 81 | ±50 mV |
| Output level; with one terminator removed (peak-to-peak)<br>with test load (nominal impedance of the trunk cable at $f_r$ (31,25 kHz)) | 0,75 V to 2,0 V<br>100 Ω ± 1 Ω |
| Maximum output level; open circuit (peak-to-peak) | 35 V |
| Maximum output signal distortion; i.e. overvoltage, ringing and droop (see Figure 80) | ±10 % |
| Quiescent transmitter output; i.e. transmitter noise (measured over the frequency band 1 kHz to 100 kHz) | ≤ 1 mV (RMS) |

**Table 99 – MAU transmit timing specification summary**

| Transmit timing characteristics, values referred to trunk (but measured using test load as shown in Figure 79) | Limits for 31,25 kbit/s (bus powered and/or IS) |
|---|---|
| Transmitted bit rate | 31,25 kbit/s ± 0,2 % |
| Instantaneous bit time | 32 µs ± 0,9 µs |
| Rise and fall times (10 % to 90 % of peak-to-peak signal, see Figure 80) | ≤ 25 % $T_{bit}$ |
| Slew rate (at any point from 10 % to 90 % of peak-to-peak signal) | ≤ 0,2 V/µs |
| Maximum transmitted bit cell jitter (zero-crossing point deviation, see Figure 81) | ± 2,5 % $T_{bit}$ |
| Transmit enable/disable time (i.e. time during which it is permissible that the output waveform do not meet the transmit requirements) | ≤ 2,0 $T_{bit}$ |

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### 12.4.2 MAU test configuration

Figure 79 shows the configuration that shall be used for testing MAUs.

Differential signal voltage: $V_d = V_a - V_b$.

Except where otherwise stated in a specific requirement, test load resistance R = 50 Ω (0,5 nominal impedance of the trunk cable at $f_r$ (31,25 kHz)) and C = 2 µF (2 × the capacitance of one terminator).

Data "+" terminal connected to the power "+" terminal and data "-" terminal connected to the power "-" terminal.

NOTE See 12.7 for the power supply specification and 12.8.5 for the terminator specification.

### 12.4.3 MAU output level requirements

Figure 80 describes the output form of the signal for the twisted-pair voltage output level requirements.

NOTE 1 Figure 80 shows an example of the AC component of one cycle of a fieldbus waveform, illustrating some key items from the transmit circuit specification. Only signal voltages are shown; this diagram takes no account of power supply voltages.

The MAU transmit circuit shall conform to the following output level requirements, all amplitudes being measured at the estimated mid-point between any peaks or troughs in the top and bottom of the waveform ("mid-point" in Figure 80):

a) the output voltage across the test load after transformer step up/down (if applicable) shall be between 0,75 V and 1,0 V peak-to-peak, with a load resistance of 50 Ω with a tolerance of ± 1 % ("min o/p" in Figure 80);

b) the output voltage at the trunk, or at the transmit terminals, with a load resistance of 100 Ω with a tolerance of with a tolerance of ± 1 % (i.e. with one trunk terminator removed) shall be between 0,75 V and 2,0 V peak-to-peak ("max. o/p one terminator removed" in Figure 80);

c) the output voltage at the trunk, or at the transmit terminals, with any load including an open circuit shall not exceed 35 V in either polarity. For test purposes, open circuit shall be defined as a load of 100 kΩ resistance in parallel with 15 pF capacitance;

d) during transmission a device shall not suffer permanent failure when a load resistance of ≤ 1 Ω is applied for 1 s;

e) the difference between positive amplitude and negative amplitude, measured as shown in Figure 80, shall not exceed ±50 mV peak;

f) the output noise from an MAU which is receiving or not powered shall not exceed 1 mV RMS, measured differentially over a frequency band of 1 kHz to 100 kHz, referred to the trunk;

g) the differential voltage across the test load shall be such that the voltage monotonically changes between 10 % and 90 % of peak-to-peak value. Thereafter, the signal voltage shall not vary more than ±10 % of peak-to-peak value until the next transition occurs. This permitted variation shall include all forms of output signal distortion, i.e. overvoltage, ringing and droop.

NOTE 2 During transmission, the output voltage developed at the device terminals can increase substantially over that specified in 12.4.3 g), but within the limit specified by 12.4.3 c), due to the effects of the combined series impedance of the device, the spur cable, and any bus protective device such as that described in 12.8.3 c).

### 12.4.4 Output timing requirements

An MAU transmit circuit shall conform to the following output timing requirements:

a) transmitted bit cell jitter shall not exceed ±0,025 $T_{bit}$ from the ideal zero crossing point, measured with respect to the previous zero crossing (see Figure 81);

b) the transmit circuit shall turn on, i.e. the signal shall rise from below the transmit circuit maximum output noise level as specified in 12.4.3 f) to full output level, in less than 2,0 $T_{bit}$. The waveform corresponding to the third and later bit times shall be as specified in Figure 80;

c) the transmit circuit shall turn off, i.e. the signal shall fall from full output level to below the transmit circuit maximum output noise level as specified in 12.4.3 f), in less than 2,0 $T_{bit}$. The time for the transmit circuit to return to its off state impedance shall not exceed 4 $T_{bit}$. For the purposes of testing, this requirement shall be met with the transmit circuit test configuration of 12.4.2 with the equivalent capacitance of a maximum length cable across the DUT terminals.

NOTE 1 This requirement is to ensure that the transition of the transmit circuit from active to passive leaves the line capacitance fully discharged.

d) rise and fall times, measured from 10 % to 90 % of the peak-to-peak signal amplitude shall not exceed 0,25 $T_{bit}$ (see Figure 80);

e) slew rate shall not exceed 0,2 V/µs measured at any point in the range 10 % to 90 % of the peak-to-peak signal amplitude (see Figure 80).

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NOTE 2 Requirements d) and e) produce a trapezoidal waveform at the transmit circuit output. Requirement d) limits the level of interference emissions that can be coupled to adjacent circuits, etc. Requirement d) is calculated from the formula:

$$\text{max. slew rate} = 2 \times \text{min. slew rate} = 2 \times 0{,}8\ V_o / 0{,}25\ T_{bit} = 6{,}4 \times V_o / T_{bit},$$

where $V_o$ is the maximum peak-to-peak output voltage (1,0 V) with a standard load.

### 12.4.5 Signal polarity

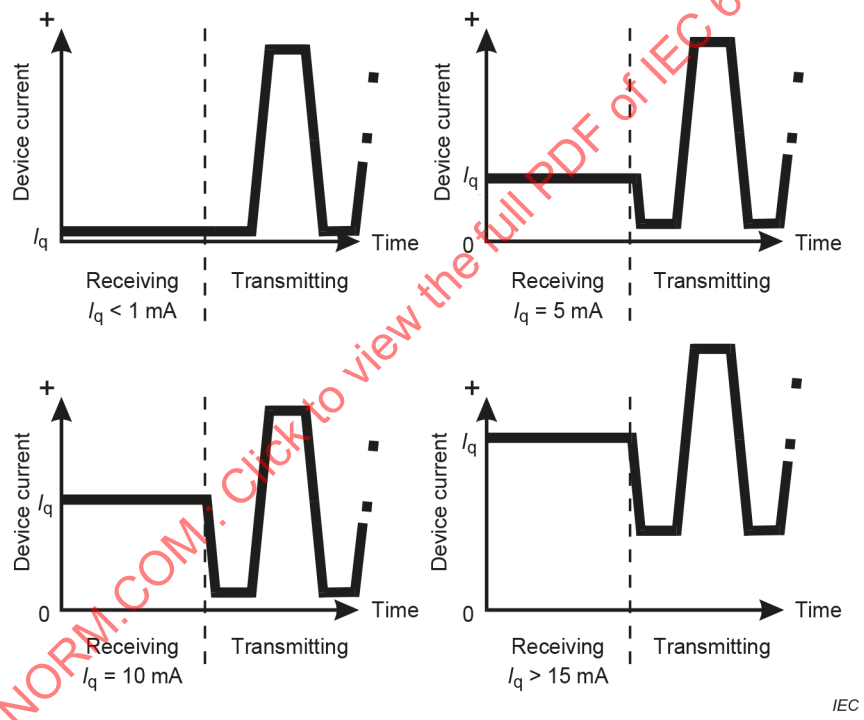
See 11.4.5.

### 12.4.6 Transition from receive to transmit

When a device starts to transmit, the output waveform shall immediately comply with the requirements of 12.4.3.

NOTE There is no requirement to ramp the device current from its receive value to the transmit value.

Figure 86 shows four examples of different values of device quiescent current.




NOTE This figure is included in this document for explanatory purposes and does not imply a specific implementation.

**Figure 86 – Transition from receiving to transmitting**

## 12.5 MAU receive circuit specification

### 12.5.1 Summary

Table 100 summarises the specification.

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**Table 100 – MAU receive circuit specification summary**

| Receive circuit characteristics (values referred to trunk) | Limits (bus powered and/or IS) |
|---|---|
| Input impedance, measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ | ≥ 3 kΩ |
| Sensitivity; min. peak-to-peak signal required to be accepted (see Figure 83) | 150 mV |
| Noise rejection; max. peak-to-peak noise required to be rejected (see Figure 83) | 75 mV |
| Maximum received bit cell jitter (zero crossing-point deviation (see Figure 80) | ±0,10 $T_{bit}$ |

### 12.5.2 Input impedance

The differential input impedance of an MAU receive circuit shall be no less than 3 kΩ over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz). This requirement shall apply after a 20 ms startup time following connection to the network or application of power to the network. Independently powered devices, and network-powered devices capable of being turned off while connected to the network, shall meet this requirement in the power-on and power-off states, and in transition between those states. This impedance shall be measured at the communication element terminals using a sine wave with a signal amplitude greater than the receiver sensitivity threshold and lower than 2,0 V peak-to-peak.

NOTE 1 The requirement for ≥ 3 kΩ input impedance during power-up and power-down can be met by automatic disabling of the transmitter during these periods.

NOTE 2 It is possible that devices with fault disconnection electronic circuits have impedances less than the specified amount under fault conditions.

### 12.5.3 Receiver sensitivity and noise rejection

An MAU receive circuit shall be capable of accepting an input signal of amplitude no less than 150 mV peak-to-peak, including overvoltage and oscillation (see "signal level" together with "positive amplitude" and "negative amplitude", all in Figure 83).

An MAU receive circuit shall not respond to an input signal with a peak-to-peak amplitude which does not exceed 75 mV (see "noise rejection" in Figure 83).

### 12.5.4 Received bit cell jitter

The receive circuit shall accept a Manchester encoded signal transmitted in accordance with 12.2 and 12.4. In addition, the receiver shall work properly with signals with the time variation between any two adjacent signal transition points (zero crossing) of ±0,10 $T_{bit}$ or less. See Figure 81.

NOTE 1 This does not preclude the use of receivers that perform better than this specification.

NOTE 2 Depending on the symbol pattern, the nominal time between zero crossings is one-half or one bit time.

NOTE 3 There is no requirement to reject a signal with a specified time variation value. The receiver reports an error when the received bit cell jitter exceeds the receiver's ability to reliably decode signaling.

### 12.5.5 Interference susceptibility and error rates

When a fieldbus is operating in a variety of standard noise environments, the probability that an Application Layer User Data Unit contains an undetected error, due to operation of the conveying Physical and DLL entities, should be less than 1 in $6 \times 10^9$ (1 error in 20 years at 10 messages/s).

A communication element is regarded as conforming to this theoretical requirement when it meets the following interference susceptibility requirements. These are specified by a detected frame error rate which is derived by using a ratio of detected to undetected errors of $10^6$.

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NOTE 1 This is readily achievable with a 16 bit Frame Check Sequence at the DLL.

A communication element which includes an MAU, operating with frames containing 32 random user data bits, with maximum frame rate and with signals of 375 mV peak-to-peak amplitude, shall produce no more than 10 detected frame errors in 60 000 frames during operation in the presence of common mode voltage or Gaussian noise as follows:

a) a common mode sinusoidal signal of any frequency from 63 Hz to 2 MHz, with an amplitude of 4 V RMS and from 47 Hz to 63 Hz with an amplitude of 250 V RMS;

b) a common mode DC signal of ±10 V;

c) white Gaussian additive differential noise in the frequency band 1 kHz to 100 kHz, with a noise density of 70 μV/√Hz RMS.

NOTE 2 The common mode voltage and Gaussian noise specifications are for receive circuit conformance testing with balanced loads and are not indicative of system installation practice.

A communication element which includes an MAU, operating with frames containing 32 random user data bits, at an average of 10 messages per second, with signals of 375 mV peak-to-peak amplitude, shall produce no more than 10 detected frame errors in 1 000 frames during operation in the presence of electromagnetic or electrical interference environments as follows:

1) 10 V/m electromagnetic field as specified in IEC 61000-4-3 at severity level 3;

2) electrical fast transient as specified in IEC 61000-4-4 at severity level 3.

The noise above error rate specification shall also be satisfied after but not during operation in the following noise environments:

i) 8 kV electrostatic discharge to exposed metalwork as specified in IEC 61000-4-2 at severity level 3. If the device suffers temporary loss of function or performance as a result of this test it shall recover from any such loss without operator intervention within 3 s after the end of the test.

ii) high frequency disturbance tests as specified in IEC 60255-22-1:1988, Appendix E, Test voltage class III (2,5 kV and 1 kV peak values of first half-cycle in longitudinal and transverse mode respectively). If the device suffers temporary loss of function or performance because of this test, it shall recover from any such loss without operator intervention within 3 s after the end of the test.

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### 12.6 Jabber inhibit

The MAU shall contain a self-interrupt capability to inhibit transmitted signals from reaching the medium. Hardware within the MAU (with no external message other than the detection of output signals or leakage via the transmit function) shall provide a window of between 120 ms and 240 ms during which time a normal frame can be transmitted. If the frame length exceeds this duration, the jabber inhibit function shall inhibit further output signals from reaching the medium and shall disable echo on the RxS line (see 10.2.2.2) to indicate jabber detection to the MDS.

The MAU shall reset the self-interrupt function after a period of 3,0 s with a tolerance of ± 50 %.

NOTE This inhibits bus traffic for no more than 16 % (≈ 240 ms / 1,5 s) of the available time.

### 12.7 Power distribution

#### 12.7.1 General

A device can receive power via the signal conductors or can be separately powered.

A device can be certified as intrinsically safe with either method of receiving power.

NOTE This document does not include requirements for IS certification but seeks to exclude conditions or situations that would prevent IS certification.

A separately powered device can be connected to a powered fieldbus.

For ease of reference, the requirements of 12.7 for network-powered devices and network power supplies are summarized in Table 101 and Table 102.

**Table 101 – Network powered device characteristics**

| Network powered device characteristics | Limits for 31,25 kbit/s |
|---|---|
| Operating voltage | 9,0 V to 32,0 VDC |
| Minimum withstand voltage, either polarity, for no damage | 35 V |
| Maximum rate of change of quiescent current (non-transmitting); this requirement does not apply within the first 20 ms after the connection of the device to an operating network or within the first 20 ms after the application of power to the network. | 1,0 mA/ms [a, b] |
| Maximum current; this requirement applies during the time interval of 500 µs to 20 ms after the connection of the device to an operating network or 500 µs to 20 ms after the application of power to the network (see Note 1 and Note 2) | Rated quiescent current plus 20 mA |

NOTE 1 These exclusions have the potential to cause a "brown out" at devices powered from the same power supply during the exclusion interval.

NOTE 2 These exclusions can substantially increase the current requirements of the power supply during the exclusion interval which occurs immediately after power is applied to the PhL segment.

[a] The first 500 µs is excluded to allow for the charging of RFI filters and other capacitance in the device. The rate of change specification applies after 20 ms.

[b] The maximum current during that first 500 µs should be no more than twice the maximum current specified above, to minimize effects of the current inrush on the rest of the connected fieldbus network.

**Table 102 – Network power supply requirements**

| Network power supply requirements [a] | Limits for 31,25 kbit/s |
|---|---|
| Output voltage, non-IS | ≤ 32 VDC |
| Output voltage, IS | Depends on barrier rating |
| Output ripple and noise | See Figure 87 |
| Output impedance | See 12.7.4 |

[a] Power supply designs should take into account the current surge at device connection or power-up permitted by Table 101.

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### 12.7.2 Supply voltage

A fieldbus device claiming conformance to Clause 12 shall be capable of operating within a voltage range of 9 V to 32 VDC between the two conductors including ripple. The device shall withstand a minimum voltage of ±35 VDC without damage.

### 12.7.3 Powered via signal conductors

A fieldbus device claiming conformance to Clause 12 shall conform to the requirements of Clause 12 when powered by a supply with the following specifications:

a) The output voltage of the power supply for non IS networks shall be 32 VDC maximum including ripple.

NOTE 1 For IS systems the operating voltage can be limited by the certification requirements. In this case, the power supply will be located in the safe area and its output voltage will be attenuated by a safety barrier or equivalent component.

b) The breakdown requirements of the isolation of the signal circuit and the power distribution circuit from ground and from each other shall be in accordance with IEC 61131-2.

NOTE 2 See 11.7.5, Note 3.

c) When a power supply powers two or more segments, the isolation impedance to each segment shall be split ±10 % between the two signal conductors of the segment.

A fieldbus device claiming conformance to Clause 12 that is powered via the signal conductors shall conform to the requirements of Clause 12 when operating with maximum levels of power supply ripple and noise as follows:

d) 16 mV peak-to-peak over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz);

e) 2,0 V peak-to-peak over the frequency range 47 Hz to 63 Hz for non-IS applications;

f) 0,2 V peak-to-peak over the frequency range 47 Hz to 625 Hz for IS applications;

g) 1,6 V peak-to-peak at frequencies greater than 125 $f_r$, up to a maximum of 25 MHz;

h) levels at intermediate frequencies generally in accordance with Figure 87.

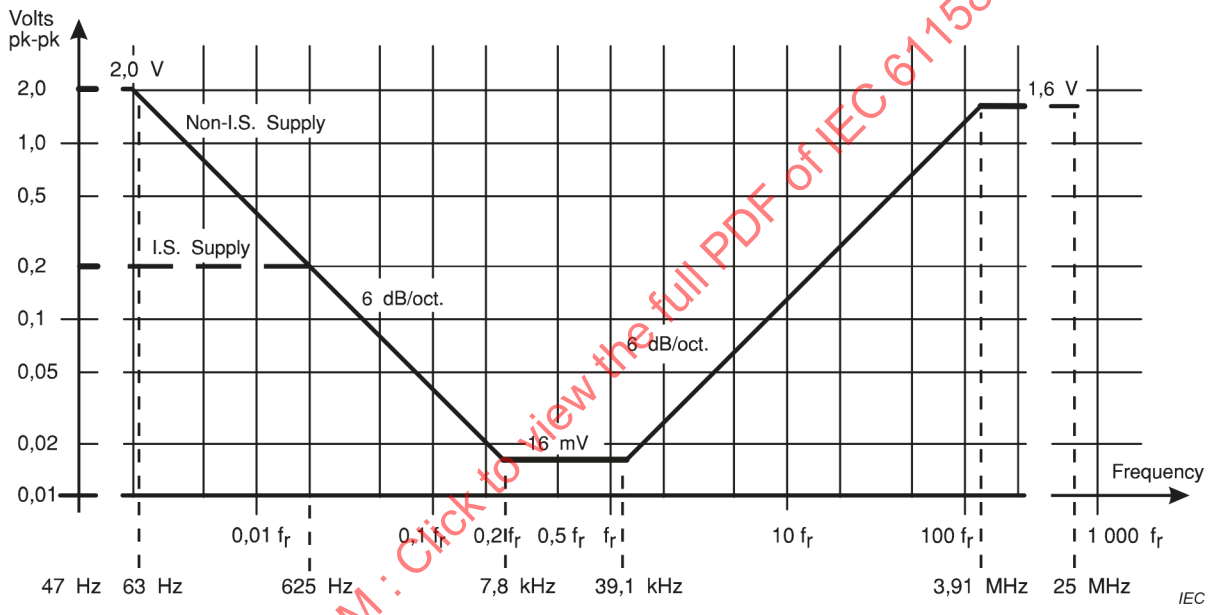


**Figure 87 – Power supply ripple and noise**

A fieldbus device claiming conformance to Clause 12 which is powered via the signal conductors shall exhibit a maximum rate of change of current drawn from the network of 1 mA/ms. This requirement does not apply:

1) when transmitting,
2) within the first 20 ms after the connection of the device to an operating network,
3) within the first 20 ms after the application of power to the network, or
4) upon disconnection from the network or removal of power to the network.

A device shall be marked with its rated quiescent current. A device shall draw no more than 20 mA above its rated current from the network during the time interval of 500 µs to 20 ms after the connection of the device to an operating network or 500 µs to 20 ms after the application of power to the network.

NOTE 3 The first 500 µs are excluded to allow for the charging of RFI filters and other capacitance in the device. The rate of change specification applies after 20 ms.

The maximum current during that initial 500 µs should be no more than twice the maximum current specified above, to minimize effects of the current inrush on the rest of the connected fieldbus network.

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NOTE 4 These exclusions have the potential to cause a "brown out" at devices powered from the same power supply during the exclusion interval.

NOTE 5 These exclusions can substantially increase the current requirements of the power supply during the exclusion interval which occurs immediately after power is applied to the PhL segment.

### 12.7.4 Power supply impedance

#### 12.7.4.1 Power supply impedance for single output power supplies

Power supply designs should take into account the current surge at device connection or power-up permitted by 12.7.3.

For power supplies having a single output, power supply impedance shall be measured using the test circuit of Figure 88.

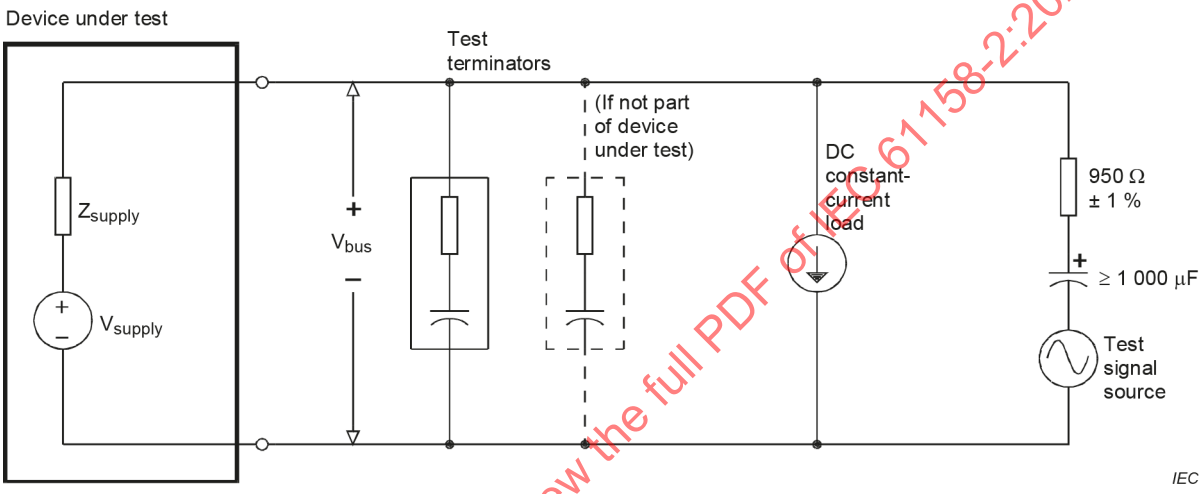


**Figure 88 – Test circuit for single-output power supplies**

The test terminators shown in Figure 88 shall each be 100 Ω with a tolerance of ± 1 % in series with 1 µF with a tolerance of ± 5 %. Two test terminators shall be used in the test circuit if the supply under test does not contain an internal terminator. If the supply under test contains an internal terminator that is always connected, only one test terminator shall be used in the test circuit. If the supply under test contains an internal terminator that can be optionally connected into the circuit, the supply shall be tested a) with the internal terminator and one test terminator and b) with two test terminators and no internal terminator.

If the power supply is intended to be used with an external impedance-determining network (for example, as might be the case with supplies designed to be used redundantly), the supply shall be tested with the external network connected.

The supply shall be tested at 20 %, 50 %, and 80 % of its rated output current (or 20 mA, whichever is greater), with the supply loaded by a DC constant-current load having 1 mA/V compliance or better (i.e. ≥ 1 kΩ impedance).

The power supply shall be tested by monitoring the AC bus voltage $V_{BUS}$ while applying a 10 $V_{pk\text{-}pk}$ sine wave from a test signal source through a 950 Ω with a tolerance of ± 1 % resistor and a coupling capacitor of at least 1 000 µF.

The measured AC bus voltage $V_{BUS}$ shall conform to the following.

a) **For non-IS power supplies intended for feeding IS barriers:** $V_{BUS}$ shall be between 0,40 $V_{pk\text{-}pk}$ and 0,60 $V_{pk\text{-}pk}$ at all frequencies from 50 Hz to 39 kHz.

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b) **For IS power supplies, and for non-IS power supplies not intended for feeding IS barriers:** $V_{BUS}$ shall be between 0,40 $V_{pk-pk}$ and 0,60 $V_{pk-pk}$ from 3 kHz to 39 kHz, and shall not increase or decrease at a rate greater than 20 dB per decade at any frequency from 50 Hz to 3 kHz.

NOTE It is acceptable for the functions of power supply and terminator to be combined as long as the combination is electrically equivalent to the independent devices meeting the requirements of Clause 12, and if the network configuration rules of 12.3 are followed.

Power supplies not intended for feeding IS barriers shall be marked "Not for use with IS barriers".

#### 12.7.4.2 Power distribution through an IS barrier

Power supply designs should take into account the current surge at device connection or power-up permitted by 12.7.3.

Intrinsic safety barrier output impedance shall be defined in terms of its frequency dependent characteristics when connected in the test circuit of Figure 89.

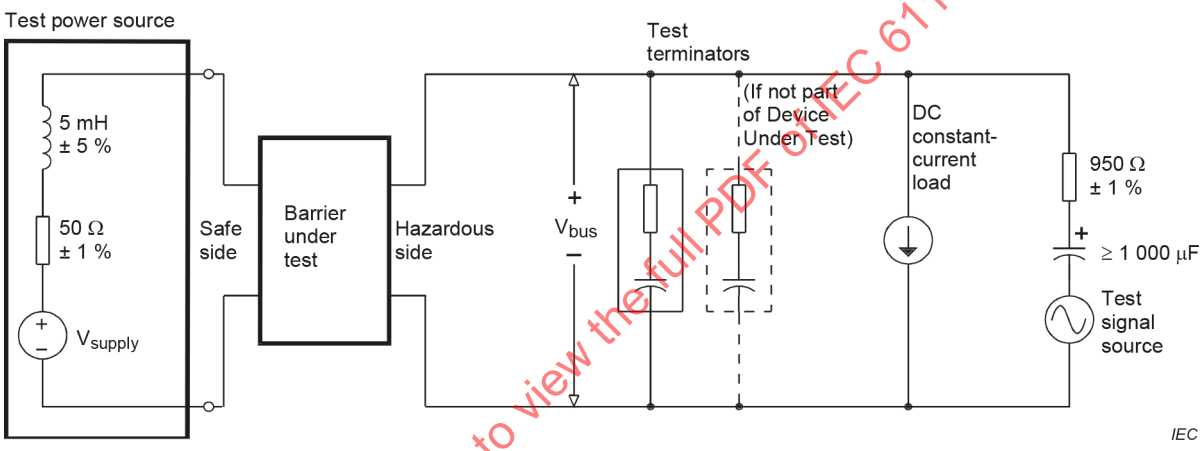


**Figure 89 – Test circuit for power distribution through an IS barrier**

The test power source shown in Figure 89 consists of a low-impedance DC voltage source in series with 5 mH with a tolerance of ± 5 % and 50 Ω with a tolerance of ± 1 %. The test terminators shall each be 100 Ω with a tolerance of ± 1 % in series with 1 µF with a tolerance of ± 5 %. If the barrier contains an internal terminator, the barrier shall be tested with one test terminator. Otherwise, the barrier shall be tested with two test terminators.

The barrier shall be tested at 20 %, 50 %, and 80 % of rated output current (or 20 mA, whichever is greater), when loaded by a DC constant-current load having 1 mA/V compliance or better (i.e. ≥ 1 kΩ impedance).

The barrier shall be tested by monitoring the bus voltage $V_{BUS}$ while applying a 10 $V_{pk-pk}$ sine wave from a test signal source through a 950 Ω with a tolerance of ± 1 % resistor and a coupling capacitor of at least 1 000 µF.

The measured AC bus voltage $V_{BUS}$ on the hazardous side of the barrier shall be between 0,40 $V_{pk-pk}$ and 0,60 $V_{pk-pk}$ from 3 kHz to 39 kHz, and shall not increase or decrease at a rate greater than 20 dB per decade at any frequency from 50 Hz to 3 kHz.

NOTE It is acceptable for the functions of power supply, IS barrier and terminator to be combined in various ways as long as the combination is electrically equivalent to the independent devices meeting the requirements of Clause 12, and if the network configuration rules of 12.3 are followed.

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### 12.7.4.3 Power supply impedance for multiple-output supplies with signal coupling between outputs

NOTE 1 Subclause 12.7.4.3 is applicable to galvanic isolators, active couplers, and other devices providing multiple power and signal ports.

Power supply designs should take into account the current surge at device connection or power-up permitted by 12.7.3.

For multiple-output power supplies with a coupling of fieldbus communication signal between outputs, power supply impedance shall be measured using the test circuit of Figure 90.

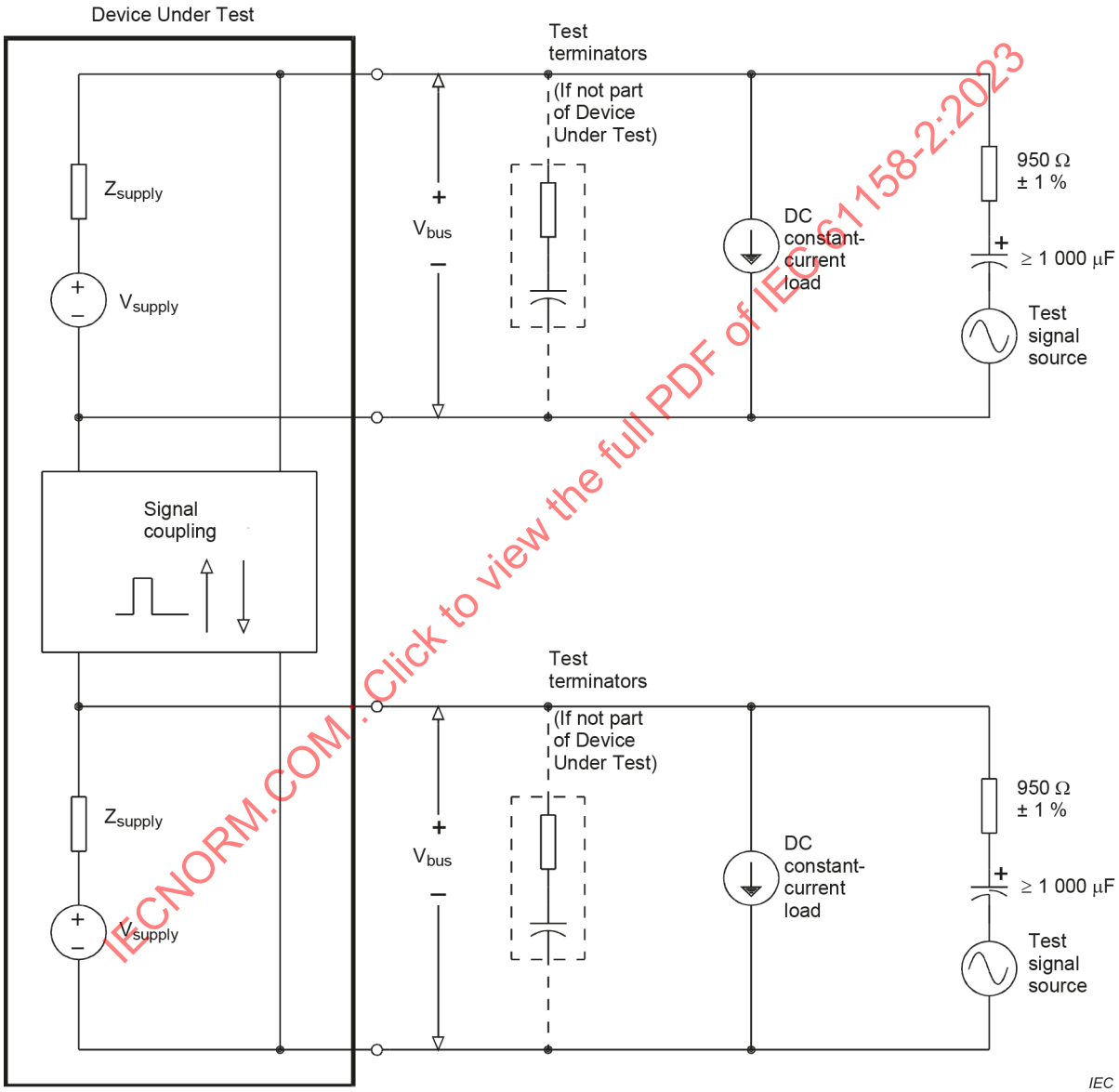


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**Figure 90 – Test circuit for multiple output supplies with signal coupling**

The test terminators shown in Figure 90 shall each be 100 Ω with a tolerance of ± 1 % in series with 1 µF with a tolerance of ± 5 %. Two test terminators shall be used in the test circuit if the device under test does not contain an internal terminator. If the device under test contains an internal terminator that is always connected, only one test terminator shall be used in the test circuit. If the device under test contains an internal terminator that can be optionally connected into the circuit, the device shall be tested a) with the internal terminator and one test terminator and b) with two test terminators and no internal terminator.

If the device under test is intended to be used with an external impedance-determining network (for example, as might be the case with supplies designed to be used redundantly), the supply shall be tested with the external network connected.

The device under test shall be tested at 20 %, 50 %, and 80 % of its rated output current (or 20 mA, whichever is greater) on each output, with the device loaded by a DC constant-current load having 1 mA/V compliance or better (i.e. ≥ 1 kΩ impedance).

The measured AC bus voltage $V_{BUS}$ shall be between 0,40 $V_{pk-pk}$ and 0,60 $V_{pk-pk}$ from 3 kHz to 39 kHz, and shall not increase or decrease at a rate greater than 20 dB per decade at any frequency from 50 Hz to 3 kHz.

NOTE 2 It is acceptable for the functions of power supply, isolator or coupler, and terminator to be combined in various ways as long as the impedance of the combination is equivalent to the parallel impedance of independent devices meeting the requirements of Clause 12 and the network configuration rules of 12.3 are followed.

### 12.7.5 Powered separately from signal conductors

NOTE Power distribution to non-bus powered fieldbus devices is by separate conductors feeding local power supplies, regulators or safety barriers. IS certification can require these conductors to be in a separate cable from the signal conductors and can also impose more stringent requirements for current levels than specified.

A separately powered fieldbus device shall draw no more than 10 mA direct current from the signal conductors nor shall it supply more than 100 µA direct current to the signal conductors when not transmitting. A device shall be marked with its rated quiescent current draw from the network.

### 12.7.6 Electrical isolation

All fieldbus devices, whether separately powered or powered via the signal conductors, shall provide low frequency isolation between ground and the fieldbus trunk cable.

NOTE 1 This is by isolation of the entire device from ground or by use of a transformer, opto-coupler or some other isolating component between trunk cable and device.

A combined power supply and communication element shall not require electrical isolation.

For shielded cables, the isolation impedance measured between the shield of the fieldbus cable and the fieldbus device ground shall be greater than 250 kΩ at all frequencies below 63 Hz.

The maximum unbalanced capacitance to ground from either input terminal of a device shall not exceed 250 pF.

The breakdown requirements of the isolation of the signal circuit and the power distribution circuit from ground and from each other shall be in accordance with IEC 61131-2.

NOTE 2 See 11.7.5, Note 3.

## 12.8 Medium specifications

### 12.8.1 Connector

Cable connectors, if used, shall be in accordance with this document (see Annex A for Type 1, and Annex I for Type 3 synchronous transmission). Field termination techniques such as screw or blade terminals and permanent termination may also be used.

### 12.8.2 Standard test cable

The cable used for testing fieldbus devices which claim conformance to Clause 12 shall be a single twisted-pair cable with overall shield meeting the following minimum requirements at 25 °C:

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a) impedance at $f_r$ (31,25 kHz) = 100 Ω with a tolerance of ± 20 %;

b) maximum attenuation at 1,25 $f_r$ (39 kHz) = 3,0 dB/km;

c) maximum capacitive unbalance to shield = 4 nF/km, tested using a 30 m or longer sample;

d) maximum DC resistance (per conductor) = 24 Ω/km;

e) maximum propagation delay change 0,25 $f_r$ to 1,25 $f_r$ = 1,7 µs/km;

f) conductor cross-sectional area (wire size) = nominal 0,8 $mm^2$;

g) minimum shield coverage shall be 90 %.

The preceding specification is for conformance testing an MAU. Other types of cable may be used in real installations (see Annex B). Cables with improved specifications may enable increased trunk length or superior interference immunity or may be required to meet environmental or installation conditions. Conversely, cables with inferior specifications may be used subject to length limitations for both trunk and spurs, plus possible non-conformance to the RFI/EMI susceptibility requirements.

For intrinsically safe applications, the inductance/resistance ratio (L/R) should be less than the limit specified by the local regulatory agency for the particular implementation.

### 12.8.3 Coupler

The coupler shall provide one or several point(s) of connection to the trunk. It may be integrated in a fieldbus device, in which case there is no spur. Otherwise, it has at least three access points as shown in Figure 91: one for the spur and one for each side of the trunk.

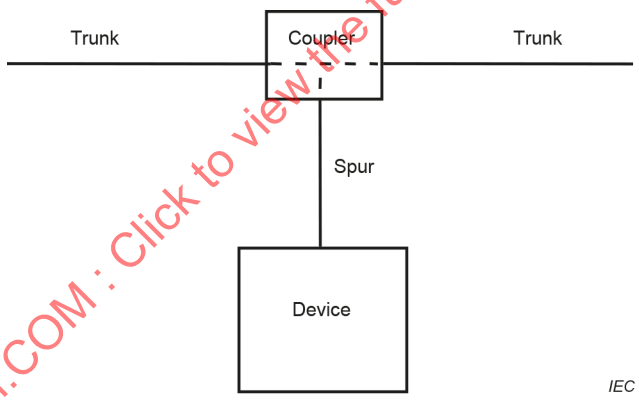


**Figure 91 – Fieldbus coupler**

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A passive coupler may contain any or all of the optional elements as described below:

a) a transformer, to provide galvanic isolation and impedance transformation between trunk and spur;

b) connectors, to provide easy connection to spur and/or trunk;

c) protection resistors, as shown in Figure 92, to protect bus traffic between other devices from the effects of a short-circuit spur on an unpowered, non-intrinsically safe trunk.

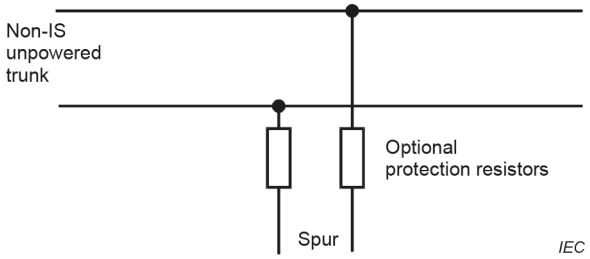


**Figure 92 – Protection resistors**

NOTE Such series resistors inherently increase the voltage at the device terminals when it is transmitting. This will affect the voltage at the receiving terminals of electrically "nearby" devices. See 12.4.3 for the maximum withstand voltage required of all such devices.

Active couplers, which require external power supplies, contain components for signal amplification and re-transmission. The transmit level and timing requirements shall conform to 12.3.

### 12.8.4 Splices

NOTE 1 A splice is any part of the network in which the characteristic impedance of the network cable is not preserved. This is possibly due to separation of the cable conductors, removal of the cable shield, change of wire gauge or type, connection to spurs, attachment to terminal strips, etc. A practical definition of a splice is therefore any part of the network that is not a continuous length of the specified medium.

For networks having a total cable length (trunk and spurs) of greater than 400 m, the sum of the lengths of all splices shall not exceed 2,0 % of the total cable length. For cable lengths of 400 m or less, the sum of the lengths of all splices shall not exceed 8 m.

NOTE 2 The motivation for this specification is to preserve transmission quality by requiring that the network be constructed almost entirely of the specified medium.

The continuity of all conductors of the cable shall be maintained in a splice.

### 12.8.5 Terminator

A terminator shall be located at both ends of the trunk cable, connected from one signal conductor to the other. No connection shall be made between terminator and cable shield.

The terminator impedance value shall be 100 Ω - 2 Ω/+ 6 Ω over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz). The terminator impedance shall be equivalent to a 100 Ω resistor in series with a 1,0 µF capacitor. The maximum component tolerances shall be 100 Ω ± 2 Ω and 1,0 µF ± 0,2 µF.

NOTE 1 This impedance value is approximately the average cable characteristic impedance value for suitable cables at the relevant frequencies and is chosen to minimize transmission line reflections.

The terminator components should be chosen to meet the specified values over the temperature range and operating life of the installation. It is recommended that the 25 °C rating of the components be 100 Ω ± 1 Ω and 1 µF ± 0,1 µF.

The direct current leakage through the terminator shall not exceed 100 µA. The terminator shall be non-polarized.

All terminators used for IS applications shall comply with isolation requirements (creepage and clearance) commensurate with the required IS approval. Terminators for non-IS applications shall not be required to have IS approval.

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NOTE 2 It is acceptable for the functions of power supply, safety barrier, and terminator to be combined in various ways as long as the impedance of the combination is equivalent to the parallel impedance of independent devices meeting the requirements of Clause 12 and the network configuration rules of 12.3.3 are followed.

### 12.8.6 Shielding rules

Where conformance to the noise immunity requirements of 12.5 is to be met by the use of shielding it is necessary to ensure the integrity of shielding throughout the cabling, connectors and couplers. The following rules can assist in meeting these requirements, but are not themselves a requirement:

a) the cable should be shielded for more than 90 % of its full length;

b) shielding should completely cover the electrical circuits in connectors, couplers, and splices.

NOTE 1 Deviation from these shielding rules can degrade noise immunity.

NOTE 2 Due to the long wavelengths involved, breaks in the shield coverage of 25 cm or so at connectors, couplers and splices, including where spurs are attached, will not usually be a problem, provided that shield continuity is maintained.

NOTE 3 Enclosure of connectors, couplers and splices in a metallic junction box can provide shielding from noise sources outside the junction box.

### 12.8.7 Grounding (earthing) rules

NOTE Grounding (earthing) means permanently connected to earth through sufficiently low impedance and with sufficient current-carrying capability to prevent voltage build-up which might result in undue hazard to connected equipment or persons.

Fieldbus devices shall be required to function to the requirements of Clause 12 with the mid-point of one terminator or one inductive coupler connected directly to ground.

Fieldbus devices shall not connect either conductor of the twisted pair to ground at any point in the network. Signals shall be applied and preserved differentially throughout the network. Zero volts (common) lines may be connected to ground where they are galvanically isolated from the fieldbus trunk.

It is standard practice for the shield of the fieldbus trunk cable (if applicable) to be effectively grounded at one point along the length of the cable. For this reason fieldbus devices should allow DC isolation of the cable shield from ground.

It is also standard practice to connect the signal conductors to ground in a balanced manner at the same point, e.g. by using the center tap of a terminator or coupling transformer.

For bus-powered systems the grounding of the shield and balanced signal conductors should be close to the power supply unit.

For IS systems the grounding should be at the safety barrier earth connection.

Capacitive coupling between the shield or the balanced signal conductors and device local ground for EMI control is permitted, subject to IS requirements.

### 12.8.8 Color coding of cables

See 11.8.8.

Where consideration of regional practices, such as those specified in 11.8.8, does not override, the following cable colors are recommended for Type 3 systems, as shown in Table 103.

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**Table 103 – Type 3 cable color specification**

| Cable Parameter | Color |
|---|---|
| Color of sheath non-IS | Black |
| Color of sheath IS | Blue or blue/black stripe |
| Color of inner cable conductor A (PA-) | Green |
| Color inner cable conductor B (PA+) | Red |

### 12.9 Intrinsic safety

#### 12.9.1 General

This document does not attempt to list the requirements by which an item of equipment may be certified as intrinsically safe nor does it require equipment to be intrinsically safe. Rather, it seeks to exclude conditions or situations that would prevent IS certification.

#### 12.9.2 Intrinsic safety barrier

The barrier impedance shall be greater than 460 Ω at any frequency in the range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz). The IS barrier impedance specification shall apply to all barriers used as part of the PhL, whether installed as a separate item of network hardware or embedded in a power supply card. The barrier impedance shall be measured across the terminals on both sides of the barrier. The barrier impedance shall be measured while the network power supply is set at the rated working voltage (not safety voltage) of the barrier.

NOTE It is acceptable for the functions of power supply, safety barrier, and terminator to be combined in various ways as long as the impedance of the combination is equivalent to the parallel impedance of independent devices meeting the requirements of Clause 12 and the network configuration rules of 12.3.3 are followed.

At the rated working voltage of the barrier, and at any frequency in the range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz), the capacitance measured from the "+" (positive) network terminal (hazardous side) to ground shall differ by no more than 250 pF from the capacitance measured from the "-" (negative) network terminal (hazardous side) to ground.

#### 12.9.3 Barrier and terminator placement

A barrier shall be separated from the nearest terminator by no more than 100 m of cable.

### 12.10 Galvanic isolators

The communications characteristics of galvanic isolators used on the fieldbus shall comply with the specifications of 12.4, 12.5 and 12.9. Galvanic isolators that provide power to fieldbus devices shall also comply with the power supply specifications of 12.7.

## 13 Type 1: Medium attachment unit: current mode, twisted-pair wire medium

### 13.1 General

The 1,0 Mbit/s current-mode MAU simultaneously provides access to a communication network and to a power distribution network. Devices attached to the network communicate via the medium and can be powered from it, or not. Power is distributed as a constant AC current. The communications signals are superimposed on the AC power.

The network medium consists of shielded twisted-pair cable.

Trapezoidal waveforms are used to reduce electromagnetic emissions and signal distortion.

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In intrinsically safe applications, available power can limit the number of devices.

The devices are connected in series on the bus whereas in the voltage-mode variants the devices are connected in parallel to the bus.

### 13.2 Transmitted bit rate

The average bit rate, BR ± ΔBR, shall be 1,0 Mbit/s with a tolerance of ± 0,01 %, averaged over a frame having a minimum length of 16 octets. The instantaneous bit time, $T_{bit}$ ± $\Delta T_{bit}$, shall be 1,0 µs ± 0,025 µs.

### 13.3 Network specifications

#### 13.3.1 Components

An MAU operates in a network composed of the following components:

a) cable;
b) terminators;
c) couplers;
d) devices (containing at least one communication element).

A wire network in current mode may additionally include the following components:

a) connectors;
b) power supplies;
c) devices which include power supplies;
d) intrinsic safety barriers.

The network medium consists of shielded twisted-pair cable. Independent of topology, all attached devices, other than possibly the transmitting device, are low impedance to prevent significant network loading.

#### 13.3.2 Topologies

A wire MAU shall operate in a network with a linear bus topology, consisting of a trunk, terminated at each end as specified in 13.8.5, to which communication elements are connected via couplers and spurs.

The coupler and communication element may be integrated in one device (i.e. zero-length spur).

A tree topology with all the communication elements located at the ends of the trunk is regarded as a special case of a bus for the purpose of Clause 13.

Several communication elements can be connected to the trunk at one point using a multi-port coupler. An active coupler can be used to extend a spur to a length that requires termination to avoid reflections and distortions. Active repeaters can be used to extend the length of the trunk beyond that of a single segment as permitted by the network configuration rules.

#### 13.3.3 Network configuration rules

An MAU that claims conformance to Clause 13 shall meet the requirements of Clause 13 when used in a network that complies with these rules.

**Rule 1:** One fieldbus shall be capable of communication between two and 32 devices, all operating at the same bit rate, both for a powered and a non-powered bus and in a hazardous area using distributed barriers.

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NOTE 1 The use of a single barrier in the safe area can limit the number of devices in the hazardous area.

NOTE 2 This rule does not preclude the use of more than the specified number of devices in an installed system. The numbers of devices were calculated on the assumption that a bus-powered device draws 100 mW.

**Rule 2:** A fully loaded (maximum number of connected devices), current-mode fieldbus segment shall have a total cable length, between any two devices, of up to 750 m.

NOTE 3 750 m maximum cable length is the requirement for conformance to Clause 13 but this does not preclude the use of longer lengths in an installed system.

**Rule 3:** The total number of waveform regenerations by repeaters and active couplers between any two devices is repeater implementation dependent.

NOTE 4 Prior editions of this document limited this total number to four.

**Rule 4:** The maximum propagation delay between any two devices shall not exceed 40 $T_{bit}$.

For efficiency of the network, that part of the turn-around time of any device on the network caused by a PhE between the end of a received frame and the beginning of the transmitted frame containing an associated immediate response should not exceed 5 bit times, no more than 2 bit times of which should be due to the MAU.

NOTE 5 As it is not mandatory to expose the DLL-PhL interface or the MDS-MAU interface, that part of the turn-around time of a fieldbus device caused by the PhL or the MAU is not specified and thus not available for conformance testing.

**Rule 5:** The fieldbus shall be capable of continued operation while a device is being connected or disconnected. Data errors induced during connection or disconnection shall be detected.

**Rule 6:** Failure of any communication element or spur (including a short circuit or open circuit, but excluding jabber) shall not interfere with transactions between other communication elements for more than 1 ms.

**Rule 7:** The network shall not be polarity sensitive with or without power injected on the line.

**Rule 8:** The degradation of the electrical characteristics of the signal, between any two devices, due to attenuation, attenuation distortion and mismatching shall be limited to the values indicated below.

a) Signal attenuation: The signal attenuation due to each device shall not exceed 0,2 dB. The configuration of the bus (trunk and spur lengths, number of devices, IS barriers, galvanic isolators, and possible matching devices) shall be such that the attenuation between any two devices at the frequency corresponding to the bit rate shall not exceed 16 dB.

b) Attenuation distortion: The configuration of the bus (trunk and spur lengths and number of devices) shall be such that between any two devices:

   [Attenuation (1,25 $f_r$) - Attenuation (0,25 $f_r$)] ≤ 6 dB

   Attenuation (1,25 $f_r$) ≥ Attenuation (0,25 $f_r$)

   where $f_r$ is the frequency corresponding to the bit rate. Attenuation shall be monotonic for all frequencies from 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz).

c) Mismatching distortion: Mismatching (due to spurs or any other effect, including one open circuit spur of maximum length) on the bus shall be such that, at any point along the trunk, in the frequency band 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz):

   $|Z - Z_{f_r}| / |Z + Z_{f_r}| \leq 0,2$

   where

   $Z_o$ is the characteristic impedance of the trunk cable;

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Z is the parallel combination of $Z_o$ and the load impedance at the coupler.

NOTE 6 This rule minimizes restrictions on trunk and spur length, number of devices etc. by specifying only the transmission limitations imposed by combinations of these factors. It is possible to use different combinations depending on the needs of the application.

**Rule 9:** The following rules shall apply to systems implemented with redundant media:

a) each channel (cable) shall comply with the network configuration rules;

b) there shall not be a non-redundant segment between two redundant segments;

c) repeaters shall also be redundant;

d) if the system is configured (by Systems management) to transmit on more than one channel simultaneously then the propagation time difference between any two devices on any two channels shall not exceed five bit times;

e) channel numbers shall be maintained throughout the fieldbus, i.e. channels 1,2,3... from Systems management shall always connect to physical channels 1,2,3...

### 13.3.4 Power distribution rules for network configuration

See 11.3.4.

## 13.4 MAU transmit circuit specification

### 13.4.1 General

The requirements of 13.4 are summarized in Table 104 and Table 105.

**Table 104 – MAU transmit level specification summary**

| Transmit level characteristics, values referred to trunk (but measured using test load as shown in Figure 93) | Limits (bus-powered and/or IS) |
|---|---|
| Output level (peak-to-peak, see Figure 80)<br>With test load (>2 × nominal $Z_o$ of trunk cable) | ≥ 2,5 V<br>320 Ω with a tolerance of ± 1 % |
| Maximum positive and negative amplitude difference (signaling bias) as shown in Figure 81 | ±0,2 V |
| Output level; open circuit (peak-to-peak) | ≤ 4,0 V |
| Maximum output signal distortion; i.e., overvoltage, ringing and droop (see Figure 80) | ±10 % |
| Quiescent transmitter output; i.e. transmitter noise (measured over the frequency band 1 kHz to 4 MHz) | ≤ 1 mV (RMS) |

**Table 105 – MAU transmit timing specification summary**

| Transmit timing characteristics, values referred to trunk (but measured using test load as shown in Figure 93) | Limits (bus-powered and/or IS) |
|---|---|
| Transmitted bit rate | 1 Mbit/s with a tolerance of ± 0,01 % |
| Instantaneous bit time | 1 µs ± 0,025 µs |
| Rise and fall times (10 % to 90 % of pk-pk signal, see Figure 80) | ≤ 20 % $T_{bit}$ |
| Slew rate (at any point from 10 % to 90 % of pk-pk signal) | ≤40,0 V/µs |
| Maximum transmitted bit cell jitter (zero crossing-point deviation, see Figure 81) | ± 2,5 % $T_{bit}$ |
| Transmit enable/disable time (i.e. time during which it is permissible that the output waveform do not meet the transmit requirements) | ≤ 2,0 $T_{bit}$ |

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### 13.4.2 Test configuration

Figure 93 shows the configuration that shall be used for testing.

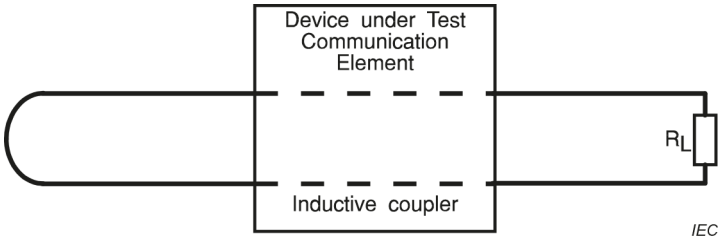


**Figure 93 – Test configuration for current-mode MAU**

The test configuration for Clause 13 shall be as shown in Figure 93 except where otherwise stated in a specific requirement.

NOTE Test load resistance R = 320 Ω (twice maximum cable $Z_o$) as the output is loaded by a series loop of the trunk.

### 13.4.3 Output level requirements

NOTE Figure 80 shows an example of one cycle of a fieldbus waveform, illustrating some key items from the transmit circuit specification. Only signal voltages are shown; this diagram takes no account of power-supply voltages.

A current-mode MAU transmit circuit shall conform to the following output level requirements, all amplitudes being measured at the estimated mid-point between any peaks or troughs in the top and bottom of the waveform ("mid-point" in Figure 80):

a) the output voltage across the test load after transformer step up/down shall be no less than 2,5 V peak-to-peak with a load resistance of 320 Ω with a tolerance of ± 1 % ("min o/p" in Figure 80);

b) the output voltage at the trunk, or at the transmit terminals, with any load including an open circuit shall not exceed 4,0 V peak-to-peak ("max. o/c at trunk" in Figure 80). For test purposes, open circuit shall be defined as a load of 100 kΩ resistance in parallel with 15 pF capacitance;

c) during transmission a device shall not suffer permanent failure when a load resistance of ≤ 1 Ω is applied for 1 s;

d) the difference between positive amplitude and negative amplitude, measured as shown in Figure 80, shall not exceed ±0,2 V peak;

e) the output noise from a current-mode MAU which is receiving or not powered shall not exceed 1 mV RMS, measured differentially over the frequency band 1 kHz to 4 MHz, referred to the trunk;

f) the differential voltage across the test load shall be such that the voltage monotonically changes between 10 % and 90 % of peak-to-peak value. Thereafter, the signal voltage shall not vary more than ±10 % of peak-to-peak value until next transition occurs. This permitted variation shall include all forms of output signal distortion, i.e. overvoltage, ringing and droop.

### 13.4.4 Output timing requirements

A current-mode MAU transmit circuit shall conform to the following output timing requirements:

a) rise and fall times, measured from 10 % to 90 % of the peak-to-peak signal amplitude shall not exceed 0,2 $T_{bit}$ (see Figure 80);

b) slew rate shall not exceed 40 V/µs measured at any point in the range 10 % to 90 % of the peak-to-peak signal amplitude (see Figure 80);

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NOTE 1 Requirements a) and b) produce a trapezoidal waveform at the transmit circuit output. Requirement b) limits the level of interference emissions that can be coupled to adjacent circuits etc. Requirement b) is calculated from the formula:

$$\text{Max. slew rate} = 3 \times \text{min. slew rate} = 3 \times 0{,}8\ V_o / 0{,}2\ T = 12 \times V_o / T_{bit},$$

where $V_o$ is an estimated maximum pk-pk output voltage with standard load (3,3 V).

c) transmitted bit cell jitter shall not exceed ±0,025 nominal bit time from the ideal zero crossing-point, measured with respect to previous zero crossing (see Figure 94);

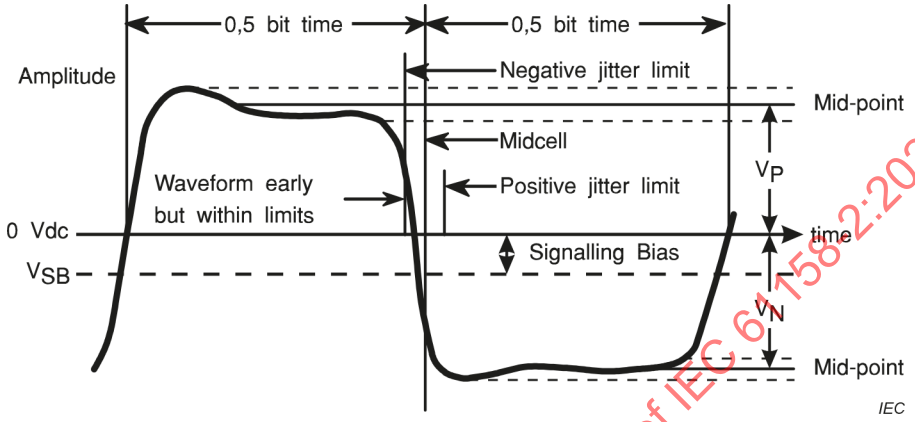


**Figure 94 – Transmitted and received bit cell jitter (zero crossing point deviation)**

d) the transmit circuit shall turn on, i.e. the signal shall rise from below the transmit circuit maximum output noise level as specified in 13.4.3 e) to full output level, in less than 2,0 $T_{bit}$. The waveform corresponding to the third and later bit times shall be as specified by other subclauses of 13.4;

e) the transmit circuit shall turn off, i.e. the signal shall fall from full output level to below the transmit circuit maximum output noise level as specified in 13.4.3 e), in less than 2,0 $T_{bit}$. The time for the transmit circuit to return to its off state impedance shall not exceed 4,0 $T_{bit}$. For the purposes of testing, this requirement shall be met with the transmit circuit test configuration of 13.4.2 with the equivalent capacitance of a maximum length cable across the DUT terminals.

NOTE 2 This requirement is to ensure that the transition of the transmit circuit from active to passive leaves the line capacitance fully discharged.

## 13.5 MAU receive circuit specification

### 13.5.1 General

For ease of reference the requirements of 13.4 are summarized in Table 106.

**Table 106 – Receive circuit specification summary**

| Receive circuit characteristics (values referred to trunk) | Limits (bus-powered and/or IS) |
|---|---|
| Input impedance, measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ | ≤ 2,5 Ω |
| Sensitivity; min. peak-to-peak signal required to be accepted (see Figure 83) | 1,3 mA |
| Noise rejection; max. peak-to-peak noise required to be rejected (see Figure 83 | 0,8 mA |
| Maximum received bit cell jitter (zero crossing-point deviation (see Figure 94) | ±0,10 $T_{bit}$ |

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### 13.5.2 Input impedance

The differential input impedance of a current-mode MAU receive circuit shall not exceed 2,5 Ω in series with the line over the frequency range 0,25 $f_r$ to 1,25 $f_r$. (250 kHz to 1,25 MHz) This requirement shall be met in the power-off and power-on (not transmitting) states and in transition between these states. This impedance shall be measured at the inductive coupler using a sinusoidal current waveform with an amplitude greater than the receiver sensitivity threshold and lower than 20 mA peak-to-peak.

NOTE The requirement for ≤ 2,5 Ω input impedance during power-up and power-down can be met by automatic disabling of the transmitter during these periods.

### 13.5.3 Receiver sensitivity and noise rejection

An MAU receive circuit shall be capable of accepting an input signal from 1,3 mA peak-to-peak to 20,0 mA peak-to-peak, including overvoltage and oscillation (see "signal level" together with "positive amplitude" and "negative amplitude", all in Figure 80).

An MAU receive circuit shall not respond to an input signal with a peak-to-peak line current amplitude which does not exceed 0,8 mA (see "noise rejection" in Figure 83).

### 13.5.4 Received bit cell jitter

The receive circuit shall accept a Manchester encoded signal transmitted in accordance with 13.2 and 13.4. In addition, the receiver shall work properly with signals with the time variation between any two adjacent signal transition points (zero crossing) of ±0,10 $T_{bit}$ or less. See Figure 94

NOTE 1 This does not preclude the use of receivers that perform better than this specification.

NOTE 2 Depending on the symbol pattern, the nominal time between zero crossings is one-half or one bit time.

NOTE 3 There is no requirement to reject a signal with a specified time variation value. The receiver reports an error when the received bit cell jitter exceeds the receiver's ability to reliably decode signaling.

### 13.5.5 Interference susceptibility and error rates

When the fieldbus is operating in a variety of standard noise environments the probability that an Application Layer User Data Unit contains an undetected error, due to operation of the conveying Physical and DLL entities, should be less than 1 in $10^{12}$ (1 error in 20 years at 1 600 messages/s).

A communication element is regarded as conforming to this theoretical requirement when it meets the following interference susceptibility requirements. These are specified by a detected frame error rate which is derived by using a ratio of detected to undetected errors of $10^6$.

NOTE 1 This is readily achievable with a 16 bit Frame Check Sequence at the DLL.

A communication element which includes a current-mode MAU, operating with frames containing 64 random user data bits, with maximum frame rate and with signals of 4,0 mA peak-to-peak amplitude, shall produce no more than 3 detected frame errors in 3 × $10^6$ frames during operation in the presence of common mode voltage or Gaussian noise as follows:

a) a common-mode sinusoidal signal of any frequency from 63 Hz to 2 MHz, with an amplitude of 4 V RMS and from 47 Hz to 63 Hz with an amplitude of 250 V RMS;

b) a common-mode DC signal of ±10 V;

c) white Gaussian additive differential noise in the frequency band 1 kHz to 4 MHz, with a noise density of 0,09 μA/√Hz RMS using the test circuit of Figure 95.

NOTE 2 The common mode voltage and Gaussian noise specifications are for receive circuit conformance testing with balanced loads and are not indicative of system installation practice.

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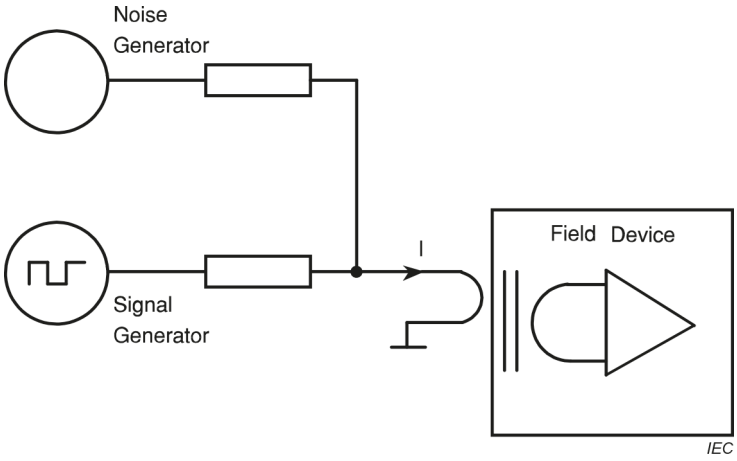


**Figure 95 – Noise test circuit for current-mode MAU**

A communication element which includes a current-mode MAU, operating with frames containing 64 random user data bits, at an average of 1 600 messages/s, with signals of 4,0 mA peak-to-peak amplitude, shall produce no more than six detected frame errors in 100 000 frames during operation in the presence of electromagnetic or electrical interference environments as follows:

1) 10 V/m electromagnetic field as specified in IEC 61000-4-3 at severity level 3;
2) electrical fast transient as specified in IEC 61000-4-4 at severity level 3.

The above error-rate specification shall also be satisfied after but not during operation in the following noise environments:

i) 8 kV electrostatic discharge to exposed metalwork as specified in IEC 61000-4-2 at severity level 3. If the device suffers temporary loss of function or performance as a result of this test it shall recover from any such loss without operator intervention within 3 s after the end of the test;

ii) high-frequency disturbance tests as specified in IEC 60255-22-1:1988, Test voltage class III (2,5 kV and 1 kV peak values of first half-cycle in longitudinal and transverse mode respectively). If the device suffers temporary loss of function or performance because of this test it shall recover from any such loss without operator intervention within 3 s after the end of the test.

### 13.6 Jabber inhibit

The MAU shall contain a self-interrupt capability to inhibit transmitted signals from reaching the medium. Hardware within the MAU (with no external message other than the detection of output signals or leakage via the transmit function) shall provide a window of between 5 ms and 15 ms during which time a normal frame can be transmitted. If the frame length exceeds this duration, the jabber inhibit function shall inhibit further output signals from reaching the medium and shall disable echo on the RxS line (see 10.2.2.2) to indicate jabber detection to the MDS.

The MAU shall reset the self-interrupt function after a period of 500 ms with a tolerance of ± 50 %.

NOTE This inhibits bus traffic for no more than 6 % (= 15/250) of the available time.

### 13.7 Power distribution

#### 13.7.1 General

A device can optionally receive power via the signal conductors or be separately powered.

A device can be certified as intrinsically safe with either method of receiving power.

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This document does not include requirements for IS certification but seeks to exclude conditions or situations that would prevent IS certification.

A separately powered device can be connected to a powered fieldbus.

For ease of reference, the requirements of 13.7 are summarized in Table 107.

**Table 107 – Network power supply requirements**

| Network power supply requirements | Limits |
|---|---|
| Output current | 50 mA to 200 mA RMS |
| Output frequency | 16 kHz ± 0,5 % |
| Maximum output voltage, IS | Depends on barrier rating |
| Harmonic distortion of supply current | ≤ 0,2 % |
| Output impedance, measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ | ≤ 5 Ω |

### 13.7.2 Powered via signal conductors

A device shall operate over a range of constant current, from 50 mA to 200 mA.

NOTE The output voltage from the supply is a function of cable loss and power consumed per device.

A fieldbus device may be designed to consume one or more standard loads. A standard load is 100 mW.

The power-supply open-circuit output voltage shall be less than the limit specified by the local regulatory agency for the particular implementation. The output impedance of the power supply shall be ≤ 5 Ω over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz).

The voltage drop in the signal coupler shall be less than 0,1 V at 16 kHz.

The voltage drop in the terminations shall be less than 0,3 V at 16 kHz.

The power waveform shall be a clean sinusoid of frequency 16 kHz with a tolerance of ± 0,5 % and maximum harmonic distortion of 0,2 %.

The device shall not introduce harmonic components of the power frequency larger than 1,0 mV peak-to-peak line to line in the main trunk.

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### 13.7.3 Powered separately from signal

NOTE Power distribution to non-bus powered fieldbus devices is by separate conductors feeding local power supplies, regulators or safety barriers. IS certification can require these conductors to be in a separate cable from the signal conductors and can also impose more stringent requirements for current levels than specified.

A separately powered fieldbus device which claims conformance to Clause 13 shall drop no more than 1 mV RMS at the power frequency on the signal conductors nor shall it supply a current of more than 100 µA RMS to the signal conductors when not transmitting.

### 13.7.4 Electrical isolation

All fieldbus devices, whether separately powered or powered via the signal conductors, shall provide low-frequency isolation between ground and the fieldbus trunk cable.

NOTE 1 This is possible by use of an inductive coupler with sufficient isolation, by isolation of the entire device from ground or by use of a transformer, opto-coupler or some other isolating component between trunk cable and device.

A combined power supply and communication element shall not require electrical isolation.

The isolation impedance measured between the shield of the fieldbus cable and the fieldbus device ground shall be greater than 250 kΩ at all frequencies below 63 Hz.

The isolation shall be bypassed at high frequencies by capacitance, so that the impedance measured between the shield of the fieldbus cable and the fieldbus device ground shall be less than 15 Ω between 3 MHz and 30 MHz.

NOTE 2 The capacitance between ground and trunk cable shield necessary to meet both these requirements can be any value between 3,5 nF and 10,6 nF.

The maximum unbalanced capacitance to ground from either input terminal of a device shall not exceed 250 pF.

The breakdown requirements of the isolation of the signal circuit and the power distribution circuit from ground and from each other shall be in accordance with IEC 61131-2.

The equivalent test voltage is to be applied between independent isolated circuits or between isolated circuits and accessible conducting parts.

NOTE 3 For circuits with a nominal voltage ≤ 50 VDC or RMS, the equivalent test voltages at sea level are 444 V RMS, 635 VDC and 635 V peak impulse test. For circuits with a nominal voltage between 150 V and 300 V RMS, the equivalent test voltages at sea level are 2 260 V RMS, 3 175 VDC and 3 175 V peak impulse test.

### 13.8 Medium specifications

#### 13.8.1 Connector

Cable connectors, if used, shall be to the IEC fieldbus standard (see Annex A). Field termination techniques such as screw or blade terminals and permanent termination may also be used.

#### 13.8.2 Standard test cable

The cable used for testing fieldbus devices with a current-mode MAU for conformance to the requirements of Clause 13 shall be a single twisted pair cable with overall shield meeting the following minimum requirements at 25 °C:

a) $Z_o$ at 0,25 $f_r$ (250 kHz) = 150 Ω with a tolerance of ± 10 %;

b) $Z_o$ at 1,25 $f_r$ (1,25 MHz) = 150 Ω with a tolerance of ± 10 %;

c) maximum attenuation at 0,25 $f_r$ (250 kHz) = 6,5 dB/km;

d) maximum attenuation at 1,25 $f_r$ (1,25 MHz) = 13 dB/km;

e) maximum capacitive unbalance to shield = 1,5 nF/km

f) maximum DC resistance (per conductor) = 57,1 Ω/km;

g) conductor cross-sectional area (wire size) = nominal 0,33 $mm^2$;

h) minimum resistivity between either conductor and shield = 16 GΩ/km;

i) minimum shield coverage shall be 95 %.

The preceding specification is for conformance testing an MAU. Other types of cable may be used in real installations (see Annex B). Cables with improved specifications may enable increased trunk length and/or superior interference immunity. Conversely, cables with inferior specifications may be used subject to length limitations for both trunk and spurs plus possible non-conformance to the RFI/EMI susceptibility requirements.

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For intrinsically safe applications the inductance/resistance ratio (L/R) should be less than the limit specified by the local Regulatory Agency for the particular implementation.

### 13.8.3 Coupler

An inductive coupler connects one device or spur to the trunk. It transfers data signals to and from the device and can transfer power to the device. The trunk cable operates as a single primary turn in the inductive coupler transformer. The following options are permitted:

a) the coupling may be performed without violation of the cable insulation;

b) the inductive coupler may be used as a connector;

c) an IS barrier element may be included as an integral part of the inductive coupler.

The coupler shall be an integral part of the MAU if the device is connected in the trunk. The input impedance of the coupler shall be a maximum of 2,5 Ω in series with the line.

### 13.8.4 Splices

NOTE A splice is any part of the network in which the characteristic impedance of the network cable is not preserved. This is possibly due to separation of the cable conductors, removal of the cable shield, change of wire gauge or type, connection to spurs, etc. A practical definition of a splice is therefore any part of the network that is not a continuous length of the specified medium.

The continuity of all conductors of the cable shall be maintained in a splice.

### 13.8.5 Terminator

A terminator shall be located at both ends of the trunk cable, connected from one signal conductor to the other. No connection shall be made between terminator and cable shield.

For test purposes, using the cable specified in 13.8.2, the terminator shall have an impedance value of 120 Ω with a tolerance of ± 2 % over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz).

NOTE 1 The terminator resistance value was selected to be lower than the test cable characteristic impedance value because the current-mode devices add impedances in series with the terminator. The value was chosen to reduce transmission line reflections for a fieldbus with 2 to 32 devices.

NOTE 2 In practical implementations with power supplied via the signal conductors the terminator would be by-passed at power frequencies to minimize power losses.

The direct current leakage through the terminator shall not exceed 100 µA. The terminator shall be non-polarized.

All terminators used for IS applications shall comply with isolation requirements (creepage and clearance) commensurate with the required IS approval. Terminators for non-IS applications shall not be required to have IS approval.

### 13.8.6 Shielding rules

For full conformance to the noise immunity requirements of 13.5 it is necessary to ensure the integrity of shielding throughout the cabling, connectors and couplers by the following means:

a) the coverage of the cable shield shall be greater than 95 % of the full cable length;

b) shielding shall completely cover the electrical circuits in connectors, couplers, and splices.

NOTE Deviation from these shielding rules can degrade noise immunity.

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### 13.8.7 Grounding rules

NOTE 1 Grounding means permanently connected to earth through a sufficiently low impedance and with sufficient current-carrying capability to prevent voltage build-up which might result in undue hazard to connected equipment or persons.

Zero volts (common) lines may be connected to ground where they are galvanically isolated from the fieldbus trunk.

Fieldbus devices shall be required to function to the requirements of Clause 13 with the mid-point of one terminator or one inductive coupler connected directly to ground.

Fieldbus devices shall not connect either conductor of the twisted pair to ground at any point in the network. Signals shall be applied and preserved differentially throughout the network.

It is standard practice for the shield of the fieldbus trunk cable (if applicable) to be effectively grounded at one point along the length of the cable. For this reason fieldbus devices should allow DC isolation of the cable shield from ground.

For bus-powered systems the grounding of the shield and balanced signal conductors should be close to the power supply unit.

For IS systems the grounding should be at the safety barrier earth connection. Capacitive coupling between the shield or the balanced signal conductors and device local ground for EMI control is permitted subject to IS requirements.

### 13.8.8 Color coding of cables

See 11.8.8.

## 14 Type 1: Medium attachment unit: current mode (1 A), twisted-pair wire medium

### 14.1 General

A 1,0 Mbit/s current-mode MAU simultaneously provides access to a communication network, and to a power distribution network with extended power capacity. Devices attached to the network communicate via the medium, and can be powered from it, or not. Power is distributed as a constant AC current with a frequency far below the signal frequency. The communication signals are superimposed on the AC power.

The network medium consists of shielded twisted-pair cable.

In hazardous area applications, a non-IS bus may have IS barriers incorporated in connected devices thereby increasing the number of devices permissible in the hazardous area over a single barrier arrangement.

The devices are connected in series on the bus, whereas in the voltage-mode variants the devices are connected in parallel to the bus.

### 14.2 Transmitted bit rate

See 13.2.

### 14.3 Network specifications

#### 14.3.1 Components

An MAU operates in a network composed of the following components:

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a) cable;
b) terminators;
c) couplers;
d) coupler mounts;
e) devices (containing at least one communication element).

A wire network in current mode may additionally include the following components:

a) connectors;
b) power supplies;
c) devices which include power supplies;
d) intrinsic safety (IS) barriers.

The network medium consists of shielded twisted-pair cable. Independent of topology, all attached devices, other than possibly the transmitting device, are low impedance to prevent significant network loading.

A coupler mount is a network element that allows a coupler to be connected to the network medium. It may be considered as a primary winding in a transformer (inductive coupler) and has, as such, electrical characteristics that affect the network.

### 14.3.2 Topologies

A wire MAU shall operate in a network with a linear bus topology, consisting of a trunk, terminated at each end as specified in 14.8.5, to which communication elements are connected via couplers.

The coupler and communication element may be integrated in one device (such as zero-length spur).

Several communication elements can be connected to the trunk at one point, using a multiport coupler. An active coupler can be used to extend a spur to a length that requires termination to avoid reflections and distortions. Active repeaters can be used to extend the length of the trunk beyond that of a single segment, as permitted by the network configuration rules.

### 14.3.3 Network configuration rules

An MAU that claims conformance to Clause 14 shall meet the requirements of Clause 14 when used in a network that complies with these rules.

**Rule 1:** One fieldbus shall be capable of communication between two and 30 devices, all operating at the same bit rate, for both a powered and a non-powered bus, and in a hazardous area using distributed barriers.

NOTE 1 This rule does not preclude the use of more than the specified number of devices in an installed system. The numbers of devices were calculated on the assumption that a bus-powered device draws 1,0 W.

**Rule 2:** A fully loaded (maximum number of connected devices), current-mode fieldbus segment shall have a total cable length, between any two devices, of up to 400 m.

NOTE 2 400 m maximum cable length is the requirement for conformance to Clause 14, but this does not preclude the use of longer lengths in an installed system.

**Rule 3:** The total number of waveform regenerations by repeaters and active couplers between any two devices is repeater implementation dependent.

NOTE 3 Prior editions of this document limited this total number to five.

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**Rule 4:** The maximum propagation delay between any two devices shall not exceed 40 $T_{bit}$.

For efficiency of the network, that part of the turnaround time of any device on the network caused by a PhE between the end of a received frame and the beginning of the transmitted frame containing an associated immediate response should not exceed five bit times, no more than two bit times of which should be due to the MAU.

NOTE 4 As it is not mandatory to expose the DLL-PhL interface, or the MDS-MAU interface, that part of the turnaround time of a fieldbus device caused by the PhL or the MAU is not specified, and thus not available for conformance testing.

**Rule 5:** The fieldbus shall be capable of continued operation while a device is being connected or disconnected. Data errors induced during connection or disconnection shall be detected.

**Rule 6:** Failure of any communication element or spur (including a short circuit or open circuit, but excluding jabber) shall not interfere with transactions between other communication elements for more than 1 ms.

**Rule 7:** The network shall not be polarity sensitive with or without power injected on the line.

**Rule 8:** The degradation of the electrical characteristics of the signal, between any two devices, due to attenuation, attenuation distortion and mismatching shall be limited to the values indicated below.

a) Signal attenuation: the signal attenuation due to each device shall not exceed 0,35 dB. The signal attenuation due to each full or empty coupler mount shall not exceed 0,6 dB. The configuration of the bus (trunk and spur lengths, number of devices, IS barriers, galvanic isolators, and possible matching devices) shall be such that the attenuation between any two devices at the frequency corresponding to the bit rate shall not exceed 10 dB.

   NOTE 5 The signal attenuation due to a device is with a cable of 80 Ω characteristic impedance. If a lower impedance cable is used, then the attenuation per device will increase.

   It will be required that the devices be connected to the bus using a mount to reach the maximum number of connected devices.

b) Attenuation distortion: the configuration of the bus (trunk and spur lengths and number of devices) shall be such that between any two devices:

   [Attenuation (1,25 $f_r$) – Attenuation (0,25 $f_r$)] ≤ 6 dB

   Attenuation (1,25 $f_r$) ≥ Attenuation (0,25 $f_r$)

   where $f_r$ is the frequency corresponding to the bit rate. Attenuation shall be monotonic for all frequencies from 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz).

c) Mismatching distortion: mismatching (due to spurs or any other effect, including one open-circuit spur of maximum length) on the bus shall be such that, at any point along the trunk, in the frequency band 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz):

   $|Z - Z_{f_r}| / |Z + Z_{f_r}| \leq 0,2$

   where

   $Z_o$ is the characteristic impedance of the trunk cable;

   $Z$ is the series combination of $Z_o$ and the load impedance at the coupler.

NOTE 6 This rule minimizes restrictions on trunk and spur length, number of devices etc., by specifying only the transmission limitations imposed by combinations of these factors. It is possible to use different combinations, depending on the needs of the application.

**Rule 9:** The following rules shall apply to systems implemented with redundant media:

a) each channel (cable) shall comply with the network configuration rules;

b) there shall not be a non-redundant segment between two redundant segments;

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c) repeaters shall also be redundant;

d) if the system is configured (by systems management) to transmit on more than one channel simultaneously, then the propagation time difference between any two devices on any two channels shall not exceed five bit times;

NOTE 7 This delay is equal to the default value of the inter-channel signal skew (see 9.2.9). The propagation delay difference can be larger, if the inter-channel signal skew parameter is set to match this difference.

e) channel numbers shall be maintained throughout the fieldbus, that is channels 1,2,3… from systems management shall always connect to physical channels 1,2,3…

### 14.3.4 Power distribution rules for network configuration

See 11.3.4.

## 14.4 MAU transmit circuit specification

### 14.4.1 General

The requirements of 14.4 are summarized in Table 108 and Table 109.

**Table 108 – Transmit level specification summary for current-mode MAU**

| Transmit level characteristics, values referred to trunk (but measured using test load as shown in Figure 93) | Limits (bus powered and/or IS) |
|---|---|
| Output level (peak-to-peak, see Figure 80)<br>With test load (> 2 × nominal $Z_o$ of trunk cable) | ≥ 2,25 V<br>160 Ω with a tolerance of ± 1 % |
| Maximum output signal distortion; this is overvoltage, ringing and droop (see Figure 80) | ±10 % |
| Quiescent transmitter output; that is transmitter noise (measured over the frequency band 1 kHz to 4 MHz) | ≤ 1 mV (RMS) |

**Table 109 – Transmit timing specification summary for current-mode MAU**

| Transmit level characteristics, values referred to trunk (but measured using test load as shown in Figure 93) | Limits (bus powered and/or IS) |
|---|---|
| Transmitted bit rate | 1 Mbit/s with a tolerance of ± 0,01 % |
| Instantaneous bit time | 1 µs ± 0,025 µs |
| Rise and fall times (10 % to 90 % of peak-to-peak signal, see Figure 80) | ≤ 20 % $T_{bit}$ |
| Slew rate (at any point from 10 % to 90 % of peak-to-peak signal) | ≤ 200,0 V/µs |
| Maximum transmitted bit cell jitter (zero-crossing point deviation, see Figure 96) | ± 2,5 % $T_{bit}$ |
| Transmit enable/disable time (that is, time during which it is permissible that the output waveform do not meet the transmit requirements) | ≤ 2,0 $T_{bit}$ |

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### 14.4.2 Configuration

Figure 93 shows the configuration which shall be used for testing.

The test configuration for Clause 14 shall be as shown in Figure 93 except where otherwise stated in a specific requirement.

NOTE Test load resistance $R_L$ = 160 Ω with a tolerance of ± 1 % as the output is loaded by a series loop of the trunk.

### 14.4.3 Output level requirements

NOTE Figure 80 shows an example of one cycle of a fieldbus waveform, illustrating some key items from the transmit circuit specification. Only signal voltages are shown; this diagram takes no account of power supply voltages.

A current-mode MAU transmit circuit shall conform to the following output level requirements, all amplitudes being measured at the estimated mid-point between any peaks or troughs in the top and bottom of the waveform ("Mid-point" in Figure 80):

a) the output voltage across the test load after transformer step up/down shall be no less than 2,25 V peak-to-peak, with a load resistance of 160 Ω with a tolerance of ± 1 % ("min. o/p" in Figure 80);

b) during transmission, a device shall not suffer permanent failure when a load resistance of ≤ 1 Ω is applied for 1 s;

c) the output noise from a current-mode MAU which is receiving or not powered shall not exceed 1 mV (RMS), measured differentially over the frequency band 100 kHz to 4 MHz, referred to the trunk;

d) the differential voltage across the test load shall be such that the voltage monotonically changes between 10 % and 90 % of peak-to-peak value. Thereafter, the signal voltage shall not vary more than ±10 % of peak-to-peak value until next transition occurs. This permitted variation shall include all forms of output signal distortion, such as overvoltage, ringing and droop.

### 14.4.4 Output timing requirements

An MAU transmit circuit shall conform to the following output timing requirements:

a) rise and fall times, measured from 10 % to 90 % of the peak-to-peak signal amplitude shall not exceed 0,2 (see Figure 80);

b) slew rate shall not exceed 200,0 V/µs measured at any point in the range 10 % to 90 % of the peak-to-peak signal amplitude (see Figure 80);

c) transmitted bit cell jitter shall not exceed ±0,025 $T_{bit}$ from the ideal zero crossing point, measured with respect to previous zero crossing (see Figure 96);

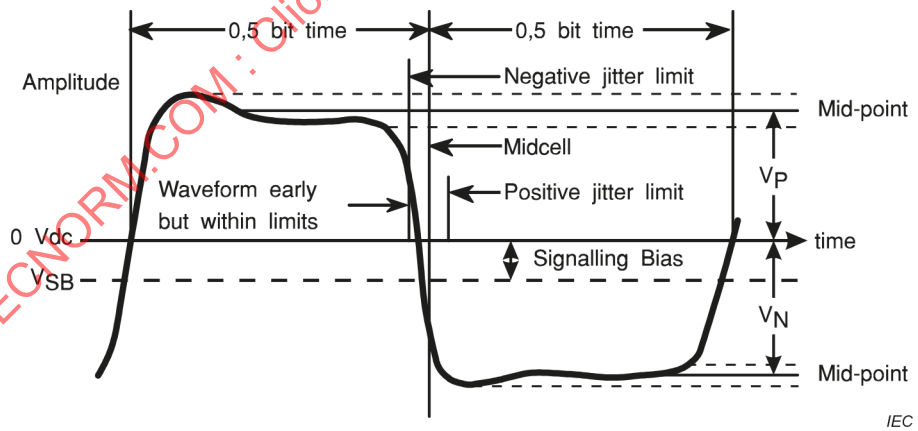


**Figure 96 – Transmitted and received bit cell jitter (zero crossing point deviation)**

d) the transmit circuit shall turn on, that is the signal shall rise from below the transmit circuit maximum output noise level as specified in 14.4.3 c) to full output level, in less than 2,0 $T_{bit}$. The waveform corresponding to the third and later bit times shall be as specified by other subclauses of 14.4;

e) the transmit circuit shall turn off, that is the signal shall fall from full output level to below the transmit circuit maximum output noise level as specified in 14.4.3 c), in less than 2,0 $T_{bit}$. The time for the transmit circuit to return to its off-state impedance shall not exceed 4,0 $T_{bit}$. For the purposes of testing, this requirement shall be met with the transmit circuit test configuration of 14.4.2.

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NOTE This requirement is to ensure that the transition of the transmit circuit from active to passive leaves the line capacitance fully discharged.

## 14.5 MAU receive circuit specification

### 14.5.1 General

The requirements of 14.5 are summarized in Table 110.

The input impedance of the receive circuit is allowed to be inductive. To prevent that the resistive part of the impedance becomes too high, both the maximum total input impedance and the maximum input resistance are specified in Table 110.

**Table 110 – Receive circuit specification summary for current-mode MAU**

| Receive circuit characteristics (values referred to trunk) | Limits for current mode (bus powered and/or IS) |
|---|---|
| Input resistance, measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz) | ≤ 0,5 Ω |
| Sensitivity; min. peak-to-peak signal required to be accepted (see Figure 83) | 4,0 mA |
| Noise rejection; max. peak-to-peak noise required to be rejected (see Figure 83) | 2,0 mA |
| Maximum received bit cell jitter (zero crossing-point deviation (see Figure 94) | ±0,10 $T_{bit}$ |
| Input impedance, measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz) | ≤ 4,0 Ω |

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### 14.5.2 Input impedance

The differential input resistance of a current-mode MAU receive circuit shall not exceed 0,5 Ω, and the differential input impedance of a current-mode MAU receive circuit shall not exceed 4,0 Ω in series with the line over the frequency 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz). This requirement shall be met in the power-off and power-on (not transmitting) states, and in transition between these states. This impedance shall be measured at the inductive coupler, using a sinusoidal current waveform with an amplitude greater than the receiver sensitivity threshold, and lower than 20 mA peak-to-peak.

### 14.5.3 Receiver sensitivity and noise rejection

An MAU receive circuit shall be capable of accepting an input signal from 4,0 mA peak-to-peak to 20,0 mA peak-to-peak, including overvoltage and oscillation (see "signal level" together with "positive amplitude" and "negative amplitude", all in Figure 80).

An MAU receive circuit shall not respond to an input signal with a peak-to-peak line current amplitude which does not exceed 2,0 mA (see "noise rejection" in Figure 83).

### 14.5.4 Received bit cell jitter

The receive circuit shall accept a Manchester encoded signal transmitted in accordance with 14.2 and 14.4. In addition, the receiver shall work properly with signals with the time variation between any two adjacent signal transition points (zero crossing) of ±0,10 $T_{bit}$ or less. See Figure 96.

NOTE 1 This does not preclude the use of receivers that perform better than this specification.

Depending on the symbol pattern, the nominal time between zero crossings can be one-half or one bit time.

NOTE 2 There is no requirement to reject a signal with a specified time variation value. The receiver reports an error when the received bit cell jitter exceeds the receiver's ability to reliably decode signaling.

### 14.5.5 Interference susceptibility and error rates

See 13.5.5.

## 14.6 Jabber inhibit

See 13.6.

## 14.7 Power distribution

### 14.7.1 General

A device can optionally receive power via the signal conductors, or be separately powered.

A device can be certified as intrinsically safe with either method of receiving power.

NOTE 1 This document does not include requirements for intrinsic safety certification, but seeks to exclude conditions or situations that would prevent intrinsic safety certification.

A separately powered device can be connected to a powered fieldbus.

NOTE 2 For ease of reference, the requirements of 14.7 are summarized in Table 111.

**Table 111 – Network power supply requirements**

| Network power supply requirements | Limits |
|---|---|
| Output current | 1,0 A RMS with a tolerance of ± 5 % |
| Output frequency | 16 kHz with a tolerance of ± 0,5 % |
| Harmonic distortion and noise of supply current | See Figure 97 |
| Output impedance, measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz) | ≤ 5 Ω |

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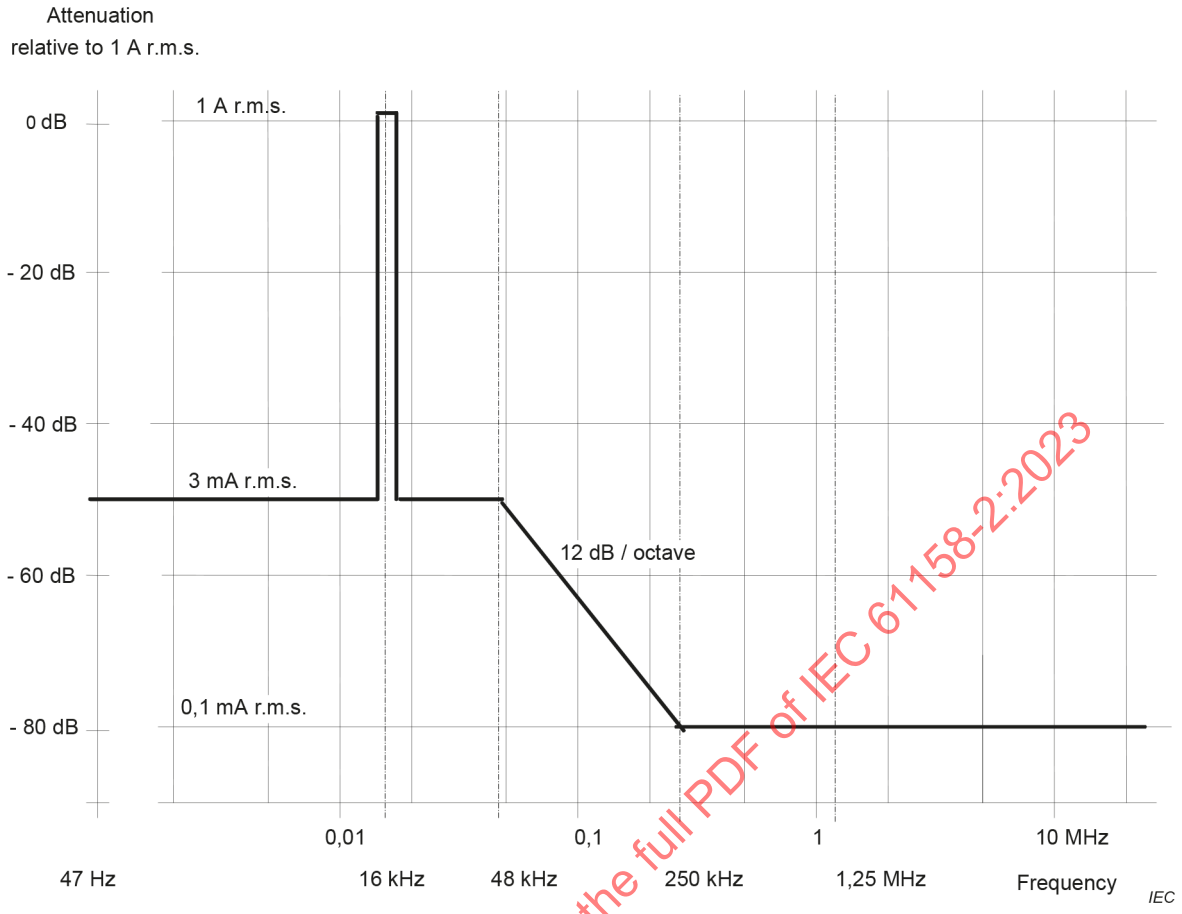


**Figure 97 – Power supply harmonic distortion and noise**

### 14.7.2 Powered via signal conductors

A fieldbus device claiming conformance to Clause 14 that is powered via the signal conductors shall conform to the requirements of Clause 14 when powered by a supply with the following specifications.

a) The output current of the power supply shall be a current of 1,0 A RMS with a tolerance of ± 5 %.

NOTE 1 The output voltage from the supply is a function of cable loss and power consumed per device.

A fieldbus device may be designed to consume one or more standard loads. A standard load is 1,0 W.

NOTE 2 The power supply open-circuit output voltage will be less than the limit specified by the local regulatory agency for the particular implementation.

b) The output impedance of the power supply shall be ≤ 5 Ω over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz).

c) The power waveform shall be a sinusoid of frequency and maximum harmonic distortion and noise as follows:

1) 0,1 mA RMS over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz);

2) 3,0 mA RMS over the frequency range 47 Hz to 48 kHz, with the exception of 16 kHz with a tolerance of ± 0,5 %;

3) levels at other frequencies in accordance with Figure 97.

The device shall not introduce harmonic components of the power frequency larger than 15 µA RMS in the main trunk.

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### 14.7.3 Powered separately from signal

NOTE Power distribution to non-bus powered fieldbus devices is by separate conductors feeding local power supplies, regulators or safety barriers. IS certification can require these conductors to be in a separate cable from the signal conductors, and can also impose more stringent requirements for current levels than specified.

A separately powered fieldbus device claiming conformance to Clause 14 shall drop no more than 200 mV RMS at the power frequency on the signal conductors, nor shall it supply a current of more than 100 µA RMS to the signal conductors when not transmitting.

### 14.7.4 Electrical isolation

See 13.7.4.

## 14.8 Medium specifications

### 14.8.1 Connector

See 13.8.1.

### 14.8.2 Standard test cable

The cable used for testing fieldbus devices with a current-mode MAU for conformance to the requirements of Clause 14 shall be a single twisted-pair cable with overall shield meeting the following minimum requirements at 25 °C:

a) $Z_o$ at 0,25 $f_r$ (250 kHz) = 80 Ω with a tolerance of ± 10 %;

b) $Z_o$ at 1,25 $f_r$ (1,25 MHz) = 80 Ω with a tolerance of ± 10 %;

c) maximum attenuation at 0,25 $f_r$ (250 kHz) = 11,0 dB/km;

d) maximum attenuation at 1,25 $f_r$ (1,25 MHz) = 20,0 dB/km;

e) maximum DC resistance (per conductor) = 15,0 Ω/km;

f) conductor cross-sectional area (wire size) = nominal 1,5 $mm^2$.

The preceding specification is for conformance testing an MAU. Other types of cable may be used in real installations (see Annex B). Cables with improved specifications may enable increased trunk length and/or superior interference immunity. Conversely, cables with inferior specifications may be used, subject to length limitations for both trunk and spurs, plus possible non-conformance to the RFI/EMI susceptibility requirements.

### 14.8.3 Coupler

See 13.8.3.

### 14.8.4 Splices

See 13.8.4.

### 14.8.5 Terminator

A terminator shall be located at both ends of the trunk cable, connected from one signal conductor to the other. No connection shall be made between terminator and cable shield.

For test purposes, using the cable specified in 14.8.2, the terminator shall have an impedance value of 80 Ω with a tolerance of ± 2 % over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (250 kHz to 1,25 MHz).

The voltage drop in the terminations shall be less than 0,3 V at 16 kHz.

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NOTE In practical implementations with power supplied via the signal conductors, the terminator would be bypassed at power frequencies to minimize power losses.

The terminator shall be non-polarized.

All terminators used for potentially explosive atmospheres shall comply with requirements commensurate with the required approval documents.

#### 14.8.6 Shielding rules

For full conformance to the noise immunity requirements of 14.5, it is necessary to ensure the integrity of shielding throughout the cabling, connectors and couplers by the following means:

a) the coverage of the cable shield shall be greater than 95 % of the full cable length;

b) shielding shall completely cover the electrical circuits in connectors, couplers, and splices.

NOTE Deviation from these shielding rules can degrade noise immunity.

#### 14.8.7 Grounding rules

See 13.8.7.

#### 14.8.8 Color coding of cables

See 11.8.8.

## 15 Types 1 and 7: Medium attachment unit: dual-fiber optical media

### 15.1 General

The network medium consists of a pair of fiber optic waveguides providing bidirectionality by use of a separate fiber for each direction of signal propagation. These are known collectively as an elementary optical path.

In all networks involving more than two devices, the fiber optic waveguides conveying signals from the devices are combined by a passive or active star coupler, then rebroadcast on all the waveguides conveying signals to the devices. A point-to-point link between a pair of devices using a single elementary optical path is also possible.

These dual fibers connect to the CPIC of a fieldbus device. The fiber optic transmission system is itself intrinsically safe.

### 15.2 Bit-rate-dependent quantities

Six bit rates are defined for a medium attachment unit (MAU) for dual-fiber optical media, where the network medium consists of a pair of unidirectional optical waveguides. A given MAU shall support at least one of these bit rates. Table 112 specifies the supported bit rates, and defines symbols for bit-rate-dependent quantities used throughout of 15.2:

**Table 112 – Bit-rate-dependent quantities of high-speed (≥ 1 Mbit/s) dual-fiber networks**

| Quantity | Symbol | Unit | Value | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal bit rate | BR | Mbit/s | 0,031 25 | 1 | 2,5 | 5 | 10 | 25 |
| Maximum deviation from BR | ΔBR | | 0,2 % | 0,01 % | | | | |
| Nominal bit duration | $T_{bit}$ | µs | 32,0 | 1,0 | 0,4 | 0,2 | 0,1 | 0,04 |
| Maximum deviation from $T_{bit}$ | $\Delta T_{bit}$ | - | 0,025 % | 0,015 % | | | | |
| Maximum propagation delay | $PD_{max}$ | $T_{bit}$ | 20 | 40 | | | | |

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The average bit rate shall be BR ± ΔBR, averaged over a frame having a minimum length of 16 octets. The instantaneous bit time shall be $T_{bit}$ ± Δ $T_{bit}$.

### 15.3 Network specifications

#### 15.3.1 Components

An optical MAU operates in a network composed of the following components:

a) optical cable;
b) devices (containing at least one communication element);
c) connectors;
d) optical passive stars;
e) optical active stars.

#### 15.3.2 Topologies

An optical MAU shall operate in a network with a star topology, or in a point-to-point network. Devices are connected to the optical stars or peer devices by elementary optical paths. Optical stars are interconnected by elementary optical paths.

#### 15.3.3 Network configuration rules

An MAU that claims conformance to Clause 15 shall meet the requirements of Clause 15 when used in a network that complies with these rules.

**Rule 1:** All network devices operate at the same bit rate.

**Rule 2:** The total number of optical active stars between any two devices shall not exceed four.

**Rule 3:** The maximum propagation delay between any two devices shall not exceed that specified in Table 112.

For network efficiency, the part of the turn-around time of any device on the network caused by a PhE between the end of a received frame and the beginning of the transmitted frame containing an associated immediate response should not exceed five bit times, no more than two bit times of which should be due to the MAU.

NOTE As it is not mandatory to expose either the DLL-PhL interface or the MDS-MAU interface, that part of the turn-around time of a fieldbus device caused by the PhL or the MAU is not specified and thus not available for conformance testing.

**Rule 4:** The fieldbus shall be capable of continuing operation while a device is being connected or disconnected. Data errors induced during connection or disconnection shall be detected.

**Rule 5:** The network shall be acyclic, with a single path between any two devices.

**Rule 6:** The following rules shall apply to systems implemented with redundant media:

a) each channel shall comply with the network configuration rules;
b) there shall not be a non-redundant segment or equipment between two redundant segments;
c) if the devices of the system are configured (by systems management) to transmit on more than one channel simultaneously then the propagation time difference between any two devices on any two channels shall not exceed five bit times;

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d) channel numbers and association with the physical transmission media shall be maintained consistently throughout the fieldbus, i.e. channels 1, 2, 3,… from systems management shall always connect to physical channels 1, 2, 3,…

## 15.4 MAU transmit circuit specifications

### 15.4.1 Test configuration

NOTE For ease of reference, the requirements of 15.4 are summarized in Table 113 and Table 114.

The output level, spectral and timing specifications are measured at the end of a 1 m standard test fiber connected to the CPIC.

### 15.4.2 Output level specification

An optical MAU transmit circuit shall conform to the following output level and spectral requirements. Level and spectral characteristics are measured at a temperature of 25 °C. Output level is the effective launch power of a Hi level. Output level specification is shown in Table 113.

**Table 113 – Transmit level and spectral specification summary**

| Transmit level and spectral characteristics (values referred to the CPIC with standard test fiber) | Limits, using 62,5/125 µm fiber |
|---|---|
| Peak emission wavelength ($\lambda p$) | (850 ± 30) nm |
| Typical half-intensity wavelength ($\Delta\lambda$) | ≤ 50 nm |
| Effective launch power Hi level | (−11,5 ± 1,5) dBm |
| Overshoot of transitions | ≤ 15 % effective power |
| Extinction ratio | ≥ 20:1 |

### 15.4.3 Output timing specification

An optical MAU transmit circuit shall conform to the following output timing requirements (see Figure 98). Timing characteristics are measured at a temperature of 25 °C. The output timing specification is shown in Table 114.

**Table 114 – Transmit timing specification summary**

| Transmit timing characteristics (values referred to the CPIC with standard test fiber) | Limits |
|---|---|
| Transmitted bit rate | BR ± ΔBR |
| Instantaneous bit time | $T_{bit} \pm \Delta T_{bit}$ |
| Rise and fall times (10 % to 90 % of peak-peak signal) | ≤ 2,0 % $T_{bit}$ |
| Difference between rise and fall times | ≤ 0,5 % $T_{bit}$ |
| Maximum transmitted bit cell jitter | ± 2,0 % $T_{bit}$ |

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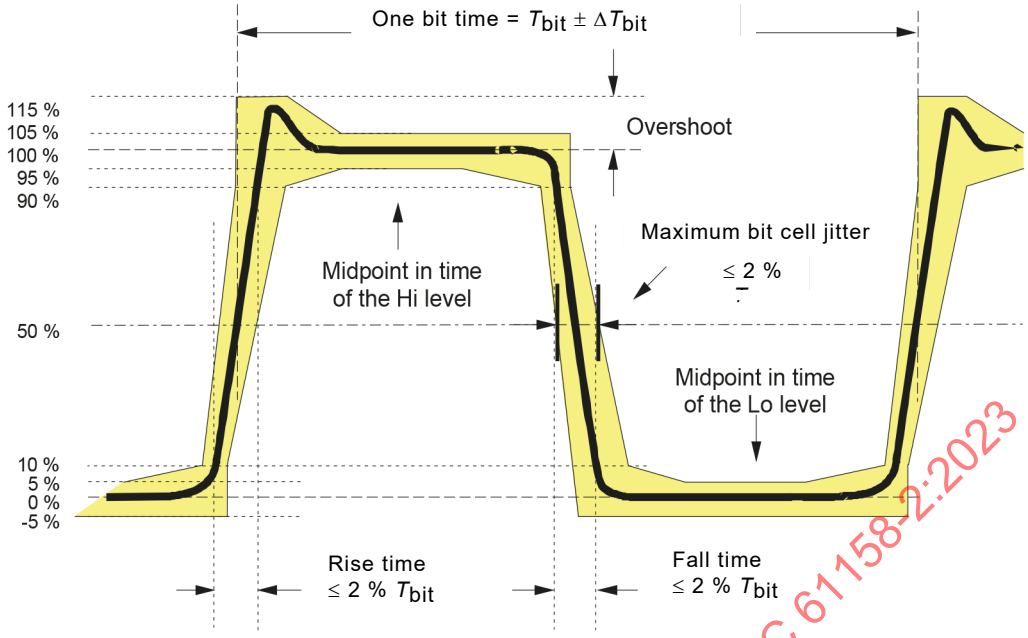


**Figure 98 – Optical wave shape template**

## 15.5 MAU receive circuit specifications

### 15.5.1 General

The requirements of 15.5 are summarized in Table 115.

**Table 115 – Receive circuit specification summary**

| Receive circuit characteristics (values referred to the CPIC with standard test fiber) | Limits | |
|---|---|---|
| | Low sensitivity system | High sensitivity system |
| Receiver operating range | −30,0 dBm to −10,0 dBm | −40,0 dBm to −20,0 dBm |
| Maximum received bit cell jitter | ± 14 % $T_{bit}$ | |

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### 15.5.2 Receiver operating range

The specified receiver sensitivity range is

a) −30,0 dBm to −10,0 dBm effective power for low sensitivity;

b) −40,0 dBm to −20,0 dBm effective power for high sensitivity.

### 15.5.3 Maximum received bit cell jitter

The receive circuit shall accept a Manchester encoded signal transmitted in accordance with 15.4. In addition, the receiver shall accept signals with time variation between two adjacent signal transition points (50 % crossing) of ±14,0 % $T_{bit}$ or less.

NOTE This does not preclude the use of receivers that perform better than this specification but in accordance with the tolerance of the received bit cell jitter of the MDS (see 9.2.6).

Depending on the symbol pattern, the nominal time between 50 % crossings can be either 1,0 $T_{bit}$ or 0,5 $T_{bit}$.

### 15.5.4 Interference susceptibility and error rates

#### 15.5.4.1 Low-speed (31,25 kbit/s)

When the fieldbus is operating in a variety of standard noise environments, the probability that an Application Layer User Data Unit contains an undetected error, due to operation of the conveying Physical and DLL entities, should be less than 1 in $6 \times 10^9$ (one error in 20 years at 10 messages/s).

A communication element is regarded as conforming to this theoretical requirement when it meets the following interference susceptibility requirements. These are specified by a detected frame error rate which is derived by using a ratio of detected to undetected errors of $10^6$.

A communication element which includes an optical MAU operating at 31,25 kbit/s with frames containing 32 random user data bits, at an average of 10 messages per second, with signals of −25 dBm, shall produce no more than 10 detected frame errors in 60 000 frames during operation in the presence of electromagnetic or electrical interference environments as follows:

a) 10 V/m electromagnetic field as specified in IEC 61000-4-3 at severity level 3;

b) electrical fast transient as specified in IEC 61000-4-4 at severity level 3.

#### 15.5.4.2 High-speed (≥ 1 Mbit/s)

When the fieldbus is operating in a variety of standard noise environments, the probability that an Application Layer User Data Unit contains an undetected error, due to operation of the conveying Physical and DLL entities, should be less than 1 in $10^{12}$ (one error in 20 years at 1 600 messages/s).

A communication element is regarded as conforming to this theoretical requirement when it meets the following interference susceptibility requirements. These are specified by a detected frame error rate which is derived by using a ratio of detected to undetected errors of $10^6$.

A communication element which includes an optical MAU operating at ≥1 Mbit/s with frames containing 64 random user data bits, at an average of 1 600 messages/s, with signals of -25 dBm, shall produce no more than 6 detected frame errors in 100 000 frames during operation in the presence of electromagnetic or electrical interference environments as follows:

a) 10 V/m electromagnetic field as specified in IEC 61000-4-3 at severity level 3;

b) electrical fast transient as specified in IEC 61000-4-4 at severity level 3.

#### 15.5.4.3 Common

The error rate specifications shall also be satisfied after, but not during, operation in the following noise environments:

a) 8 kV electrical discharge to exposed metalwork as specified in IEC 61000-4-2 at severity level 3. If the device suffers temporary loss of function or performance as a result of this test, it shall recover from any such loss without operator intervention within 3 s after the end of the test;

b) high frequency disturbance tests as specified in IEC 60255-22-1:1988, 3.1 (test voltage class III, 2,5 kV and 1 kV peak values of first half-cycle in longitudinal and transverse mode respectively). If the device suffers temporary loss of function or performance because of this test it shall recover from any such loss without operator intervention within 3 s after the end of the test.

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### 15.6 Jabber inhibit

The MAU shall contain a self-interrupt capability to inhibit transmitted signals from reaching the medium. Hardware within the MAU (with no external message other than the detection of output signals or leakage via the transmit function) shall provide a window of between 3 750 $T_{bit}$ and 7 500 $T_{bit}$, during which time a normal frame can be transmitted. If the frame length exceeds this duration, the jabber inhibit function shall inhibit further output signals from reaching the medium and shall disable echo on the RxS line (see 10.2.2.2) to indicate jabber detection to the MDS.

For a data rate of 31,25 kbit/s, the MAU shall reset the self-interrupt function after a period of 3 s with a tolerance of ± 50 %.

NOTE 1 This inhibits bus traffic for no more than 8 % (≈ 1/12,5) of the available time.

For a data rate of 1 Mbit/s or greater, the MAU shall reset the self-interrupt function after a period of 500 000 $T_{bit}$ with a tolerance of ± 50 %.

NOTE 2 This inhibits bus traffic for no more than 3 % (≈ 1/32) of the available time.

### 15.7 Medium specifications

#### 15.7.1 Connector

Cable connectors, if used, shall be in accordance with this document (see Annex A). Permanent terminations (splices) may also be used.

#### 15.7.2 Standard test fiber

The cable used for testing fieldbus devices or optical active stars with an optical MAU, for conformance to the requirements of Clause 15, shall be a 1 m fiber optic cable with two silica fiber optic waveguides. The characteristics of those waveguides shall be compatible with IEC 60793 [fiber type: A1b (62,5/125 µm)] as follows:

– core diameter (µm): 62,5 ± 3
– cladding diameter (µm): 125 ± 3
– core/cladding concentricity (%): ≤ 6
– no circularity core (%): ≤ 6
– no circularity cladding (%): ≤ 2
– external primary coating diameter (µm): 250 ± 15
– numerical aperture: 0,275 ± 0,015
– attenuation for 850 nm (dB/km): ≤ 3,0
– bandwidth for 850 nm (MHz ×km): ≥ 200

Alternate test fibers are allowed.

NOTE Operation using a 50 µm or 100 µm alternate test fiber is described in Annex E.

#### 15.7.3 Optical passive star

NOTE For more information, see Annex C.

#### 15.7.4 Optical active star

##### 15.7.4.1 Definition

An opto-electronic device or module in an optical communication system, that receives a signal, amplifies it and retransmits it (retiming is optional).

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#### 15.7.4.2 Operating

Three types of links shall be considered.

a) Link between two optical active stars

Any frame coming directly from an optical active star and reaching an optical access of another optical active star is retransmitted without feedback (the access which receives the frame does not retransmit that frame).

b) Link between an optical active star and a fieldbus device

Any frame coming from an optical active star and reaching a fieldbus device is received and not retransmitted. Any frame coming from a fieldbus device and reaching an optical active star is retransmitted without feedback.

c) Link between an optical passive star and an optical active star

Any frame coming from an optical passive star and reaching an optical active star is retransmitted without feedback. A passive star reflects all frames by design. An optical active star shall not retransmit the feedback signs of an optical passive star.

An optical active star restores signals to standard transmit power levels. The timing characteristics (jitter) can be regenerated or not; that function is optional.

#### 15.7.4.3 Transmit and receive characteristics

The following characteristics are given:

a) Level characteristics

Transmit and receive level specifications are the same as those of an optical MAU (15.4.2 and 15.5.2). Level and spectral characteristics are measured at a temperature of 25 °C. These specifications are summarized in Table 116.

**Table 116 – Transmit and receive level and spectral specifications for an optical active star**

| Transmit level and spectral characteristics (values referred to the CPIC with standard test fiber) | Limits, with 62,5/125 µm fiber | |
|---|---|---|
| Peak emission wavelength ($\lambda p$) | (850 ± 30) nm | |
| Typical half-intensity wavelength ($\Delta\lambda$) | ≤ 50 nm | |
| Extinction ratio | ≥ 20:1 | |
| Effective launch power Hi level | (-11,5 ± 1,5) dBm | |
| Receiver operating range (effective power) | Low sensitivity system | High sensitivity system |
| | −30,0 dBm to −10,0 dBm | −40,0 dBm to −20,0 dBm |

b) Timing characteristics

Transmit and receive timing specifications of an optical active star concern (see Table 117):

– rise and fall times of the transmitted signal;

– temporal deformation of signals due to an optical active star.

Timing characteristics are measured at a temperature of 25 °C. For optical active stars that have a timing regenerative function, the timing characteristics are the same as those of an optical MAU.

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**Table 117 – Timing characteristics of an optical active star**

| Timing characteristics (values referred to the CPIC) | Limits |
|---|---|
| Rise and fall times of transmitted signals (10 % to 90 % of peak-peak signal) | ≤ 2 % $T_{bit}$ |
| Maximum temporal deformation between optical input ports and optical output ports (see Note 1) | ±3 % $T_{bit}$ |
| Propagation time of a data bit between an optical input port and any output ports for an active star with timing regenerative function (see Note 2) | ≤ 2 $T_{bit}$ |
| Maximum transmitted bit cell jitter for an optical active star with timing regenerative function (see Note 2) | ±2,0 % $T_{bit}$ |
| NOTE 1 The temporal deformation due to an optical active star is the temporal difference of width of a same physical bit, bit pattern, waveform, or other appropriate term.<br>NOTE 2 Only for optical active stars with timing regenerative function. | |

# 16 Type 1: Medium attachment unit: 31,25 kbit/s, single-fiber optical medium

## 16.1 General

The network medium consists of a set of bidirectional single-fiber optic waveguides, each known as an elementary optical path.

In all networks involving more than two devices, the fiber optic waveguides conveying signals from the devices are combined by a reflective passive star coupler, where the received signals are retransmitted on all the fiber optic waveguides to the devices. A point-to-point link between a pair of devices using a single elementary optical path is also possible.

These bidirectional single fibers connect to the CPIC of a fieldbus device. The fiber optic transmission system is itself intrinsically safe.

## 16.2 Transmitted bit rate

The transmitted bit rate, BR ± ΔBR, shall be 31,25 kbit/s with a tolerance of ± 0,2 %, averaged over a frame having a minimum length of 16 octets. The instantaneous bit time, $T_{bit}$ ± Δ $T_{bit}$, shall be 32 µs with a tolerance of ± 0,025 %.

## 16.3 Network specifications

### 16.3.1 Components

See 15.3.1.

### 16.3.2 Topologies

See 15.3.2.

### 16.3.3 Network configuration rules

An MAU that claims conformance to Clause 16 shall meet the requirements of Clause 16 when used in a network that complies with these rules.

The rules are the same as 15.3.3, except as follows.

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### 16.4 MAU transmit circuit specifications

#### 16.4.1 Test configuration

NOTE For ease of reference, the requirements of 16.4 are summarized in Table 118 and Table 114.

See 15.4.1.

#### 16.4.2 Output level specification

An optical MAU transmit circuit shall conform to the following output level and spectral requirements. Level and spectral characteristics are measured at a temperature of 25 °C. Output level is the effective launch power of a Hi level. Output level specification is shown in Table 118.

**Table 118 – Transmit level and spectral specification summary**

| Transmit level and spectral characteristics (values referred to the CPIC with standard test fiber) | Limits for 31,25 kbit/s (100/140 µm fiber) |
|---|---|
| Peak emission wavelength (λp) | (850 ± 30) nm |
| Typical half-intensity wavelength (Δλ) | ≤ 50 nm |
| Effective launch power Hi level | (-13,5 ± 1,0) dBm |
| Overshoot of transitions | ≤ 15 % effective power |
| Extinction ratio | ≥ 20:1 |

#### 16.4.3 Output timing specification

An optical MAU transmit circuit shall conform to the following output timing requirements (see Figure 98). Timing characteristics are measured at a temperature of 25 °C. The output timing specification is shown in Table 114.

### 16.5 MAU receive circuit specifications

#### 16.5.1 General

The requirements of 16.5 are summarized in Table 115, but relative to the standard 100/140 µm test fiber of Clause 16.

#### 16.5.2 Receiver operating range

The specified receiver sensitivity range is

a) −30,0 dBm to −12,5 dBm effective power for low sensitivity;

b) −40,0 dBm to −20,0 dBm effective power for high sensitivity.

#### 16.5.3 Maximum received bit cell jitter

See 15.5.3.

#### 16.5.4 Interference susceptibility and error rates

See 15.5.4.1 and 15.5.4.3.

### 16.6 Jabber inhibit

The requirement is the same as 15.6, except as follows:

The MAU shall reset the self-interrupt function after a period of 3 s with a tolerance of ± 50 %.

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NOTE This inhibits bus traffic for no more than 8 % (≈ 1/12,5) of the available time.

## 16.7 Medium specifications

### 16.7.1 Connector

See 15.7.1.

### 16.7.2 Standard test fiber

Silica fiber optic waveguide whose nominal characteristics are compatible with IEC 60793 [fiber type: A1d (100/140 µm)].

The cable used for testing fieldbus devices or optical active stars with an optical MAU, for conformance to the requirements of Clause 16, shall be a 1 m fiber optic cable with one fiber optic waveguides, whose characteristics are as follows:

– core diameter (µm): 100 ± 5
– cladding diameter (µm): 140 ± 4
– core/cladding concentricity (%): ≤ 6
– no circularity core (%): ≤ 6
– no circularity cladding (%): ≤ 4
– numerical aperture: 0,26 ± 0,03
– attenuation for 850 nm (dB/km): ≤ 4,0
– bandwidth for 850 nm (MHz × km): ≥ 100

Alternate test fibers are allowed.

NOTE Operation using a 50 µm or 62,5 µm alternate test fibers is described in Annex E.

### 16.7.3 Optical passive star

NOTE For more information, see Annex C.

### 16.7.4 Optical active star

#### 16.7.4.1 Definition

Subclause 15.7.4.1 applies.

#### 16.7.4.2 Operating

Subclause 15.7.4.2 applies.

#### 16.7.4.3 Transmit and receive characteristics

##### 16.7.4.3.1 Level characteristics

Transmit and receive level specifications are the same as those of an optical MAU (see 16.4.2 and 16.5.2). Level and spectral characteristics are measured at a temperature of 25 °C. These specifications, summarized in Table 119.

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**Table 119 – Transmit and receive level and spectral specifications for an optical active star**

| Transmit level and spectral characteristics (values referred to the CPIC with standard test fiber) | Limits, with 100/140 µm fiber | |
|---|---|---|
| Peak emission wavelength (λp) | (850 ± 30) nm | |
| Typical half intensity wavelength (Δλ) | ≤ 50 nm | |
| Extinction ratio | ≥ 20:1 | |
| Effective launch power Hi level | (−13,5 ± 1,0) dBm | |
| Receiver operating range (effective power) | Low sensitivity system | High sensitivity system |
| | −30,0 dBm to −12,5 dBm | −40,0 dBm to −20,0 dBm |

#### 16.7.4.3.2 Timing characteristics

The timing characteristics of 15.7.4.3 apply.

## 17 Void

NOTE Clause 17 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the clause numbering of the prior edition.

## 18 Type 2: Medium attachment unit: 5 Mbit/s, voltage-mode, coaxial wire medium

### 18.1 General

Only one attachment method is specified for the 5 Mbit/s, voltage-mode, coaxial wire medium. Other methods may be used but they shall conform to the same signaling and performance characteristics. If the specified coaxial wire medium attachment method is used, then it shall incorporate transformer coupling at the node and it shall use a Passive Tap for attachment to the medium. The tap shall include a 1 m spur.

The 5 Mbit/s, voltage-mode, coaxial wire PhL variant shall connect to coaxial wire medium with network segments up to 1 km long with up to 48 nodes (see 18.5).

NOTE The physical layer can be implemented to allow certification for operation in explosive atmospheres, without sacrificing distance or reducing the number of nodes. This document does not include requirements for intrinsic safety certification, but seeks to exclude conditions or situations that would prevent intrinsic safety certification.

The MAU shall consist of a transceiver, transformer, and connector as shown in Figure 99. The transceiver shall use the signals defined in the MDS-MAU interface to generate those necessary to drive the transformer. Attachment to the medium shall be via BNC or TNC connectors as specified in Annex F. Ground isolation shall be provided via the transformer as specified in 18.3.

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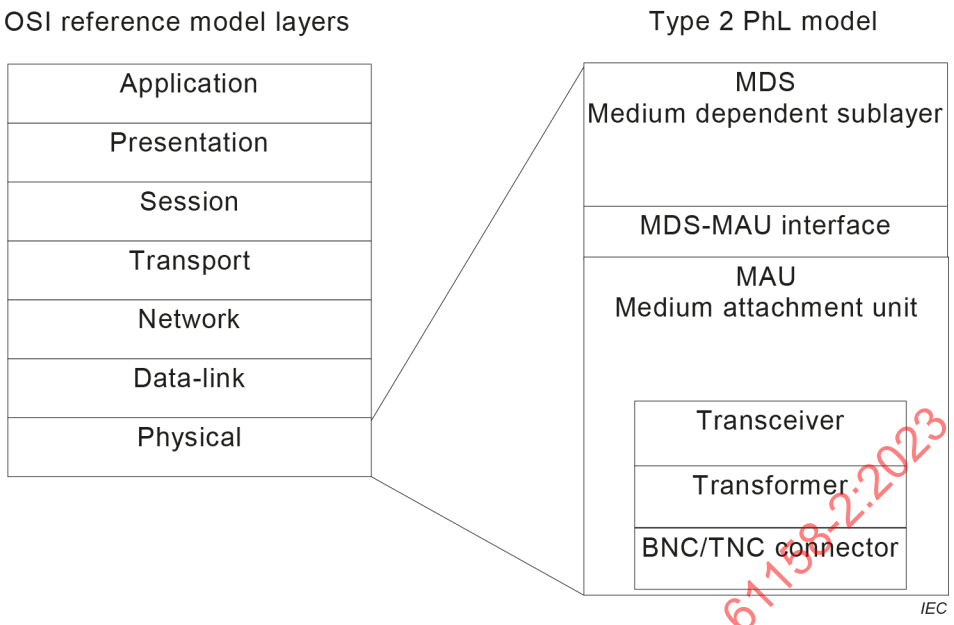


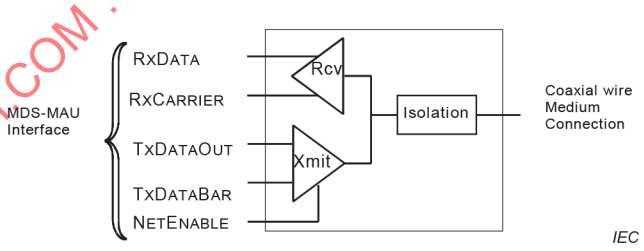

**Figure 99 – Components of 5 Mbit/s, voltage-mode, coaxial wire PhL variant**

### 18.2 Transceiver: 5 Mbit/s, voltage-mode, coaxial wire

When using a 5 Mbit/s, voltage-mode, coaxial wire medium, a coaxial wire transceiver shall be used to transmit and receive the L and H signals. The transmitter portion of the transceiver shall obtain transmit signals from the MDS-MAU interface, representing H and L symbols. It shall transmit a single-ended, ground-isolated signal onto the cable via the isolation transformer. The complement of this function shall be performed in the receiver that shall provide RXDATA and RXCARRIER indications to the MDS-MAU interface.

A functional block diagram depicting the MAU sublayer components is shown in Figure 100.

NOTE 1 Figure H.3 shows an example of a redundant transceiver and Figure H.4 shows an example of a single channel transceiver.




NOTE The blocks labeled Xmit and Isolation combine to represent the transmitter.

**Figure 100 – Coaxial wire MAU block diagram**

Figure 101 shows a simplified functional diagram of the transmitter.

NOTE 2 Refer to the example schematics found in Figure H.3 and Figure H.4 for more detail.

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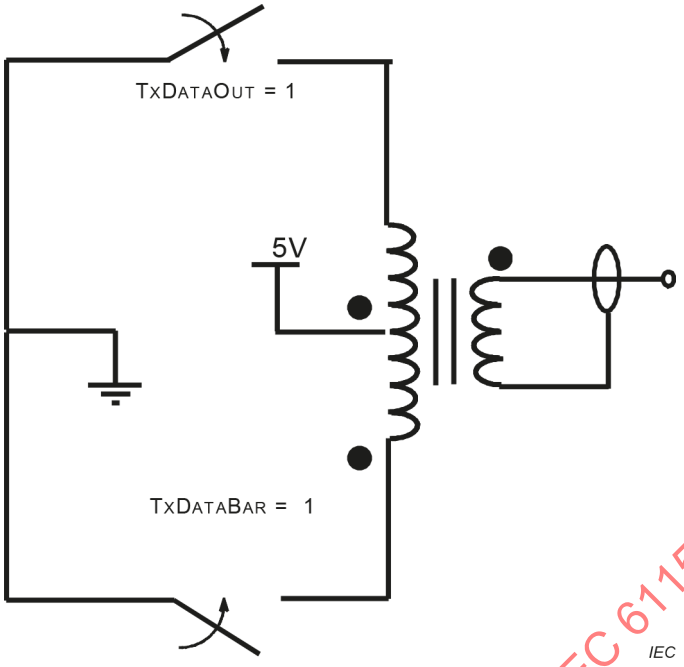


**Figure 101 – Coaxial wire MAU transmitter**

Three signals shall be available at the MDS-MAU interface for controlling transmission onto the medium, TxDataOut, TxDataBar, and NetEnable. These three transmit signals, when connected to the transceiver, shall define the physical symbols on the wire. The relationship between these transceiver request lines and the signals on the medium shall be as specified in Table 120.

**Table 120 – Transmit control line definitions 5 Mbit/s, voltage-mode, coaxial wire**

| TxDataOut | TxDataBar | NetEnable | Physical symbol | Signal on medium |
|---|---|---|---|---|
| don't care(x) | don't care(x) | false(0) | none | Transmitter off, see Table 123. |
| false(0) | false(0) | true(1) | none | Transmitter off, see Table 123. |
| true(1) | false(0) | true(1) | H | + voltage (positive), see Table 123. |
| false(0) | true(1) | true(1) | L | − voltage (negative), see Table 123. |
| true(1) | true(1) | true(1) | not allowed (see Note) | Not allowed (see Note) |
| NOTE This state can result in damage to the transmitter circuitry. | | | | |

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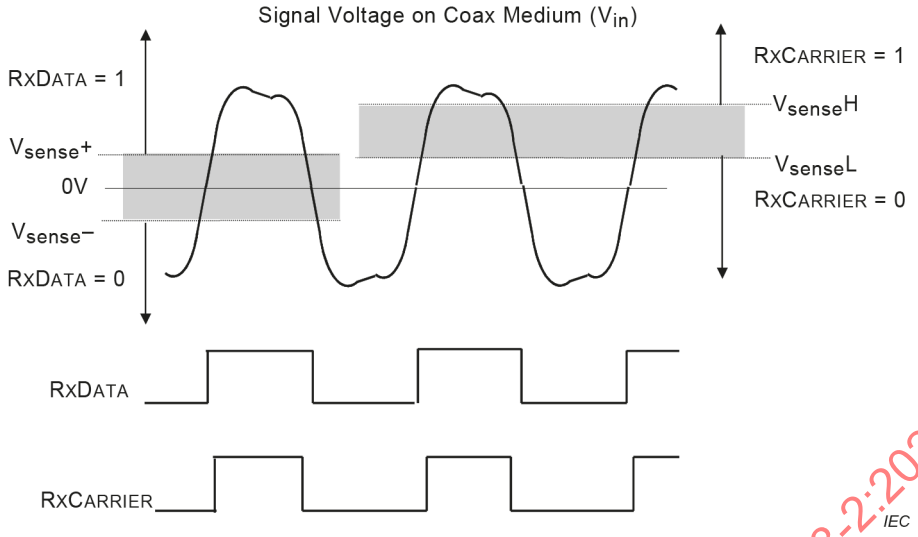


NOTE The shaded areas shown above are not defined.

**Figure 102 – Coaxial wire MAU receiver operation**

Two indication signals shall be provided at the MDS-MAU interface from the MAU with RxDATA and RxCARRIER as shown in Table 120. The relationship between the signal voltage on the wire and these two signals for nominal thresholds shall be as shown in Table 121 and Table 122. The values referenced in Table 121 and Table 122 are defined in Table 124. The input level ($V_{in}$) as shown in Figure 102 shall be defined as the voltage as measured between the coaxial cable center conductor and the coaxial shield. All polarities shall be defined in terms of the voltage on the coaxial cable center conductor ($V_{in}$+ or $V_{in}$-) as referenced to the coaxial shield.

**Table 121 – Receiver data output definitions: 5 Mbit/s, voltage-mode, coaxial wire**

| Input level at medium | RxDATA | Comments |
|---|---|---|
| $V_{in}$ more positive than positive data sensitivity limit ($V_{sense}$+) | true (1) | See Table 124 |
| $V_{in}$ more negative than negative data sensitivity limit ($V_{sense}$-) | false (0) | See Table 124 |
| $V_{in}$ between positive and negative data sensitive limits | undefined | Allows for hysteresis and tolerance |

**Table 122 – Receiver carrier output definitions: 5 Mbit/s, voltage-mode, coaxial wire**

| Input level at medium | RxCARRIER | Comments |
|---|---|---|
| $V_{in}$ more positive than high carrier sensitivity limit ($V_{sense}$H) | true (1) | See Table 124 |
| $V_{in}$ lower than low carrier sensitivity limit (or negative) ($V_{sense}$L) | false (0) | See Table 124 |
| $V_{in}$ between low and high carrier sensitivity limits | undefined | Allows for hysteresis and tolerance |

The medium interface shall conform to the requirements shown in Table 123, Table 124 and Table 125.

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**Table 123 – Coaxial wire medium interface – transmit specifications**

| Specification | Limits / characteristics | Comments |
|---|---|---|
| Transmit level (Tx level) peak-to-peak | 8,2 V ± 1,3 V [a, b, c] | See Figure 103 |
| Transmit level asymmetry (between 0 and 1) | < 450 mV max [b, d] | |
| Transmit signal distortion (over voltage, droop, ring) | ± 10 % [a, e] | See Figure 103 |
| Total transmit jitter (Tx Jitter) | < 5 ns | See Figure 103 |
| Transmitter output impedance | 20 Ω max | |
| Maximum transmitter off noise level | 5 mV max [a] | |
| Time from NETENABLE false to transmitter off noise level | 400 ns [a] | |
| Slew limit | 1 V/ns max [a] | See Figure 103 |
| Rise / fall limit (10 % to 90 % of peak-to-peak) | 30 ns max [a] | See Figure 103 |

[a] This shall be a peak-to-peak voltage as measured into a 37,5 Ω load from 0 MHz to 20 MHz.

[b] The transmit level shall be measured at the estimated mid-point between any peaks or troughs in both top and bottom of the waveform.

[c] This level shall be 0,5 V lower when measured as inside of eye pattern when driving a tap for a minimum signal of 6,4 V (peak-to-peak).

[d] This shall be measured as the absolute difference between the absolute value of Transmit level for 1 (+ voltage) and the absolute value of transmit level for 0 (- voltage) as measured into a 37,5 Ω load from 0 MHz to 20 MHz.

[e] Levels shall be a function of the actual measured transmit voltage.

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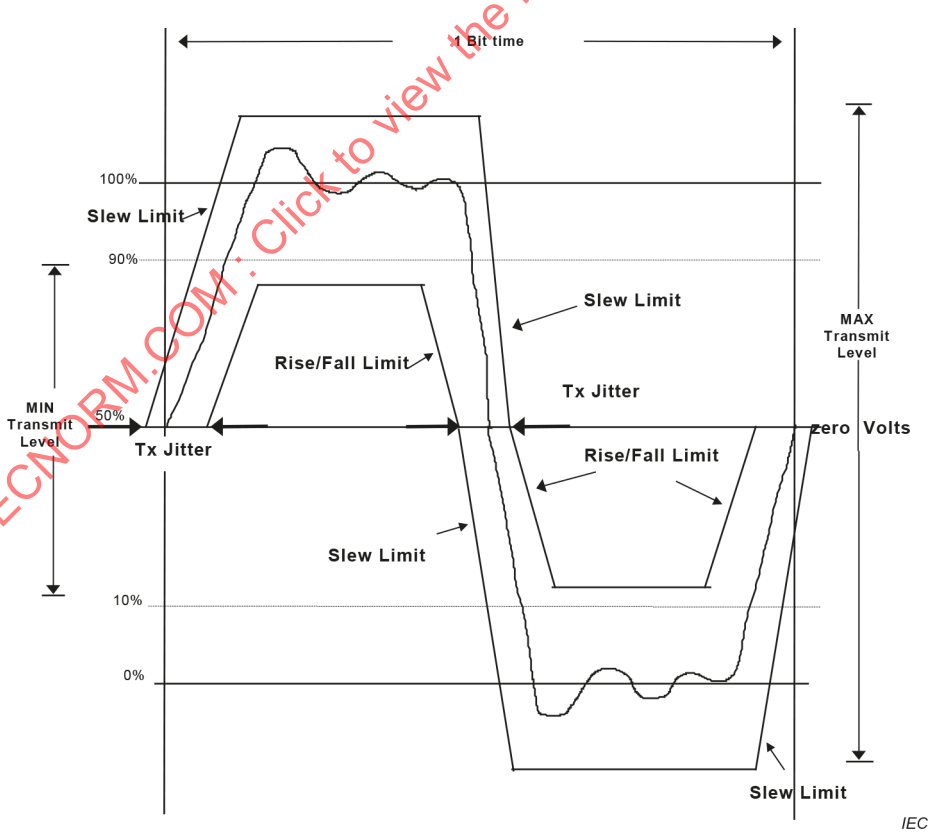


**Figure 103 – Coaxial wire MAU transmit mask**

**Table 124 – Coaxial wire medium interface – receive**

| Specification | Limits / characteristics | Comments |
|---|---|---|
| Minimum receive signal level (peak-to-peak) | 510 mV | Inside of eye pattern as shown in Figure 104 |
| Data threshold voltage | zero V | Negative and positive sensitivity limits allow for hysteresis and tolerance |
| Negative data sensitivity limits ($V_{sense}$-) | −140 mV | Allows for hysteresis and tolerance |
| Positive data sensitivity limits ($V_{sense}$+) | +140 mV | Allows for hysteresis and tolerance |
| Low carrier sensitivity limit ($V_{sense}$L) | +23 mV | Allows for hysteresis and tolerance |
| High carrier sensitivity limit ($V_{sense}$H) | +255 mV | Allows for hysteresis and tolerance |
| `RxData` pattern jitter (peak-to-peak) for $V_{in}$ > 510 mV | < 40 ns | Inside of eye pattern as shown in Figure 104 shall be true when $V_{in}$ > minimum receive signal level |

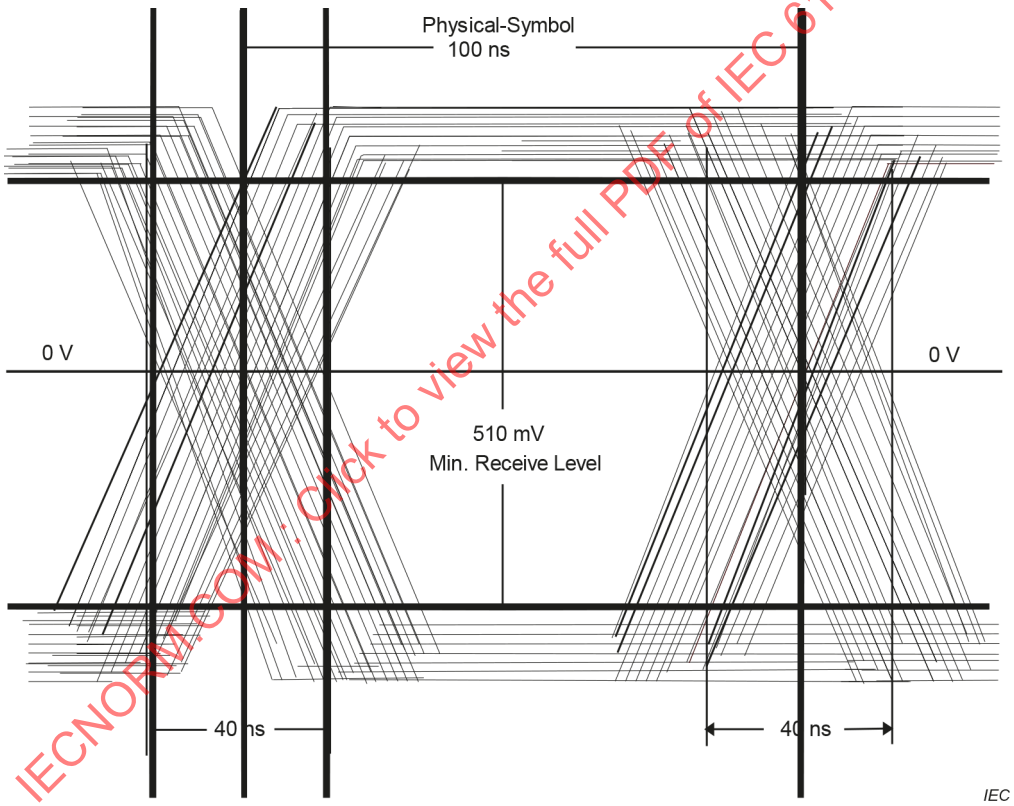


**Figure 104 – Coaxial wire MAU receive mask**

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**Table 125 – Coaxial wire medium interface – general**

| Specification | Limits / characteristics | Comments |
|---|---|---|
| Coupling | Transformer coupled | Ground isolated |
| Isolation at 0 Hz | 500 kΩ min [a] | Shield shall be R/C coupled to local earth |
| Input impedance (Tx Off) | 0,2 dB tap loss | (See Figure 108)<br>Alternative to impedance model |
| Impedance model (Tx Off) | | Alternative to input impedance |
| Series inductance | 0,56 µH with a tolerance of ± 20 % [b] | Power on |
| Parallel inductance | 425 µH with a tolerance of ± 20 % [b] | Power on |
| Parallel capacitance | 50 pF max [b]<br>55 pF max [b] | Power on<br>Power off |
| Parallel resistance | 3,9 kΩ with a tolerance of ± 20 % [b]<br>3,4 kΩ with a tolerance of ± 20 % [b] | Power on<br>Power off |
| Connector | BNC or TNC | See Annex F for more details |

[a] Capacitor value shall be 0,01 µF/500 V minimum. This requirement applies to all medium interfaces connected to the network.

[b] All impedance specifications shall be met with the transmitter off and with power applied or removed as shown. All impedance specifications shall be met over the entire receiver dynamic range from minimum receive level to maximum transmit level.

NOTE 3 A reference design example for a 5 Mbit/s, voltage mode, coaxial wire MAU transceiver is shown in H.1.1

## 18.3 Transformer 5 Mbit/s, voltage-mode, coaxial wire

NOTE 1 The Transformer couples the transmit and receive signals to and from the medium. An important feature of the transformer is that it provides galvanic isolation or ground isolation between nodes. This prevents large common-mode voltages due to ground voltage differences between nodes. Also prevented are large ground loops, which can be susceptible to low frequency magnetic coupling.

Figure 105 shows the schematic symbol for the transformer.

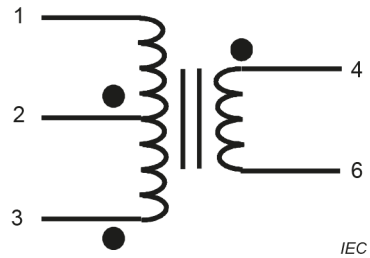


**Figure 105 – Transformer symbol**

Coupling transformers shall conform to the requirements specified in Table 126.

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**Table 126 – 5 Mbit/s, voltage-mode, coaxial wire transformer electrical specifications**

| Specification | Min. | Typical | Max. |
|---|---|---|---|
| Inductance (measured at 40 kHz and 100 mV) | 350 µH | 750 µH | |
| Winding capacitance (measured at 10 MHz) | 16,0 pF | 24,8 pF | 29,5 pF |
| Parallel resistance (core loss) | 8,0 kΩ | 9,1 kΩ | 11,2 kΩ |
| Leakage inductance | 255 nH | 441 nH | 625 nH |
| Galvanic isolation (at 47 Hz -63 Hz, less than 1,0 mA) | 500 $V_{RMS}$ for 60 s<br>600 $V_{RMS}$ for 1 s | | |
| Resonant frequency | 1,0 MHz | 1,4 MHz | 1,8 MHz |

Leakage inductance shall be measured between pins 1 and 2 with pins 4 and 6 connected together. Galvanic isolation shall be measured with pins 1, 2 and 3 tied together and with pins 4 and 6 tied together. The galvanic isolation requirement shall be met from pin 1 to pin 4, from pin 1 to core, and from pin 4 to core. All other measurements shall be made between pins 4 and 6 with pin 2 connected to instrument ground.

NOTE 2 A reference design example for a 5 Mbit/s, voltage mode, coaxial wire MAU transformer is shown in H.1.2.

### 18.4 Connector 5 Mbit/s, voltage-mode, coaxial wire medium

The connector used on a node shall be a BNC or TNC jack, in accordance with the requirements of this document (see Annex F).

### 18.5 Topology 5 Mbit/s, voltage-mode, coaxial wire medium

A segment shall comprise a trunk-spur architecture. The trunk shall consist of coaxial cable and shall be terminated at both ends by a resistor equal to 75 Ω with a tolerance of ± 5 %.

NOTE 1 This limits the reflections from transmitted signals on the trunk reflecting at the ends of the cable.

Nodes shall be attached to the network via drop cables. The drop cables shall attach to the trunk using the specified taps. These taps shall contain passive circuitry that allows trunk attachment while minimizing reflections due to attachment loading.

Nodes connected to the deterministic control network shall not terminate the drop cable shield directly to ground. Termination of the shield shall be in accordance with Table 125. To properly terminate each drop cable's shield, a resistor in parallel with a 0,01 µF capacitor shall be used. The parallel R-C shall be connected from shield to ground.

Figure 106 shows a topology example.

NOTE 2 In this example, two segments are connected by a repeater to form a seven node link.

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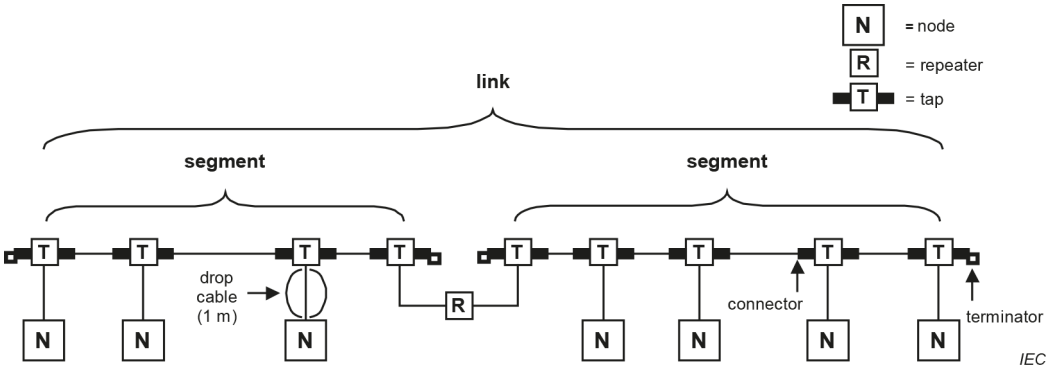


**Figure 106 – 5 Mbit/s, voltage-mode, coaxial wire topology example**

Topology limits are shown in Figure 107. Up to 48 nodes can be connected to a segment of length up to 1 km as shown in Figure 107. The trade-off between distance and number of nodes is shown in Figure 107. If a combination of nodes and distance is required that exceeds the segment limits, then a PhL repeater device shall be used (see Annex G). With respect to the medium, a PhL repeater device shall appear, electrically and mechanically, to be the same as a node. The PhL repeater device shall require a tap for each segment to which it is connected, and therefore, can be attached anywhere on each segment. The repeaters shall not be placed in a manner that causes more than one connection between segments.

Any topology that supports a single path between any two PhL entities shall be supported. Multiple paths between PhL entities shall not be allowed by an implementation that claims conformance to Clause 18.

This PhL variant may be combined with other PhL variants within the same node, or in different nodes, by using the RM (repeater machine) and/or PhL repeater devices (see Annex G).

NOTE 3 See Annex G for more information on repeaters.

NOTE 4 These limits are based upon the cable specifications in 18.7.1.

Figure 107 shall apply when using taps as specified in 18.6 and trunk coaxial cable as specified in Table 128. Cables with attenuation characteristics other than those shown in Table 128 may be used if an appropriate segment length multiplier is applied to Figure 107.

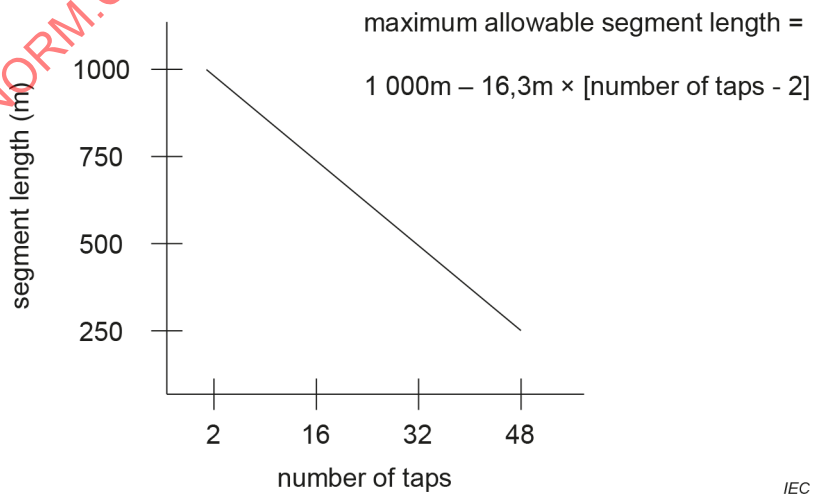


**Figure 107 – Coaxial wire medium topology limits**

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## 18.6 Taps 5 Mbit/s, voltage-mode, coaxial wire medium

### 18.6.1 Description

The tap shall contain passive circuitry that compensates for the added loading of the attached node.

NOTE 1 In this way, a small amount of transmission loss is experienced rather than an impedance discontinuity, and therefore a reflection, on the trunk for every node.

A tap shall be used for all nodes that conform to the specified coaxial wire medium attachment method.

NOTE 2 A reference design example for a 5 Mbit/s, voltage mode, coaxial wire MAU Tap is shown in H.1.3.

### 18.6.2 Requirements

The standard tap variant shall provide BNC jack connections at the trunk and a BNC plug at the node, the IP67 sealed tap variant shall provide TNC jack connections at the trunk and a TNC or BNC plug at the node, in accordance with the requirements of this document (see Annex F). A 1 m length of spur cable of the specified type shall be used in the tap if proper compensation for the spur cable is to be achieved.

NOTE 1 The electrical requirements of the tap are defined by the transmitted and reflected characteristics as seen by the trunk when the tap port is properly connected by the required spur and a node equivalent load. Although the tap has three ports, it can be viewed as a two port device when it is configured this way. The term, node equivalent load, means a load that represents the nominal impedance of a node. A node equivalent load can be constructed from discrete components so long as the equivalent load meets all requirements in Clause 18.

The transmission and reflection requirements shall be as shown in Figure 108. Scattering parameters (S11, S22, S12, and S21) shall be used to define the tap electrical requirements. S11 and S22 shall be used to define the reflection characteristics of the trunk connector of a tap while the spur is terminated by a node equivalent load and the other trunk connector is terminated with a trunk terminator (75 Ω with a tolerance of ± 5 %). S12 and S21 shall be used to define the transmission characteristics of the tap from one trunk connector to the other with the drop cable terminated by a node equivalent load. The transmission and reflection characteristics of all taps shall fall in the pass region defined in Figure 108.

NOTE 2 The tap is a reciprocal device (S11=S22, S12=S21) so trunk port orientation is arbitrary.

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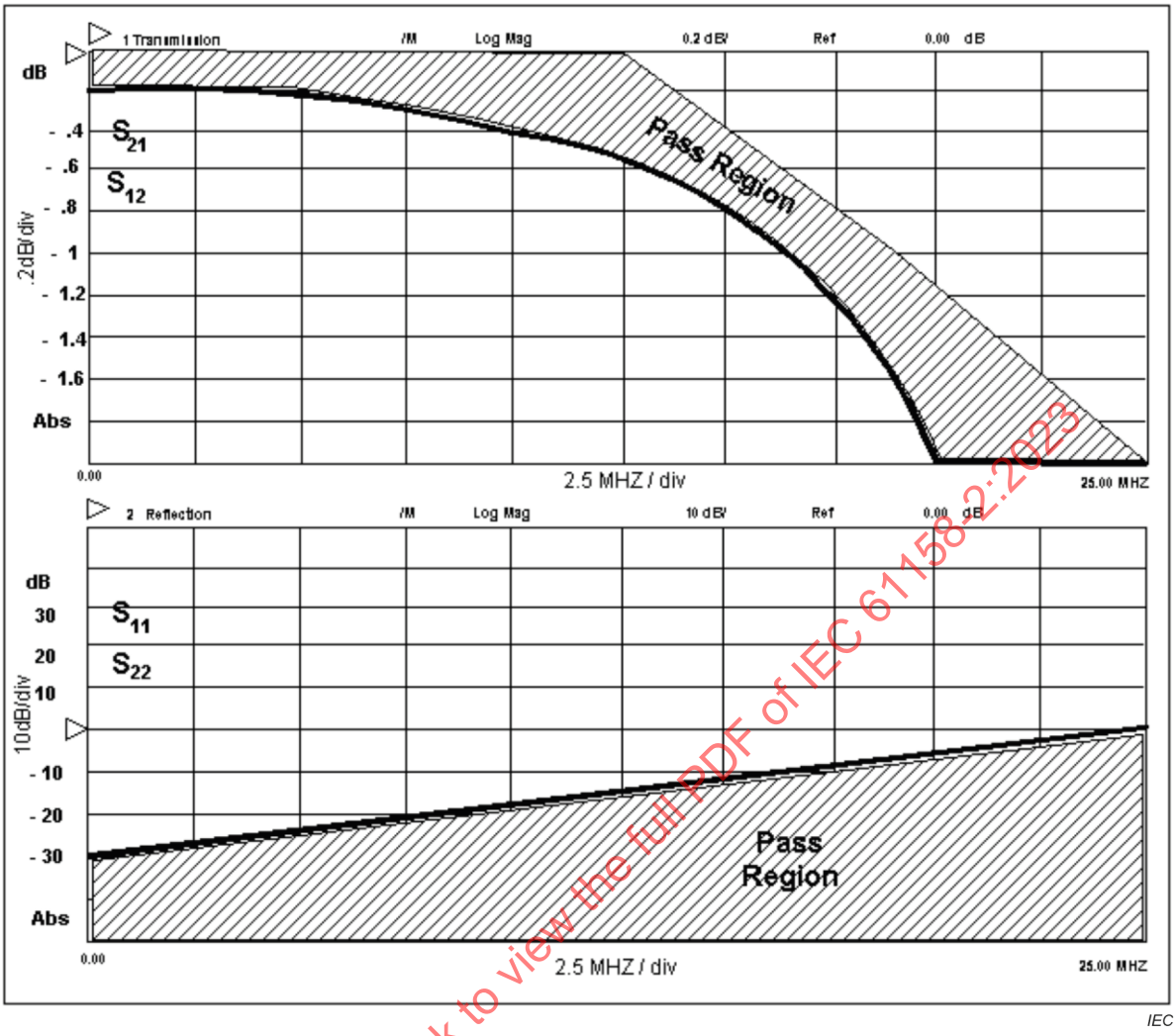


**Figure 108 – Coaxial wire medium tap electrical characteristics**

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### 18.6.3 Spur

The spur cable shall conform to the limits and characteristics shown in Table 127.

**Table 127 – Coaxial spur cable specifications**

| Specification | Limits / characteristics |
|---|---|
| Shielding | Dual braided shield, each braid is 95 % coverage |
| Impedance | 75 Ω ± 3 Ω |
| Delay | 4,1 ns/m ± 0,1 ns/m |
| Attenuation (dB/100 m) at | |
| 1 MHz | 1,25 |
| 5 MHz | 3,01 |
| 10 MHz | 4,33 |
| 25 MHz | 6,89 |
| 50 MHz | 10,1 |
| Structural return loss | 23 dB minimum from 5 MHz to 50 MHz |
| Conductor DC resistance | 92 Ω/km nominal |
| Shield DC resistance | 10,5 Ω/km nominal |
| Nominal capacitance | 54,13 pF/m |

## 18.7 Trunk 5 Mbit/s, voltage-mode, coaxial wire medium

### 18.7.1 Trunk Cable

The trunk cable shall meet the specification given in Table 128.

**Table 128 – Coaxial trunk cable specifications**

| Specification | Limits / characteristics |
|---|---|
| Shielding | Quad shield |
| Impedance | 75 Ω ± 3 Ω |
| Delay | 4,1 ns/m ± 0,1 ns/m |
| Attenuation (dB/100 m) at | |
| 1 MHz | 1,15 |
| 2 MHz | 1,25 |
| 5 MHz | 1,48 |
| 10 MHz | 1,94 |
| 20 MHz | 2,82 |
| 50 MHz | 4,49 |
| Structural return loss | 23 dB minimum from 5 MHz to 50 MHz |
| Conductor DC resistance | 92 Ω/km nominal |
| Shield DC resistance | 24 Ω/km nominal |
| Nominal capacitance | 53,15 pF/m |

Spur cable as specified in Table 127 may also be used for trunk cable in limited lengths (up to 10 m per segment).

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### 18.7.2 Connectors

The trunk connection shall use a BNC or TNC plug, in accordance with the requirements of this document (see Annex F).

## 19 Type 2: Medium attachment unit: 5 Mbit/s, optical medium

### 19.1 General

NOTE 1 Clause 19 specifies the optical medium and PhL variant. Information important to designing the PhL connection is captured here.

NOTE 2 The fiber medium attachment method defines three fiber media and PhL variants. The first variant covers fiber media and PhL requirements for a short-range system for distances of up to 300 m (nominal), the second variant covers fiber media and PhL requirements for a medium-range system for distances of up to 7 km (nominal), and the last variant covers fiber media and PhL requirements for a long-range system for distances of up to 20 km (nominal).

The fiber medium attachment method shall incorporate a full duplex point to point or ring topology using a transmitter and receiver at each end of a pair of fibers.

For all variants, the fiber medium attachment methods shall be defined either as a point-to-point link or as a ring topology. The point-to-point link shall connect between end nodes, end nodes and PhL repeater devices, or PhL repeater and PhL repeater. The ring topology shall connect between any two or more nodes or devices that implement the ring repeater machine (RRM), which is described in Annex G. Switching between media or topologies shall require the use of a PhL repeater device. This shall be implemented as an active hub, active star or active ring. An active hub or active star shall consist of a minimum of two ports.

NOTE 3 The physical layer can be implemented to allow certification for operation in explosive atmospheres, without sacrificing distance or reducing the number of nodes. This document does not include requirements for intrinsic safety certification, but seeks to exclude conditions or situations that would prevent intrinsic safety certification.

The fiber medium MAU shall consist of the fiber transceiver and fiber connector. The transceiver shall use the signals defined in the MDS-MAU interface to generate those necessary to drive the transceiver. Attachment to the medium shall be via fiber connectors.

### 19.2 Transceiver 5 Mbit/s, optical medium

To support a fiber medium, a fiber transceiver shall transmit and receive the L and H signals from the MDS. The transmitter portion of the transceiver shall obtain transmit signals from the MDS-MAU interface, representing H and L symbols, and transmits either 'light on' (for H) or 'light off' (for L) using a direct coupled transceiver. This means that the transceiver shall be capable of transmitting and receiving PhL signaling at frequencies from zero (no Ph-symbol transitions) to 10 MHz minimum.

NOTE Direct coupled transceivers are required because the MDS and MAU sublayers, as specified, do not provide for the insertion and deletion of an idle sequence when there is no L or H data to be sent, i.e. during periods of no Ph-symbol activity.

The complement of this function shall be performed in the receiver, which shall provide RxDATA and RxCARRIER indications to the MDS-MAU interface as shown in Figure 109, a functional block diagram depicting the MAU components.

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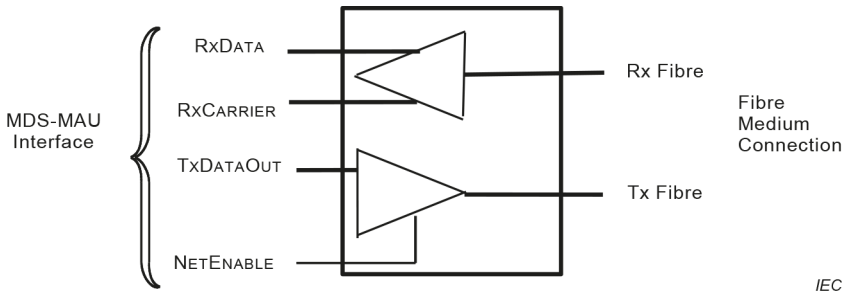


**Figure 109 – MAU block diagram 5 Mbit/s, optical fiber medium**

The transmit signals shall be as shown in Table 129.

**Table 129 – Transmit control line definitions 5 Mbit/s, optical fiber medium**

| TxDataOut | NetEnable | Physical symbol | Signal on fiber medium |
|---|---|---|---|
| don't care(x) | false(0) | don't care (x) | light off |
| false(0) | true(1) | L | light off |
| true(1) | true(1) | H | light on |

The fiber interface transmit and receive limits shall be as shown in Table 130.

**Table 130 – Fiber medium interface 5,0 Mbit/s, optical**

| Specification | Limits / Characteristics | Comments |
|---|---|---|
| Input pattern jitter | 40 ns peak-to-peak max. | Measured on RxData |
| Total transmit jitter | < 5 ns peak-to-peak | |

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### 19.3 Topology 5 Mbit/s, optical medium

The media topology defined for a fiber medium attachment variant shall be a point-to-point link or a ring topology. The point-to-point topology shall be between any two PhL entities that meet the requirements of Clause 19 and that do not implement the RRM. The ring topology shall be between any two PhL entities that meet the requirements of Clause 19 and that implement the RRM (see Annex G). Switching between these two topologies shall require the use of a PhL repeater or of any device implementing the RRM function and repeater PhL. In either case, nodes and repeaters shall be cascadable as long as each link meets the requirements specified in Clause 19. The total signal propagation delay shall be used in the calculation of the slot time value as described in IEC 61158-4-2.

Any topology that supports a single path between any two PhL entities shall be supported. Multiple paths between PhL entities shall not be allowed by an implementation that claims conformance to Clause 19.

This PhL variant may be combined with other PhL variants within the same node, or in different nodes, by using the RM (repeater machine) and/or PhL repeater devices (see Annex G).

### 19.4 Trunk fiber 5 Mbit/s, optical medium

The trunk fiber shall meet the requirements specified in 19.6 for the appropriate fiber PhL variant.

### 19.5 Trunk connectors 5 Mbit/s, optical medium

The Trunk connectors shall be in accordance with the requirements of this document (see Annex F) for the different fiber PhL variants.

### 19.6 Fiber specifications 5 Mbit/s, optical medium

The signal characteristics for fiber media and PhL variant at 25 °C shall be as shown in Table 131, Table 132 and Table 133.

**Table 131 – Fiber signal specification 5 Mbit/s, optical medium, short range**

| Specification | Min. | Nominal | Max. |
|---|---|---|---|
| **Fiber** | | | |
| Distance | 0 m | 300 m | |
| Fiber attenuation at λ | | 6 dB/km | |
| Fiber technology | Step index, hard clad silica (HCS) | | |
| Core/cladding | 200/230 µm | | |
| Numerical aperture | 0,5 | | |
| **System** | | | |
| BER | $10^{-9}$ | | |
| Power budget | 3,9 dB | 9,5 dB | |
| **Transmitter** | | | |
| Wavelength λ | 640 nm | 650 nm | 660 nm |
| Spectral width | | 21 nm | |
| Coupled power, $P_{T\ on}$ (transmit light on) | −16,1 dBm, peak | −12,5 dBm, peak | −8,5 dBm, peak |
| Coupled power, $P_{T\ off}$ (transmit light off) | | | −44 dBm, peak |
| Optical rise time $T_{rise}$ | | | |
| Optical fall time $T_{fall}$ | | | |
| **Receiver** | | | |
| $P_{R\ MIN}$ (receive light on) | | −25 dBm, pk | −23 dBm, peak |
| $P_{R\ MAX}$ (receive light on) | −1,0 dBm | +3,0 dBm | |
| Pulse width distortion | | | 30 ns |

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**Table 132 – Fiber signal specification 5 Mbit/s, optical medium, medium range**

| Specification | Min. | Nominal | Max. |
|---|---|---|---|
| **Fiber** | | | |
| Distance | 0 m | 7 km | |
| Fiber attenuation at λ | | 1,5 dB/km | |
| Fiber technology | Graded index, multi-mode | | |
| Core/cladding | 62,5/125 µm | | |
| Numerical aperture | 0,275 | | |
| **System** | | | |
| BER | $10^{-9}$ | | |
| Power budget | 11,3 dB | 16,4 dB | |
| **Transmitter** | | | |
| Wavelength λ | 1 270 nm | 1 300 nm | 1 370 nm |
| Spectral width | | 130 nm | 185 nm |
| Coupled power, $P_{T\ on}$ (transmit light on) | −15,5 dBm, peak | −13,5 dBm, peak | −12,0 dBm, peak |
| Coupled power, $P_{T\ off}$ (transmit light off) | | | −40 dBm, peak |
| Optical rise time $T_{rise}$ | | 1,8 ns | 4,0 ns |
| Optical fall time $T_{fall}$ | | 2,2 ns | 4,0 ns |
| **Receiver** | | | |
| $P_{R\ MIN}$ (receive light on) | −33,5 dBm, pk | −31,8 dBm, peak | −28,8 dBm, peak |
| $P_{R\ MAX}$ (receive light on) | | | |
| Pulse width distortion | | | 2 ns |

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**Table 133 – Fiber signal specification 5 Mbit/s, optical medium, long range**

| Specification | Min. | Nominal | Max. |
|---|---|---|---|
| **Fiber** | | | |
| Distance | | | 20 km |
| Fiber attenuation at λ | | 0,5 dB/km | |
| Fiber technology | Graded index, single mode | | |
| Core/cladding | 10/125 µm | | |
| Numerical aperture | 0,1 | | |
| **System** | | | |
| BER | $10^{-9}$ | | |
| Power budget | 10 dB | | |
| **Transmitter** | | | |
| Wavelength λ | 1 270 nm | 1 300 nm | 1 370 nm |
| Spectral width | | 70 nm | |
| Coupled power, $P_{T\ on}$ (transmit light on) | −18 dBm, pk | −15 dBm, pk | −10 dBm, pk |
| Coupled power, $P_{T\ off}$ (transmit light off) | | | −40 dBm pk |
| Optical rise time $T_{rise}$ | | 2 ns | 4,0 ns |
| Optical fall time $T_{fall}$ | | 2,2 ns | 4,0 ns |
| **Receiver** | | | |
| $P_{R\ MIN}$ (receive light on) | | −32 dBm, pk | −30 dBm, pk |
| $P_{R\ MAX}$ (receive light On) | −10 dBm | | |
| Pulse width distortion | | | 2 ns |

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# 20 Type 2: Medium attachment unit: network access port (NAP)

## 20.1 General

Figure 110 shows the location of the network access port (NAP) PhL and Medium within the ISO/OSI reference model.

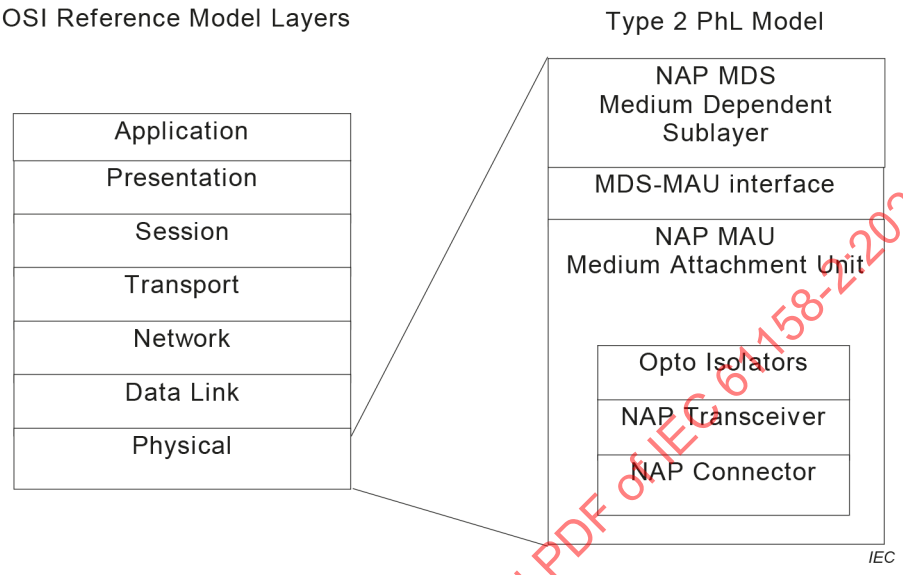


**Figure 110 – NAP reference model**

Local connection to a computer (desktop or laptop), handheld programming device or other temporary network connection shall be made through the NAP transceiver using protocol and data rates as specified for the trunk. The NAP transceiver shall obtain a single transmit line from the MDS-MAU interface, transmit to and receive from, another node at the other end of the NAP cable and provide a single receive line back to the MDS-MAU interface.

As these are single lines, no representation of carrier on/off shall be present. These signals shall be either a logical 'zero' or a logical 'one' at all times. The medium shall be driven from the single transmit line at all times.

The NAP PhL shall support a point-to-point connection between two nodes. This topology shall not be multi-dropped to support more than two nodes.

Any topology that supports a single path between any two PhL entities shall be supported. Multiple paths between PhL entities shall not be allowed by an implementation that claims conformance to Clause 20.

A node, whose primary connection to the link is through the NAP PhL variant, shall be considered a transient network node. A node, whose primary connection to the link is via any other PhL variant, shall be considered a permanent network node. A transient node shall communicate with another transient node or a permanent node using the NAP medium. The permanent node shall utilize the repeater machine (RM) functionality (see Annex G) contained in the DLL of that node to allow the transient node to communicate to other permanent nodes as shown in Figure 111. A permanent node shall function as a transient node when no other PhL medium is connected as shown in Figure 111.

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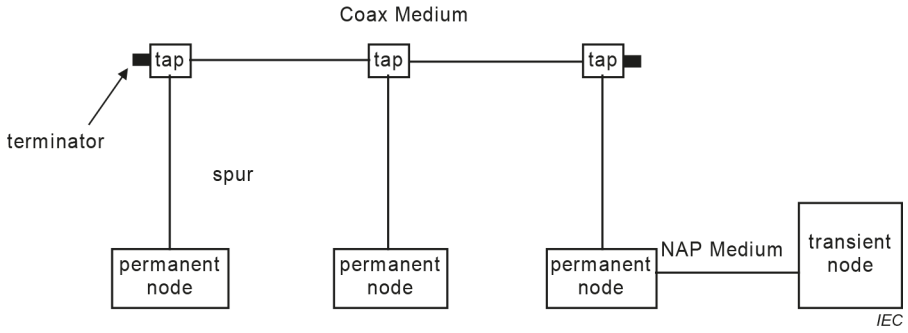


**Figure 111 – Example of transient and permanent nodes**

This PhL variant may be combined with other PhL variants within the same node, or in different nodes, by using the RM (repeater machine) and/or PhL repeater devices (see Annex G).

## 20.2 Signaling

The signaling requirements for the NAP port shall be as shown in Table 134.

**Table 134 – NAP requirements**

| NAP interface specification | Design specification | Comments |
|---|---|---|
| **NAP interface - General** | | |
| Coupling | DC | Opto-isolator required for programming nodes |
| Link configuration | Two uni-directional TIA-422-B pair | One Rx, one Tx |
| Connector | Shielded RJ-45 | See Annex F |
| Termination | 100 Ω internal on /RxPTC only | |
| **NAP - Transmit** | | |
| Output level at NAP medium with /TxPTC = true | 2,5 V min. | Measured between Tx_H and GND REF pin with 100 Ω NAP receive load connected (see Table F.2) |
| Output level at NAP medium with /TxPTC = false | 2,5 V min. | Measured between Tx_L and GND REF pin with 100 Ω NAP receive load connected (see Table F.2) |
| Output level at NAP medium with /TxPTC = true | 0,5 V max. | measured between Tx_L and GND REF pin with 100 Ω NAP receive load connected (see Table F.2) |
| Output level at NAP medium with /TxPTC = false | 0,5 V max. | measured between Tx_H and GND REF pin with 100 Ω NAP receive load connected (see Table F.2) |
| Output level at NAP medium with /TxPTC = data | 4,0 V min. | (Tx_H - Tx_L) measured as peak to peak with 100 Ω load (see Table F.2) |
| Total Transmit Jitter | ± 5 ns max. | |
| Termination | None | |
| **NAP - Receive** | | |
| Receive level at NAP medium with /TxPTC = data | 2,5 V min. | (Rx_H - Rx_L) measured as peak to peak (see Table F.2) |
| Receive jitter | ± 15 ns max. | |
| Termination | 100 Ω with a tolerance of ± 10 % | Across differential lines |
| Fault receive signal | /RxPTC = true | If medium is disconnected, shorted, receiver turned off or disabled, /RxPTC shall be true |

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### 20.3 Transceiver

The NAP MAU block diagram shown in Figure 112 represents both the isolated and non-isolated implementations. The isolated NAP shall be used on transient nodes. Opto-isolation shall be provided to prevent ground loop currents from flowing between nodes at different ground potentials. Opto-isolation shall not be required if the node is self-powered and is not grounded. The non-isolated NAP shall be used on permanent nodes.

NOTE 1 A transient node is defined as a node with primary and normal connection to the network through the NAP of another node. This includes, but is not limited to, computer interface cards, configuration nodes and other nodes that are transient or temporary network connections.

NOTE 2 A permanent node is defined as a node with primary and normal connection to the network through a PhL other than the NAP. This includes, but is not limited to: PLCs, I/O rack adapters, controllers, robots, welders and other nodes that are connected to the network on a mostly permanent basis.

If a node can be used as both a transient and permanent node, it shall include opto-isolation in the design of the NAP (unless it is self-powered and cannot be grounded).

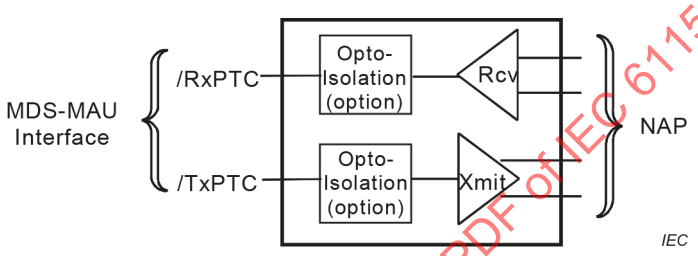


**Figure 112 – NAP transceiver**

NOTE 3 A reference design example for a Network Access Port MAU is shown in Clause H.2.

### 20.4 Connector

The connector used at both ends of a NAP connection shall be a shielded 8-pin RJ-45 type connector, as specified in Annex F.

### 20.5 Cable

The NAP cable shall have 8 conductors and an overall shield. The shield shall be designed to minimize electromagnetic interference. The cable connector pins shall be as shown in Table F.2

As the NAP connector and pin connections are the same for both a node and a transient node, the cable shall be built in a way that allows the correct transmit data and receive data connection. This shall be accomplished be reversing the connection on one end of the NAP cable as shown in Figure 113.

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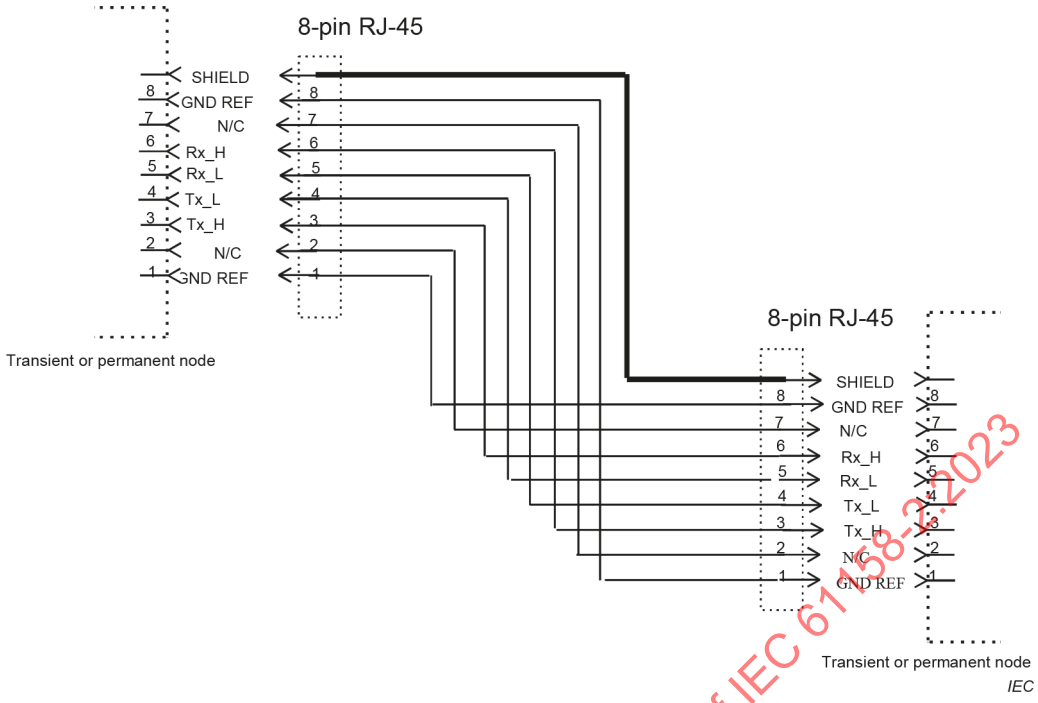


NOTE The NAP cable connectors are installed so that the signal lines are reversed to allow the correct connection. This allows the equipment to use the same pinout independent of function.

**Figure 113 – NAP cable**

The NAP cable shall meet the following requirements:

a) paired line characteristics = 100 Ω;

b) resistance (at 0 Hz) = 0,122 Ω/m;

c) wire gauge = 26 (7 strands, diameter 0,16 mm);

d) conductors = 8 plus overall shield;

e) maximum cable length = 10 m.

## 21 Type 3: Medium attachment unit: synchronous transmission, 31,25 kbit/s, voltage mode, wire medium

### 21.1 General

The 31,25 kbit/s voltage-mode MAU simultaneously provides access to a communication network and to an optional power distribution network. Devices attached to the network communicate via the medium and can be powered from it, or not. If bus-powered, power is distributed as direct voltage and current, and communications signals are superimposed on the DC power. In intrinsically safe applications, available power can limit the number of devices.

The network medium consists of twisted pair cable. Independent of topology, all attached devices, other than possibly the transmitting device, are high impedance to prevent significant network loading. Trapezoidal waveforms are used to reduce electromagnetic emissions.

Bus and tree topologies are supported. In either topology a network contains one trunk cable, terminated at both ends. In the bus topology, spurs are distributed along the length of the trunk. In the tree topology, spurs are concentrated at one end of the trunk. A spur can connect more than one device to the network, the number of devices depending on spur length.

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At the power frequency (DC), devices appear to the network as current sinks, with a limited rate of change of the supply current drawn from the medium. This prevents transient changes in load current from interfering with communication signals.

### 21.2 Transmitted bit rate

See 12.2.

### 21.3 Network specifications

#### 21.3.1 Components

Subclause 12.3.1 applies.

When selecting the individual components, make sure that all components meet the requirements of the FISCO model. Only components that are identified as an intrinsically safe electrical apparatus or as an associated electrical apparatus in accordance with IEC 60079-11 may be installed in intrinsically safe fieldbus segments. To comply with IEC 60079-14:xxx, 12.2.5.1, the permitted values of the input parameters $U_I$, $I_I$, and $P_I$ of an intrinsically safe apparatus (e.g. a field devices) shall not be less than the certified maximum values of the output parameters $U_0$, $I_0$ and $P_0$ of the associated power device. Additional restrictions applicable to the individual components (e.g., limitation of the supply power of ≤1,2 W) have to be taken into account as well.

Table 135 lists possible combinations of devices from different system categories.

**Table 135 – Mixing devices from different categories**

| Explosion protection of the bus-segment | Explosion protection of the power device | Explosion protection of the field device | | | | | |
|---|---|---|---|---|---|---|---|
| | | EEx ia | | | EEx ib | | |
| | | IIC | IIB | IIC/IIB | IIC | IIB | IIC/IIB |
| EEx ia IIC (Group IIC) | [EEx ia] IIC | x | | x | | | |
| EEx ia IIB (Group IIB) | [EEx ia] IIB | x | x | x | | | |
| | [EEx ia] IIC | x | x | x | | | |
| EEx ib IIC (Group IIC) | [EEx ib] IIC | x | | x | x | | x |
| | [EEx ia] IIC | x | | x | x | | x |
| EEx ib IIB (Group IIC) | [EEx ib] IIB | (x)[a] | x | x | (x)[a] | x | x |
| | [EEx ib] IIC | x | x | x | x | x | x |
| | [EEx ia] IIB | (x)[a] | x | x | (x)[a] | x | x |
| | [EEx ia] IIC | x | x | x | x | x | x |
| By any combination it shall be assured that the absolute maximum ratings for the input of the field device fit to the output characteristics of the power device: $U_I \geq U_O$ $I_I \geq I_O$ $P_I \geq P_O$ | | | | | | | |

[a] These combinations are possible in theory but in practice they are irrelevant, because the field devices may be certified for group IIC and for group IIB as well (see column IIC/IIB).

Connection of bus-powered devices and local-powered devices on an intrinsically safe fieldbus is permitted if the local-powered devices are provided with suitable isolation in accordance with IEC 60079-11.

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Although connection of a fieldbus station (i.e., field device, hand-held terminal, and coupler for the bus master) with its poles reversed does not affect the functionality of the other devices connected to the fieldbus, an incorrectly installed bus station which is not equipped with automatic polarity detection will not be supplied with power or be able to send and receive. Stations with automatic polarity detection operate correctly with any allocation of the input terminals to the wires.

### 21.3.2 Topologies

A wire MAU shall operate in a network with a linear bus topology, consisting of a trunk, terminated at each end as specified in 21.8.5, to which communication elements are connected via couplers and spurs.

The coupler and communication element may be integrated in one device (i.e. zero length spur).

A tree topology with all the communication elements located at the ends of the trunk is regarded as a special case of a bus for the purpose of Clause 21.

Several communication elements can be connected to the trunk at one point using a multi-port coupler. An active coupler can be used to extend a spur to a length that requires termination to avoid reflections and distortions. Active repeaters can be used to extend the length of the trunk beyond that of a single segment as permitted by the network configuration rules.

### 21.3.3 Network configuration rules

A 31,25 kbit/s voltage-mode MAU shall be required to conform to the requirements of Clause 21 when used in a network which complies with these rules.

**Rule 1:** One fieldbus shall be capable of communication between the following numbers of devices, all operating at the same bit rate:

a) for a non IS fieldbus without power supplied via the signal conductors: between two and 32 devices;

b) for a non IS fieldbus with power supplied via the signal conductors: between two and the number of devices which can be powered via the signal conductors, assuming that a minimum of 120 mA shall be available to devices at the remote end from the power supply communicating with one device at the power supply end drawing 10 mA;

c) for an IS fieldbus: between two and the number of devices that can be powered via the signal conductors, assuming that a minimum of 40 mA shall be available to devices in the hazardous area.

NOTE 1 Rule 1 does not preclude the use of more than the specified number of devices in an installed system. Since the device power consumption is not specified, the number of bus-powered devices cannot be specified. Item b) assumes that the minimum power supply voltage is 20 VDC Item c) assumes that the IS barrier operates with a 19 VDC output.

**Rule 2:** A fully loaded (maximum number of connected devices) 31,25 kbit/s voltage-mode fieldbus segment shall have a total cable length, including spurs, between any two devices, of up to 1 900 m.

NOTE 2 1 900 m maximum cable length is the requirement for conformance to Clause 21 but this does not preclude the use of longer lengths in an installed system.

**Rule 3:** The total number of waveform regenerations by repeaters and active couplers between any two devices shall not exceed four.

**Rule 4:** The maximum propagation delay between any two devices shall not exceed 20 $T_{bit}$.

For efficiency of the network, that part of the turn-around time of any device on the network caused by a PhE between the end of a received frame and the beginning of the transmitted

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frame containing an associated immediate response should not exceed 5 bit times, no more than 2 bit times of which should be due to the MAU.

NOTE 3 As it is not mandatory to expose the DLL-PhL interface or the MDS-MAU interface, that part of the turn-around time of a fieldbus device caused by the PhL or the MAU is not specified and thus not available for conformance testing.

**Rule 5:** The fieldbus shall be capable of continued operation while a device is being connected or disconnected. Data errors induced during connection or disconnection shall be detected.

**Rule 6:** Failure of any communication element or spur (with the exception of a short circuit, low impedance, or jabber) shall not interfere with transactions between other communication elements for more than 1 ms.

**Rule 7:** In polarity sensitive systems the medium twisted pairs shall have distinctly marked conductors that uniquely identify individual conductors. The polarization shall be maintained at all connection points.

**Rule 8:** The degradation of the electrical characteristics of the signal, between any two devices, due to attenuation, attenuation distortion and mismatching shall be limited to the values indicated below.

a) Signal attenuation: The configuration of the bus (trunk and spur lengths, number of devices, IS barriers, galvanic isolators, and possible matching devices) shall be such that the attenuation between any two devices at the frequency corresponding to the bit rate shall not exceed 10,5 dB.

b) Attenuation distortion: The configuration of the bus (trunk and spur lengths and number of devices, IS barriers, and galvanic isolators) shall be such that between any two devices:

   [Attenuation (1,25 $f_r$) - Attenuation (0,25 $f_r$)] ≤ 6 dB

   Attenuation (1,25 $f_r$) ≥ Attenuation (0,25 $f_r$)

   where $f_r$ is the frequency corresponding to the bit rate. Attenuation shall be monotonic for all frequencies from 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz).

c) Mismatching distortion: Mismatching (due to spurs or any other effect, including one open circuit spur of maximum length) on the bus shall be such that, at any point along the trunk, in the frequency band 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz):

   $|Z - Z_{f_r}| / |Z + Z_{f_r}| \leq 0{,}2$

   where $Z_o$ is the characteristic impedance of the trunk cable and Z is the parallel combination of $Z_o$ and the load impedance at the coupler.

The concentration of couplers shall be less than 15 per 250 m.

NOTE 4 Rule 8 minimizes restrictions on trunk and spur length, number of devices etc. by specifying only the transmission limitations imposed by combinations of these factors. It is possible to use different combinations depending on the needs of the application.

**Rule 9:** The following rules shall apply to systems implemented with redundant media:

a) each channel (cable) shall comply with the network configuration rules;

b) there shall not be a non-redundant segment between two redundant segments;

c) repeaters shall also be redundant;

d) if the system is configured (by Systems management) to transmit on more than one channel simultaneously then the propagation time difference between any two devices on any two channels shall not exceed five bit times;

e) channel numbers shall be maintained throughout the fieldbus, i.e. channels 1, 2, 3… from Systems management shall always connect to physical channels 1, 2, 3…

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### 21.3.4 Power distribution rules for network configuration

See 12.3.4.

## 21.4 Transmit circuit specification for 31,25 kbit/s voltage-mode MAU

### 21.4.1 Summary

For ease of reference, the requirements of 21.2 and 21.4 are summarized in Table 98 and Table 99 (see 12.4.1).

### 21.4.2 Test configuration

Figure 79 (see 11.4.2) shows the configuration that shall be used for testing.

Differential signal voltage: $V_d = V_a - V_b$.

Test load resistance R = 50 Ω (0,5 cable $Z_o$) and C = 10 µF except where otherwise stated in a specific requirement.

### 21.4.3 Impedance

For both the bus interfaces (i.e., medium attachment unit MAU) of the field devices and coupling elements and the power supplies, 11.4 requires that the input impedance (can be measured from the bus line) in the signal frequency range (7,8 kHz to 39 kHz) does not pass below a minimum value during normal operation. With the exception of the first 10 ms following connection of a field device to a power supply, this requirement applies to all aspects of operation. Table 136 shows the input impedances of bus interfaces and power supplies.

**Table 136 – Input Impedances of bus interfaces and power supplies**

| | Impedance | Voltage range | Current range |
|---|---|---|---|
| Bus interface (e.g., field device) | ≥ 3 kΩ | 9 V to 32 V | For operating current |
| Intrinsically safe bus power supply | ≥ 400 Ω | For operating voltage | 0 to $I_{Max}$ |
| Non intrinsically safe bus power supply | ≥ 3 kΩ | For operating voltage | 0 to $I_{Max}$ |

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The input impedance of the bus interface shall be measured with a sinus signal whose amplitude shall be greater than the receiver sensitivity but always less than 2 Vss.

NOTE No measuring signal is defined for the power supply.

Impedance of the field device and the power supply shall be determined using the measuring circuit shown in Figure 114.

Impedance X of the tested device is calculated from the ratio of the two voltages $U_D$ and $U_R$.

$$X = R_M \times \frac{U_D}{U_R}$$

The two measured voltages represent complex values whose phase difference is included in the result. If $U_R$ is used as the reference, then:

$$X = R_M \times \frac{|U_D|}{|U_R|} \times e^{j\varphi}$$

where

$\varphi$ is the phase angle $\varphi(U_D)$ - $\varphi(U_R)$.

This reduces impedance measurement to a ratio measurement of two voltages and one phase difference measurement.

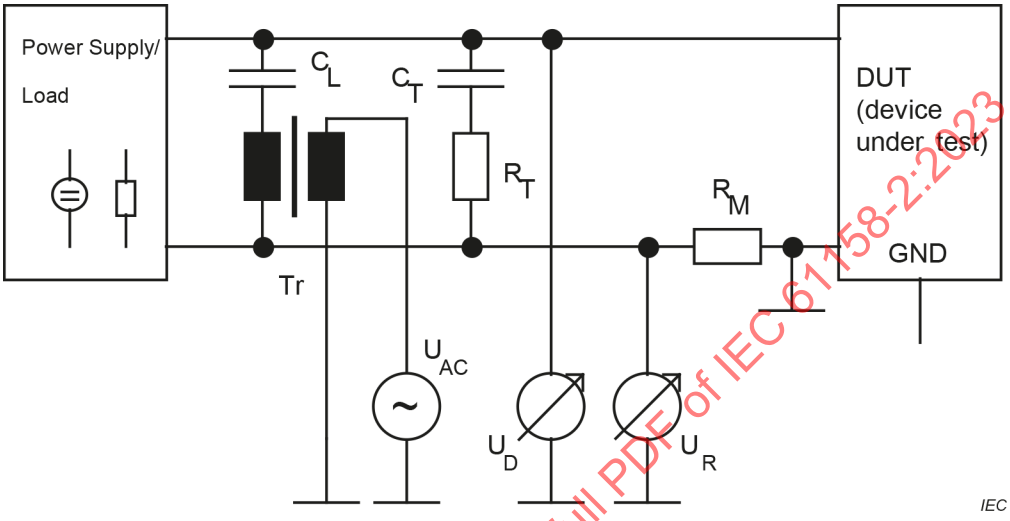


**Figure 114 – Circuit diagram of the principle of measuring impedance**

Example

CL = CT = 2 µF, RT = RM = 100 Ω

The phase angle can also be negative. If so, the object to be measured represents a negative load that amplifies rather than attenuates. This can be disregarded (it even has positive effects) for the signal frequency range from 7,9 kHz to 39 kHz as long as |X| remains within the specified range.

NOTE There is no specification for the impedance. Any low value is possible. In combination with unfavourable outside circuiting conditions (e.g., long stub lines), negative impedance can create an unattenuated oscillating circuit which turns the bus system into an oscillator although the object to be measured remains stable in the measuring circuit.

The following sources of errors can affect the result of the impedance measurement.

a) Non-linear distortions. Correction: Use frequency-selective measurement (i.e., only evaluate the fundamental wave) and oscillographic monitoring of the measuring signal.

b) Asymmetries in the measuring setup. Correction: Use symmetrical transformer Tr and avoid ground capacitances. Leave open any ground connection on the test object (e.g., caused by EMC filter) when measuring the impedance.

c) Noise signals generated by the test object. Correction: Measure the background noise. It shall be ≤ 1 $mV_{eff}$ (measured at 50 Ω). If this condition is met, the effect on the impedance measurement can be disregarded.

### 21.4.4 Symmetry

All bus interfaces shall be isolated from earth. The unbalanced capacitance between the two bus terminals and earth shall not exceed 250 pF. That is also required for barriers and power supplies.

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Under the condition that the impedance between each of the two bus terminals and earth only contains one capacitive component, measuring the two effective earth capacitances and then calculating the difference can determine asymmetry. Particularly when non-intrinsically safe bus interfaces, which can be coupled to the bus via a transformer, are used, significant inductive components are present. Even when coupling elements are used, which do not contain inductivities as components, inductive behavior caused by parasitic effects can be detected particularly for higher frequencies. At best, a purely capacitive asymmetry only can be assumed within a limited frequency range. For this reason, it is recommended to determine the Common Mode Rejection Ratio CMRR as defined in Figure 115 to evaluate the characteristics of symmetry.

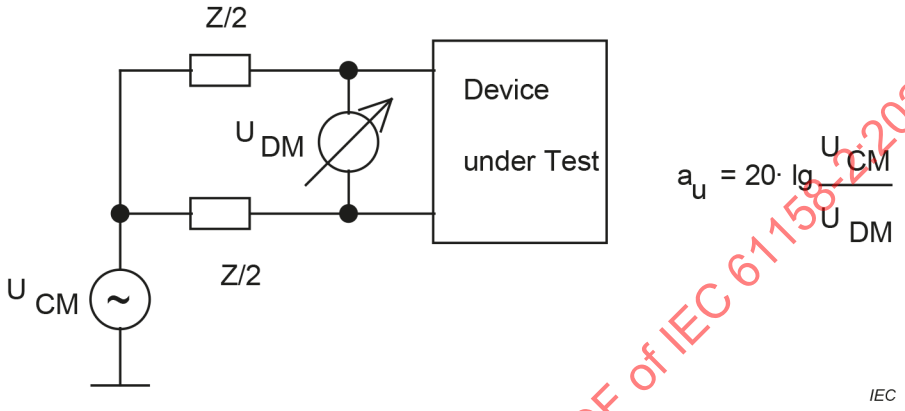


**Figure 115 – Definition of CMRR**

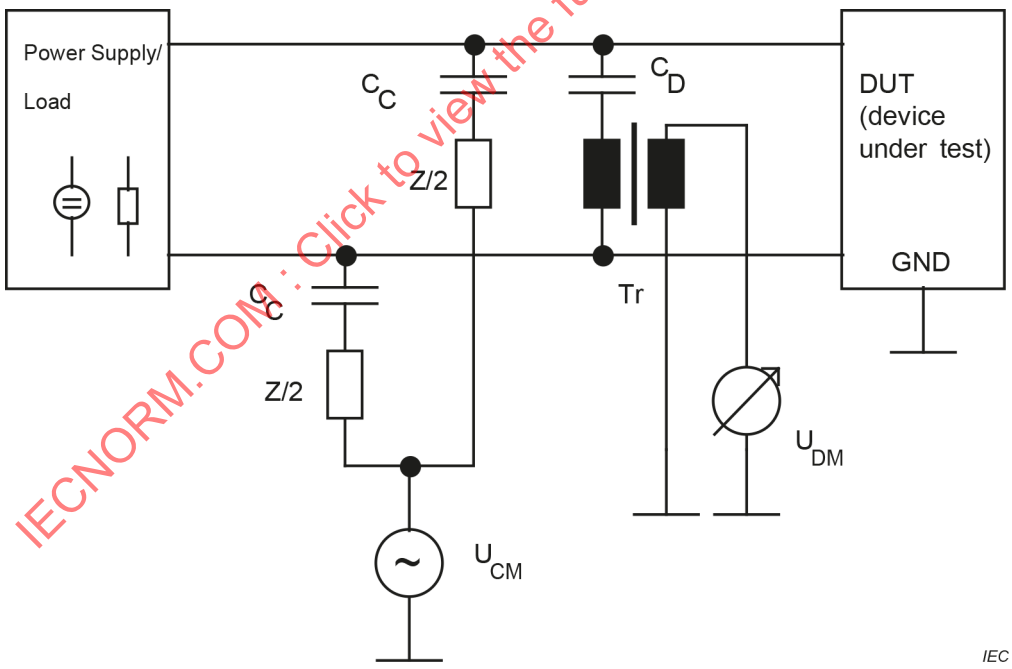


**Figure 116 – Block circuit diagram of the principle of measuring CMRR**

EXAMPLE

$C_C = C_D = 2$ µF, Z/2 = 25 Ω with a tolerance of ± 0,1 %.

Field device, barrier or power supply shall meet the required CMRR of Table 137. With regard to the unbalanced capacitance, the CMRR shall be higher than the values listed in Table 137. CMRR of the measuring instrument (e.g. as shown in Figure 116) without the device under test (i.e., DUT) shall be at least 10 dB above the listed values.

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**Table 137 – Required CMRR**

| Frequency | kHz | ≤ 40 | 120 | 400 | 1 200 |
|---|---|---|---|---|---|
| CMRR | dB | ≥ 50 | ≥ 40 | ≥ 30 | ≥ 20 |

### 21.4.5 Output level requirements

See 12.4.3.

### 21.4.6 Output timing requirements

See 12.4.4.

### 21.4.7 Signal polarity

See 11.4.5.

## 21.5 Receive circuit specification for 31,25 kbit/s voltage-mode MAU

See 12.5.

## 21.6 Jabber inhibit

See 12.6.

## 21.7 Power distribution

### 21.7.1 General

A device can optionally receive power via the signal conductors or be separately powered.

A device can be certified as intrinsically safe with either method of receiving power.

NOTE This document does not include requirements for IS-certification but seeks to exclude conditions or situations that would prevent IS certification.

A separately powered device can be connected to a powered fieldbus.

For ease of reference, the requirements of 21.7 are summarized in Table 138 and Table 139.

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**Table 138 – Network powered device characteristics for the 31,25 kbit/s voltage-mode MAU**

| Network powered device characteristics | Limits for 31,25 kbit/s |
|---|---|
| Operating voltage | 9,0 VDC to 32,0 VDC |
| Minimum withstand voltage, either polarity, for no damage | 35 V |
| Maximum rate of change of quiescent current (non-transmitting); this requirement does not apply within the first 10 ms after the connection of the device to an operating network or within the first 10 ms after the application of power to the network | 1,0 mA/ms |
| Maximum current; this requirement applies during the time interval of 100 µs to 10 ms after the connection of the device to an operating network or 100 µs to 10 ms after the application of power to the network (see Note) | Rated quiescent current plus 10 mA |
| NOTE The first 100 µs is excluded to allow for the charging of RFI filters and other capacitances in the device. The rate of change specification applies after 10 ms. | |

**Table 139 – Network power supply requirements for the 31,25 kbit/s voltage-mode MAU**

| Network power supply requirements | Limits for 31,25 kbit/s |
|---|---|
| Output voltage, non-IS | ≤ 32 VDC |
| Output voltage, IS | Depends on barrier rating |
| Output ripple and noise | See Figure 117 |
| Output impedance, non-IS,<br>measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ | ≥ 3 kΩ |
| Output impedance, IS,<br>measured over the frequency range 0,25 $f_r$ to 1,25 $f_r$ | ≥ 400 Ω<br>(See Note) |
| NOTE The IS power supply is assumed to include an IS barrier. | |

### 21.7.2 Supply voltage

A fieldbus device that includes a 31,25 kbit/s voltage-mode MAU shall be capable of operating within a voltage range of 9 V to 32 VDC between the two conductors including ripple. The device shall withstand a minimum voltage of ±35 VDC without damage.

NOTE 1 For IS systems the operating voltage is possibly limited by the certification requirements. In this case the power supply will be located in the safe area and its output voltage will be attenuated by a safety barrier or equivalent component.

A fieldbus device that includes a 31,25 kbit/s voltage-mode MAU shall conform to the requirements of Clause 21 when powered by a supply with the following specifications.

a) The output voltage of the power supply for non-IS networks shall be 32 VDC maximum including ripple.

b) The output impedance of the power supply for non-IS networks shall be ≥ 3 kΩ over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz). This requirement does not apply within 10 ms of the connection or removal of a field device.

c) The output impedance of an IS power supply shall be ≥ 400 Ω over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz).

NOTE 2 The IS power supply is assumed to include an IS barrier.

d) The breakdown requirements of the isolation of the signal circuit and the power distribution circuit from ground and from each other shall be in accordance with IEC 61131-2.

   The equivalent test voltage is to be applied between independent isolated circuits or between isolated circuits and accessible conducting parts.

NOTE 3 For circuits with a nominal voltage ≤ 50 VDC or RMS, the equivalent test voltages at sea level are 444 V RMS, 635 VDC and 635 V peak impulse test. For circuits with a nominal voltage between 150 V RMS and 300 V RMS, the equivalent test voltages at sea level are 2 260 V RMS, 3 175 VDC and 3 175 V peak impulse test.

### 21.7.3 Powered via signal conductors

A fieldbus device which includes a 31,25 kbit/s voltage-mode MAU and is powered via the signal conductors shall be required to conform to the requirements of Clause 21 when operating with maximum levels of power supply ripple and noise as follows:

a) 16 mV peak-to-peak over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz);

b) 2,0 V peak-to-peak over the frequency range 47 Hz to 63 Hz for non-IS applications;

c) 0,2 V peak-to-peak over the frequency range 47 Hz to 625 Hz for IS applications;

d) 1,6 V peak-to-peak at frequencies greater than 125 $f_r$, up to a maximum of 25 MHz;

e) levels at intermediate frequencies generally in accordance with Figure 117.

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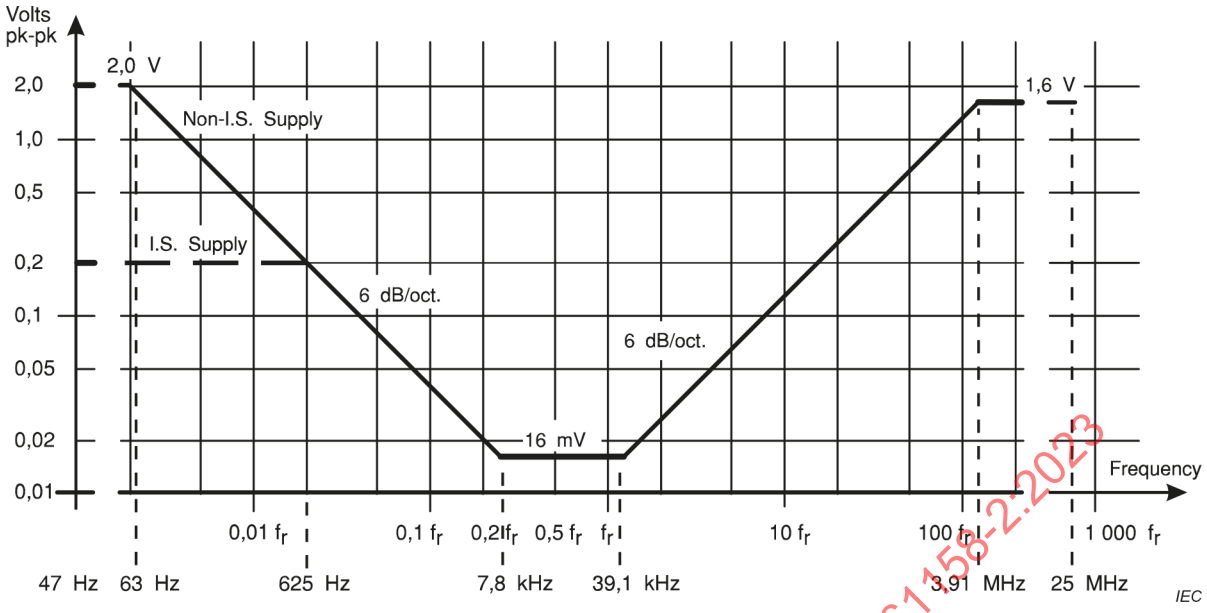


**Figure 117 – Power supply ripple and noise**

A fieldbus device which includes a 31,25 kbit/s voltage-mode MAU and is powered via the signal conductors shall exhibit a maximum rate of change of current drawn from the network of 1 mA/ms. This requirement does not apply:

- when transmitting;
- within the first 10 ms after the connection of the device to an operating network;
- within the first 10 ms after the application of power to the network;
- upon disconnection from the network or removal of power to the network.

A device shall be marked with a rated quiescent current. A device shall draw no more than 10 mA above its rated current from the network during the time interval of 100 µs to 10 ms after the connection of the device to an operating network or 100 µs to 10 ms after the application of power to the network.

NOTE The first 100 µs is excluded to allow for the charging of RFI filters and other capacitance in the device. The rate of change specification applies after 10 ms.

### 21.7.4 Electrical isolation

All fieldbus devices that use wire medium, whether separately powered or powered via the signal conductors, shall provide low-frequency isolation between ground and the fieldbus trunk cable.

NOTE 1 This is possible by isolation of the entire device from ground or by use of a transformer, opto-coupler or some other isolating component between trunk cable and device.

A combined power supply and communication element shall not require electrical isolation.

For shielded cables, the isolation impedance measured between the shield of the fieldbus cable and the fieldbus device ground shall be greater than 250 kΩ at all frequencies below 63 Hz.

The maximum unbalanced capacitance to ground from either input terminal of a device shall not exceed 250 pF.

The breakdown requirements of the isolation of the signal circuit and the power distribution circuit from ground and from each other shall be in accordance with IEC 61131-2.

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The equivalent test voltage is to be applied between independent isolated circuits or between isolated circuits and accessible conducting parts.

NOTE 2 For circuits with a nominal voltage ≤ 50 VDC or RMS, the equivalent test voltages at sea level are 444 V RMS, 635 VDC and 635 V peak impulse test. For circuits with a nominal voltage between 150 V RMS and 300 V RMS, the equivalent test voltages at sea level are 2 260 V RMS, 3 175 VDC and 3 175 V peak impulse test.

### 21.8 Medium specifications

#### 21.8.1 Connector

The connector is specified in Clause I.1.

#### 21.8.2 Standard test cable

The cable used for testing fieldbus devices with a 31,25 kbit/s voltage-mode MAU for conformance to the requirements of Clause 21 shall be a single twisted pair cable with overall shield meeting the following minimum requirements at 25 °C:

a) $Z_o$ at $f_r$ (31,25 kHz) = 100 Ω ± 20 Ω;

b) maximum attenuation at 1,25 $f_r$ (39 kHz) = 3,0 dB/km;

c) maximum capacitive unbalance to shield = 2 nF/km;

d) maximum DC resistance (per conductor) = 24 Ω/km;

e) maximum propagation delay change 0,25 $f_r$ to 1,25 $f_r$ = 1,7 µs/km;

f) conductor cross-sectional area (wire size) = nominal 0,8 $mm^2$;

g) minimum shield coverage shall be 90 %.

The preceding specification is for conformance testing an MAU. Other types of cable may be used in real installations (see Annex B). Cables with improved specifications may enable increased trunk length and/or superior interference immunity. Conversely, cables with inferior specifications may be used subject to length limitations for both trunk and spurs plus possible non-conformance to the RFI/EMI susceptibility requirements.

For intrinsically safe applications special requirements should be met such as specified by relevant intrinsically safe standards, e.g. IEC 60079-11 and IEC 60079-25.

#### 21.8.3 Coupler

See 12.8.3.

#### 21.8.4 Splices

See 12.8.4.

#### 21.8.5 Terminator

A terminator shall be located at both ends of the trunk cable, connected from one signal conductor to the other. No connection shall be made between terminator and cable shield.

The terminator impedance value shall be 100 Ω ± 2 Ω over the frequency range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz).

NOTE 1 This value is approximately the average cable characteristic impedance value for suitable cables at the relevant frequencies and is chosen to minimize transmission line reflections.

The direct current leakage through the terminator shall not exceed 100 µA. The terminator shall be non-polarized.

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All terminators used for IS applications shall comply with isolation requirements (creepage and clearance) commensurate with the required IS approval. Terminators for non-IS applications shall not be required to have IS approval.

NOTE 2 It is acceptable for the functions of power supply, safety barrier, and terminator to be combined in various ways as long as the impedance of the combination is equivalent to the parallel impedance of independent devices meeting the requirements of Clause 21 and the network configuration rules of 21.3.3 are followed.

### 21.8.6 Shielding rules

See 12.8.6.

### 21.8.7 Grounding rules

NOTE 1 Grounding means permanently connected to earth through a sufficiently low impedance and with sufficient current-carrying capability to prevent voltage build-up which might result in undue hazard to connected equipment or persons. Zero volts (common) lines can be connected to ground where they are galvanically isolated from the fieldbus trunk.

Fieldbus devices shall be required to function to the requirements of Clause 21 with the mid-point of one terminator or one inductive coupler connected directly to ground.

Fieldbus devices shall not connect either conductor of the twisted pair to ground at any point in the network. Signals shall be applied and preserved differentially throughout the network.

It is best practice for the shield of the fieldbus trunk cable (if applicable) to be effectively grounded at several points along the length of the cable. But the fieldbus devices should allow DC isolation of the cable shield from ground.

It is also standard practice to connect the signal conductors to ground in a balanced manner at one central grounding point, e.g. by using the center tap of a terminator or coupling transformer. For bus powered systems the grounding of the shield and balanced signal conductors should be close to the power supply unit. For IS systems the grounding should be in accordance with the related Intrinsic safety standards, e.g. IEC 60079-11 and IEC 60079-25.

### 21.8.8 Cable colours

See 12.8.8.

## 21.9 Intrinsic safety

### 21.9.1 General

This document does not attempt to list the requirements by which an item of equipment may be certified as intrinsically safe nor does it require equipment to be intrinsically safe. Rather, it seeks to exclude conditions or situations that would prevent IS certification.

### 21.9.2 Intrinsic safety barrier

The barrier impedance shall be greater than 460 Ω at any frequency in the range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz). The IS barrier impedance specification shall apply to all barriers used as part of the PhL, whether installed as a separate item of network hardware or embedded in a power supply card. The barrier impedance shall be measured across the terminals on both sides of the barrier. The barrier impedance shall be measured while the network power supply is set at the rated working voltage (not safety voltage) of the barrier.

NOTE It is acceptable for the functions of power supply, safety barrier, and terminator to be combined in various ways as long as the impedance of the combination is equivalent to the parallel impedance of independent devices meeting the requirements of Clause 21 and the network configuration rules of 21.3.3 are followed.

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At the rated working voltage of the barrier, and at any frequency in the range 0,25 $f_r$ to 1,25 $f_r$ (7,8 kHz to 39 kHz), the capacitance measured from the "+" (positive) network terminal (hazardous side) to ground shall differ by no more than 250 pF from the capacitance measured from the "-" (negative) network terminal (hazardous side) to ground.

#### 21.9.3 Barrier and terminator placement

A barrier shall be separated from the nearest terminator by no more than 100 m of cable.

NOTE The barrier can appear as a shunt impedance as low as 460 Ω at the signaling frequencies. The terminator resistance is sufficiently low that when it is placed in parallel with the barrier impedance, the resulting impedance is almost entirely resistive (non-reactive).

### 21.10 Galvanic isolators

The communications characteristics of galvanic isolators used on the fieldbus shall comply with the specifications of 21.9.

### 21.11 Coupling elements

#### 21.11.1 General

Coupling elements are used to connect different Type 3 segments with the same PhL or a different PhL.

With the exception of signal levels this document does not describe the required characteristics of a coupling element. This means that it is the task of the system planner to ensure that "Network Configuration Rules" standard is complied with when coupling elements are used. The following specifications are important.

- Maximum signal delay;
- Maximum deviation from nominal signal zero crossing (signal jitter).

Two types of coupling elements can be used:

- MBP-IS repeaters;
- MBP-IS - RS 485 signal couplers.

#### 21.11.2 MBP-IS repeater

A MBP-IS repeater connects two MBP-IS segments. It contains a MAU on each segment and a galvanic isolation between the two MAU. The electrical characteristics shown in Table 140 are mandatory for both fieldbus interfaces. MAU related requirements in Clause 12 and 21.1 to 21.10 also apply to repeaters.

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**Table 140 – Electrical characteristics of fieldbus interfaces**

| Parameter | Values | Subclause of this document |
|---|---|---|
| Signal coding | Manchester II | 9.2.2 |
| Start delimiter | 1, N+, N-, 1, 0, N-, N+, 0 (Note 1) | 9.2.4 |
| End delimiter | 1, N+, N-, N+, N-,1, 0, 1 (Note 1) | 9.2.5 |
| Preamble | 1, 0, 1, 0, 1, 0, 1, 0 | 9.2.6 |
| Data transmission rate | 31,25 kbit/s with a tolerance of ± 0,2 % | 21.2 |
| Output level (peak to peak) | 0,75 V to 1 V | 21.4.5 |
| Max. difference between positive and negative transmit amplitude | ± 50 mV | 21.4.5 |
| Max. transmit signal distortion (oversvoltage, ringing a drop) | ± 10 % | 21.4.5 |
| Transmitter noise | 1 mV (RMS) (Note 2) | 21.4.5 |
| Output impedance | ≥ 3 kΩ (Note 3) | 21.7.1 |
| Operating voltage | 9 V to 32 V (Note 4) | 21.7.1 |
| Common Mode Rejection Ratio (CMRR) | ≥ 50 dB (Note 5) | |
| Leakage current (Note 6) | 50 µA | |
| NOTE 1 N+ and N- are non-data symbols. | | |
| NOTE 2 In frequency range of 1 kHz to 100 kHz. | | |
| NOTE 3 In frequency range of 7,8 kHz to 39 kHz. | | |
| NOTE 4 Operational voltage range. Can be limited to 9 V to 17,5 V or to 9 V to 24 V for intrinsically safe devices. | | |
| NOTE 5 Corresponds to an unbalanced capacitance of 250 pF at 39 kHz. | | |
| NOTE 6 Only for intrinsic safety. | | |

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Repeaters which are connected to intrinsically safe bus segments shall be certified as intrinsically safe apparatus. The certificate shall contain a statement that the devices conform to the FISCO model. The specifications of IEC 60079-11 shall be adhered to for galvanic isolation.

To be able to determine whether the network configuration rules in 21.3.3 are met, the system planner requires information on the signal delay caused by repeaters and the maximum deviation from the nominal signal zero crossing (i.e., signal jitter). This information shall be documented in the data sheet.

A repeater can be combined with a power supply and with line terminators.

### 21.11.3 MBP-IS – RS 485 signal coupler

A MBP-IS – RS 485 signal coupler connects a MBP-IS segment with a RS 485 segment. It contains a MAU on each segment, a galvanic isolation between the two MAU, and a Manchester encoding/decoding.

The electrical characteristics shown in Table 140 are mandatory for the MBP-IS interface. MAU related requirements in Clause 12 and 21.1 to 21.10 also apply. Clause 22 applies to the design of the RS 485 bus interface.

Signal couplers which are connected to intrinsically safe bus segments shall be certified as intrinsically safe apparatus. The certificate shall contain a statement that the devices conform to the FISCO model. The specifications of IEC 60079-11 shall be adhered to for galvanic isolation (see 21.10).

To be able to determine whether the network configuration rules in 21.3.3 are met, the system planner requires information on the signal delay caused by repeaters and the maximum deviation from the nominal signal zero crossing (i.e., signal jitter). This information shall be documented in the data sheet of a signal coupler.

A signal coupler can be combined with a power supply and with a bus terminator.

NOTE Such a device is usually called segment coupler.

### 21.12 Power supply

#### 21.12.1 General

A power supply shall be connected to the bus to supply the field devices with power. The supply voltage depends on the requirements of the particular application.

The power for an intrinsically safe bus can either be provided by a power supply with intrinsically safe output or by a non intrinsically safe power supply supplemented by a barrier.

To prevent any impact on the data transmission, the electrical characteristics in Clause 21 of this document and listed in Table 141 are mandatory for all power supplies.

The output terminals of a power supply shall be clearly marked with "+" and "-".

Although a power supply isolated against earth is not specifically required, asymmetrical grounding of the bus cable conductors is not permitted. It is essential that any connection between the conductors and earth is balanced. For more details, see 21.8.7.

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**Table 141 – Electrical characteristics of power supplies**

| | Not intrinsically safe | Intrinsically safe, IIC FISCO [a] | Intrinsically safe, IIB FISCO [a] | Intrinsically safe, IIC linear barrier [b] |
|---|---|---|---|---|
| According to FISCO model | no | yes | yes | |
| Max. DC supply voltage $U_0$ | ≤ 32 V | ≤ 17,5 V | ≤ 17,5 V | ≤ 24 V |
| Max. DC short-circuit current $I_0$ | | ≤ 360 mA | ≤ 380 mA [g] | ≤ 250 mA |
| Max. output power $P_0$ | | ≤ 2,52 W | ≤ 5,32 W | ≤ 1,2 W |
| Ripple, noise | ≤ 16 mV [c] | ≤ 16 mV [c] | ≤ 16 mV [c] | ≤ 16 mV [c] |
| Output impedance [g] | ≥ 3 k Ω [c d] | ≥ 400 Ω [c d] | ≥ 400 Ω [c d] | ≥ 400 Ω [c d e] |
| Ripple, noise | ≤ 16 mV [c] | | | |
| Asymmetry attenuation | ≥ 50 dB [f] | | | ≥ 50 dB [e f] |

| | |
|---|---|
| a | Power supply with rectangular or trapezoidal characteristic in accordance with the FISCO model. |
| b | Power supply or barrier with linear characteristic. |
| c | In frequency range from 7,8 kHz to 39 kHz. Otherwise see Figure 117. |
| d | With integrated line terminator: 100 Ω with a tolerance of ± 2 %. It is recommended to provide each power supply with a terminating resistor. |
| e | Including barrier if required. |
| f | No mandatory specification in the standard, but required functionally. |
| g | The current limit results from a rectangular characteristic. |

Power supplies that are used to supply field devices located in potentially explosive areas shall be certified as intrinsically safe associated apparatus for use in hazardous locations.

### 21.12.2 Non-intrinsically safe power supply

Non intrinsically safe power supplies shall have the technical characteristics listed in Table 141.

Non intrinsically safe power supplies can be used together with an approved barrier to supply an intrinsically safe bus.

### 21.12.3 Intrinsically safe power supply

To supply field devices in potentially explosive areas, a power supply with intrinsically safe output can be connected to the bus instead of the combination of non-intrinsically safe power supply and barrier. This device is usually located outside the hazardous area in the control room. In the sense of IEC 60079-11, this is a so-called associated apparatus since, although it is not protected against explosion itself, it does generate an intrinsically safe electric circuit which leads to the potentially explosive area.

In addition to the requirements in Clause 21 especially in Table 141, intrinsically safe power supplies shall meet the safety requirements stated in IEC 60079-14 and IEC 60079-11.

If the power supply is located within the hazardous area, an additional standardized type of protection shall be provided (e.g., installation in a housing of protection type "flameproof enclosure d").

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Intrinsically safe power supplies can be part of other fieldbus components (e.g., segment couplers, see 21.11).

The FISCO model is based on a rated DC voltage of 13,5 V. The ignition curves for power supplies with rectangular characteristic indicate that the maximum permissible power considerably decreases if the voltage increases. On the other hand, a low voltage power supply causes a higher transmission line voltage drop. Therefore, the voltage of 13,5 V seems to be an acceptable compromise.

Due to tolerances and in order to offer a margin for the signal amplitude the maximum output voltage $U_0$ of a power device shall be greater than the rated output voltage. The signal amplitude is ≤ 1 $V_{pp}$, therefore a margin of 0,5 V is needed. If the tolerances are assumed to be ≤ 1 V the calculation results in a guaranteed maximum output voltage $U_0$ = 15 V. The admissible maximum output current (short circuit current), depending on the gas group, can be taken from available ignition curves or can be derived from ignition tests. In group IIC the allowed output current is $I_0$ = 128 mA. Other voltage/current combination in accordance with FISCO may be chosen.

Design and implementation of the safety-related voltage, and current limiters depends on the chosen category of the intrinsically safe circuit ("ia" or "ib") The maximum values of the output parameters have to meet the requirements of FISCO.

An inspection certificate shall be obtained for the bus power supply as "associated apparatus" in the sense of IEC 60079-11. This certificate shall state that the power supply conforms to the FISCO model.

In addition to the usual data (i.e maximum output parameters), the certificate may also contain primary specifications applicable to permissible fieldbus configuration.

NOTE Usually limit values for the maximum permissible external inductance La and capacity Ca are not required. If these values had been included, it would create the impression that La and Ca are present in the intrinsically safe circuit as unprotected inductivity and capacity, which is not the case for the FISCO model. The cable here is not considered as concentrated inductivity and capacity as long as the parameters of the system remain within the range of limits defined in the FISCO model.

### 21.12.4 Power supply of the category "ib"

NOTE 1 Since the output current circuit of the power supply should have a low inner resistance for direct current, use of a power supply with a voltage regulator and an active current control (i.e., electronic current limitation) comes to mind. For example, it is possible to achieve an inner resistance ≥ 400 Ω in the signal frequency range according Table 141 by using a frequency-dependent negative feedback.

The ideal output characteristic curve of a power supply (i.e., current/voltage characteristic) is rectangular (see Figure 118). When the output current increases, the output voltage remains constant until the current reaches a certain limit. IEC 60079-11 permits such a solution under the assumption that redundant current and voltage limitation has been set up and reliable galvanic isolation (optional) from the non-intrinsically safe electric circuits has been provided.

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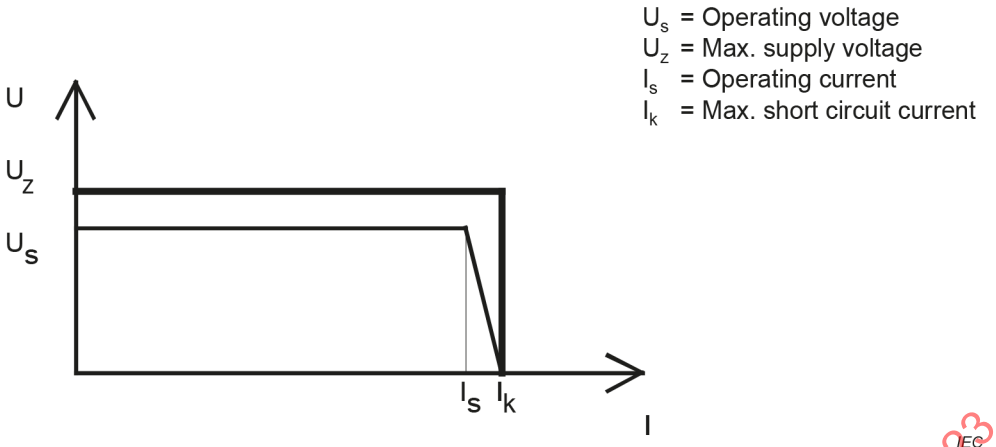


**Figure 118 – Output characteristic curve of a power supply of the category EEx ib**

NOTE 2 A voltage of 13,5 V direct current seems realistic since higher voltages would restrict the available power. The explosion limit curves for sources with square output characteristic curve show that the permissible power decreases significantly when the voltage increases.

### 21.12.5 Power supply in category "ia"

Power supplies with electronic current limitation shall be certified in accordance with IEC 60079-11 for category "ib".

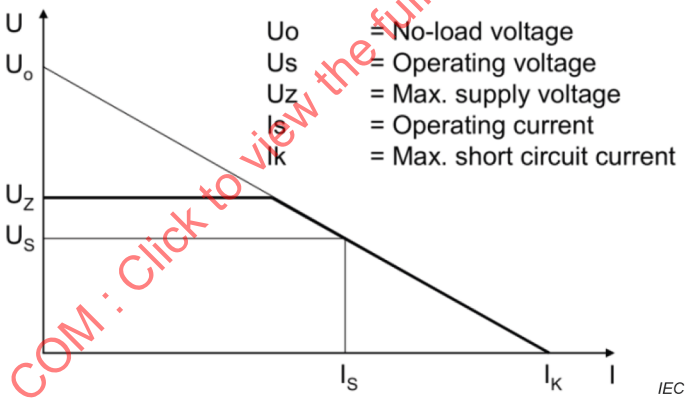


**Figure 119 – Output characteristic curve of a power supply of the category EEx ia**

The ia-power supply shall be according FISCO. The maximum output current IK of Figure 118 corresponds to the current IZul (at U = Uz) of Figure 119.

Example

An example of a power supply suitable for category "ia" contains the following safey-related elements: Voltage source with Uo = 34 V, fixed resistance with R = 158 Ω, and Zener diodes with UZD = 15 V (maximum value). Such a circuit has a trapezoidal output characteristic curve as shown in Figure 119. The approximate operational values which can be achieved for the power supply are listed below.

U = 13,5 V

I = 120 mA

P = 1,7 W

$$P_{v\,max} = \frac{U_0^2}{Rv} = 7{,}32\ \text{W}$$

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NOTE 1 Thus, the operational values are comparable to those of the "ib" concept with electronic current limitation. A disadvantage is the requirement of a relatively high thermal stress of the series resistor and the power loss in the series resistor which is always present under operational conditions.

Applying a safety factor of 1,5, the allowed power dissipation of the resistor shall be 11 W.

NOTE 2 Use of two resistors in series can be helpful.

The maximum power dissipation of the Zener diodes is 1,8 W.

$$P_{vmax} = \frac{Uo\text{-}Uz}{Rv} \times 15\ V = \frac{34\ V - 15\ V}{158\ \Omega} \times 15\ V = 1{,}8\ W$$

Taking into account the safety factor, the Zener diodes shall be suitable for a maximum power dissipation of 2,7 W.

NOTE 3 The use of two diodes in series is also possible here.

IEC 60079-14 and IEC 60079-11 apply.

#### 21.12.6 Reverse powering

With the exception of one power supply per segment, the FISCO model does not permit devices that are connected to the intrinsically safe fieldbus to feed power back to the fieldbus, even when a short circuit occurs on the fieldbus line. This is usually ensured by connection in series of two (for EEx ib) or three (for EEx ia) silicon or Schottky diodes in the input electric circuit. The field device conforms to the FISCO model when the leakage current of these diodes (up to the maximum reverse voltage in the permissible temperature range) does not exceed 50 µA. Diode manufacturer specifications (i.e., typical values as per data sheet) usually apply here in addition to a safety factor.

Final judgment of these measures is the responsibility of the certifying authority performing the safety tests and certification of the particular field device.

## 22 Type 3: Medium attachment unit: asynchronous transmission, wire medium

### 22.1 Medium attachment unit for non intrinsic safety

#### 22.1.1 Characteristics

This MAU specification describes a balanced line transmission corresponding to TIA-485-A:1998. Terminators, located at both ends of the twisted-pair cable, enable the PhL to support in particular higher speed transmission. The maximum cable length is 1 200 m for data rates ≤ 93,75 kbit/s. For 1 500 kbit/s the maximum length is reduced to 70 m for type B and 200 m for type A cable. For 12 Mbit/s the maximum length is 100 m (only cable type A, see 22.1.2.2).

NRZ bit encoding is combined with TIA-485-A:1998 signaling targeted to low cost line couplers, which can isolate the station from the line (galvanic isolation), or not; line terminators are required, especially for higher date rates (up to 12 Mbit/s).

Table 142 shows the required characteristics.

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**Table 142 – Characteristics for non intrinsic safety**

| Characteristic | Constraints |
|---|---|
| Topology: | Linear bus, terminated at both ends, stubs ≤ 0,3 m, no branches; see Note.<br>The total line length includes the sum of the stub lengths. |
| Medium: | Shielded twisted pair cable recommended, see 22.1.2 "Medium specifications" |
| Line Length:[a] | ≤ 1 200 m, depending on the data rate and cable type |
| Number of stations:[a] | 32 (Master stations, slave stations or repeaters) |
| Data rates: | 9,6 / 19,2 / 45,45 / 93,75 / 187,5 / 500 / 1 500 / 3 000 / 6 000 / 12 000 kbit/s, additional data rates can be supported. |
| | |
| NOTE In contrast to the TIA-485-A:1998 recommendations it is good practice to allow longer stubs, if the total of the capacities of all stubs (Cstges) does not exceed the following values:<br>0,05 nF at 3 Mbit/s, 6 Mbit/s and 12 Mbit/s.<br>0,2 nF at 1,5 Mbit/s.<br>0,6 nF at 500 kbit/s.<br>1,5 nF at 187,5 kbit/s.<br>3,0 nF at 93,75 kbit/s.<br>15 nF at 9,6 kbit/s and 19,2 kbit/s. | |
| [a] Repeater extends both line length and number of stations, see Table 143. | |

The line length and number of connected stations can be increased by using repeaters. A maximum of 3 repeaters between two stations is permissible. If the data rate is ≤ 93,75 kbit/s and if the linked sections form a chain (linear bus topology, no active star, for example, as in Figure 120) and assuming a conductor cross-sectional are of 0,22 $mm^2$, the maximum permissible topology is shown in Table 143.

**Table 143 – Characteristics using repeaters**

| Number of repeaters | Characteristic | Constraints |
|---|---|---|
| 1 | Line Length | < 2,4 km |
| | Number of stations | 62 (Master stations, slave stations or repeaters) |
| 2 | Line Length | < 3,6 km |
| | Number of stations | 92 (Master stations, slave stations or repeaters), see Figure 120 |
| 3 | Line Length | < 4,8 km |
| | Number of stations | 122 (Master stations, slave stations or repeaters) |

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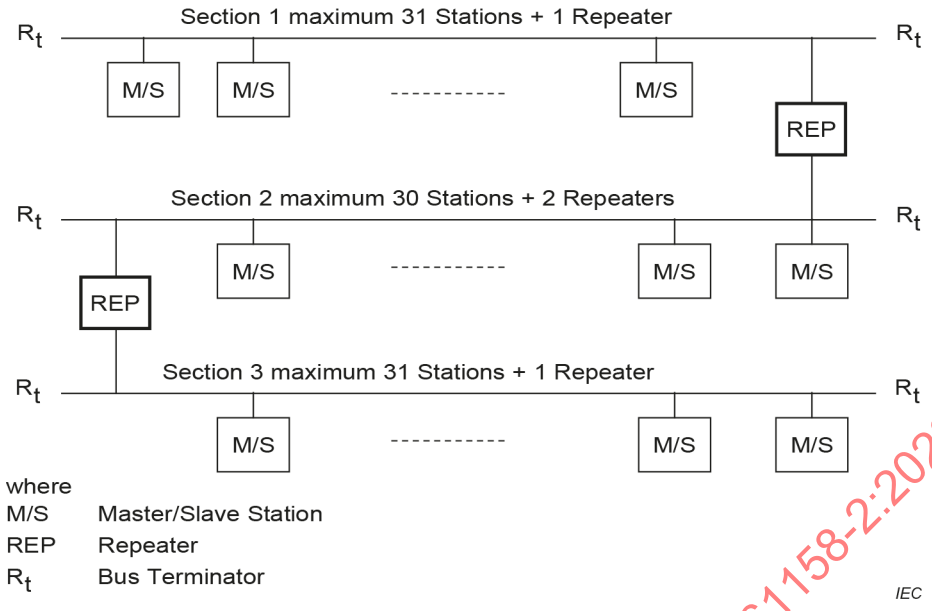


**Figure 120 – Repeater in linear bus topology**

In a tree topology, for example, as in Figure 121, more than 3 repeaters can be used and more than 122 stations can be connected, for example, 5 repeaters and 127 stations. A large area can be covered by this topology, for example, 4,8 km length at a data rate less than 93,75 kbit/s and a cross-sectional area of 0,22 mm$^2$.

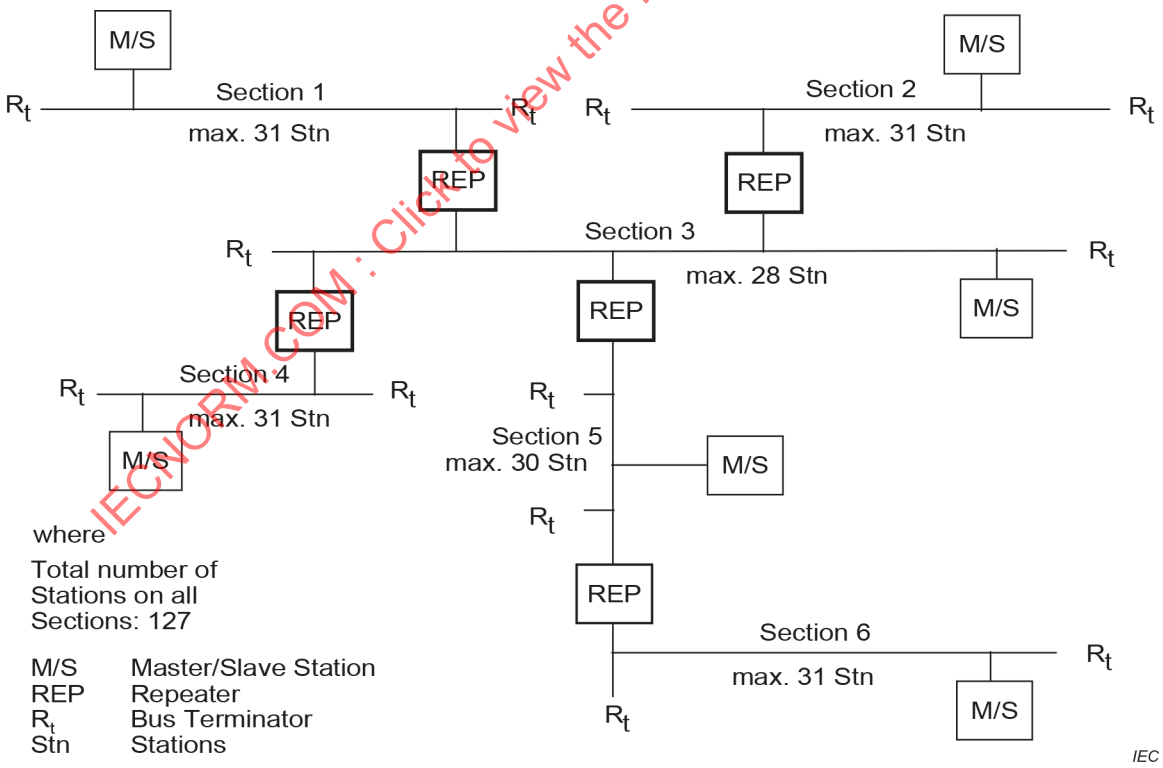


**Figure 121 – Repeater in tree topology**

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### 22.1.2 Medium specifications

#### 22.1.2.1 Connector

The connector is specified in I.2.1.

#### 22.1.2.2 Cable

The bus medium is a shielded twisted-pair cable. The shield helps to improve the electromagnetic compatibility (EMC). Unshielded twisted pair may be used, if there is no severe electromagnetic interference (EMI).

The characteristic impedance of the cable shall be in the range between 100 and 220 Ω, the cable capacity (conductor - conductor) should be less than 60 pF/m and the conductor cross-sectional area should be equal or greater than 0,22 $mm^2$. Cable selection criteria are included in the appendix of the TIA-485-A:1998.

Two types of cables are defined, as specified in Table 144.

**Table 144 – Cable specifications**

| Cable parameter | Type A | Type B |
|---|---|---|
| Impedance | 135 to 165 Ω<br>(f = 3 MHz to 20 MHz) | 100 to 130 Ω<br>(f > 100 kHz) |
| Capacity | < 30 pF/m | < 60 pF/m |
| Resistance | < 110 Ω/km | not specified |
| Conductor cross-sectional area | ≥ 0,34 $mm^2$ | ≥ 0,22 $mm^2$ |
| Colour of sheath non-IS | Violet | Not specified |
| Colour of inner cable conductor A (RxD/TxD-N) | Green | Not specified |
| Colour inner cable conductor B (RxD/TxD-P) | Red | Not specified |

Table 145 shows the maximum length of cable type A and cable type B for the different transmission speeds.

**Table 145 – Maximum cable length for the different transmission speeds**

| Item | Unit | Value | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Data rate** | kbit/s | 9,6 | 19,2 | 93,75 | 187,5 | 500 | 1 500 | 3 000 | 6 000 | 12 000 |
| **Cable type A** | m | 1 200 | 1 200 | 1 200 | 1 000 | 400 | 200 | 100 | 100 | 100 |
| **Cable type B** | m | 1 200 | 1 200 | 1 200 | 600 | 200 | 70 | Not permissible | | |

For data rates equal or less 1 500 kbit/s the sum of the stub lengths (total of the capacities of all stubs (Cstges)) is specified in 22.1. For example, at 1 500 kbit/s the maximum stub length for cable type A is 6,6 m.

At 3 Mbit/s and higher data rates the total capacities of all stubs shall be less than 0,05 nF. For cable type A the total stub length is therefore 1,6 m. At this data rate it is necessary to integrate impedance into the wiring to avoid reflections.

The following example, Figure 122, shows the integration of inductances L1 to L4 in the connector.

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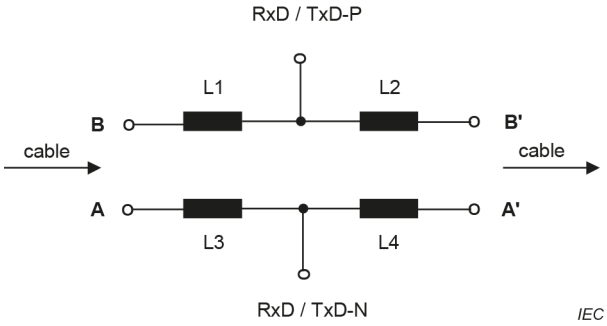


**Figure 122 – Example for a connector with integrated inductance**

For cable type A the inductances L1 to L4 shall have the value of 110 nH ±22 nH with the following constraint:

The resistance between A and A' as well as B and B' shall be ≤ 0,35 Ω.

The typical capacity of each connected station (connector, cable to TIA-485-A Transceivers, Transceivers itself and other parts) shall be: 15 to 25 pF.

NOTE 1 The calculation of the inductance includes the contribution of the connected station. In case of disconnection of such connectors wiring reflections can occur which cause distortion on the bus.

The dependency of the permissible data rate upon the local link expanse (maximum distance between two stations) is shown in Figure 2-A.1 of the TIA-422-B (also included in ITU-T V.11).

NOTE 2 The recommendations concerning the line length presume a maximum signal attenuation of 6 dB. Experience shows that the distances possibly is doubled if conductors with a cross-sectional area ≥ 0,5 $mm^2$ are used.

The minimum wiring between two stations is shown in Figure 123.

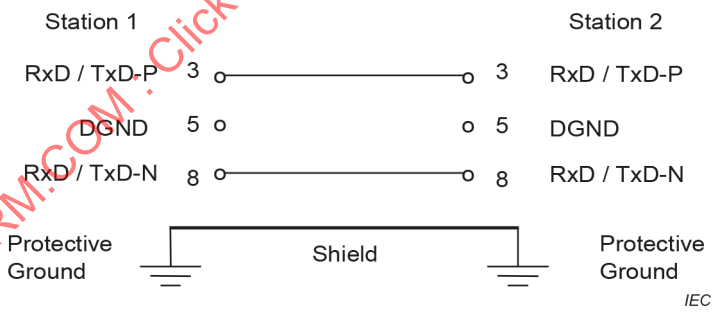


**Figure 123 – Interconnecting wiring**

The wiring shown in Figure 123 allows a common mode voltage between both stations (that is, the voltage difference between the protective grounds) of at most ± 7 V. If a higher common mode voltage is expected, a compensation conductor between the grounding points shall be installed.

### 22.1.2.3 Grounding and shielding rules

If a shielded twisted-pair cable is used it is recommended to connect the shield to the protective ground at both ends of the cable via low impedance (that is, low inductance) connections. This is necessary to achieve a reasonable electromagnetic compatibility.

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Preferably the connections between the cable shield and the protective ground (for example, the metallic station housing) should be made via the metallic housings and the metallic fixing screws of the sub-D connectors. If this is not possible the pin 1 of the connectors may be used.

#### 22.1.2.4 Bus terminator

The bus cable type A and type B shall be terminated at both ends with $R_{tA}$ respectively $R_{tB}$. The termination resistor $R_t$ specified in TIA-485-A:1998 shall be complemented by a pulldown resistor $R_d$ (connected to Data Ground DGND) and by a pullup resistor $R_u$ (connected to Voltage-Plus VP), as shown in Figure 124. This supplement forces the differential mode voltage (that is, the voltage between the conductors) to a well-defined value when no station is transmitting (during the idle periods).

Each station that is destined to terminate the line (in common with a bus terminator) shall make Voltage-Plus (for example, + 5 V ± 0,25 V) available at pin 6 of the bus connector.

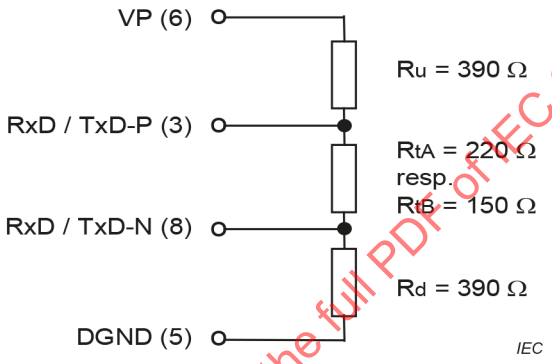


**Figure 124 – Bus terminator**

Assuming a power supply voltage of +5 V ±0,25 V the following resistor values are recommended:

$R_{tA}$ = 220 Ω ± 4,4 Ω, min. 1/4 W;

$R_{tB}$ = 150 Ω ± 3 Ω, min. 1/4 W;

$R_u = R_d$ = 390 Ω ± 7,8 Ω, min. 1/4 W

The power source supplying pin 6 (VP) shall be able to deliver a current of at least 10 mA within the specified voltage tolerances.

A mixture of both cable types and cable termination resistors as described above is allowed. However, the maximum line length has to be reduced up to the half of the above fixed values if line termination and line impedance do not match.

### 22.1.3 Transmission method

#### 22.1.3.1 Bit coding

The "Non Return to Zero" (NRZ) coded data from DLL is transmitted via a twisted pair cable. A binary "1" (DL_symbol = "ONE") is represented by a constant positive differential voltage between pin 3 (RxD/TxD-P) and pin 8 (RxD/TxD-N) of the bus connector, a binary "0" (DL_symbol = "ZERO") by a constant negative differential voltage.

#### 22.1.3.2 Transceiver control

When a station is not transmitting the transmitter output shall be disabled (DL_symbol = "SILENCE"), it shall present a high impedance to the line. During the idle periods, that is, when

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no data is transmitted by any station, the receive line signal shall represent a binary "1" (DL_symbol = "ONE"). Therefore, the Bus Terminator shall force the differential voltage between the connector pins 3 and 8 to be positive when all transmitters are disabled. The line receivers shall always be enabled, therefore during idle the binary signal "1" is received by every station.

## 22.2 Medium attachment unit for intrinsic safety

### 22.2.1 Characteristics

This MAU specification describes a MAU for explosion protection type Ex i in accordance with IEC 60079-11 and IEC 60079-25 on the basis of balanced line transmission corresponding to TIA-485-A:1998. Terminators, located at both ends of the twisted-pair cable, enable the PhL to support in particular higher speed transmission. The maximum cable length is 1 200 m for data rates ≤ 93,75 kbit/s. For the maximum transmission rate of 1 500 kbit/s the maximum cable length is reduced to 200 m. Only cable type A, see 22.2.2.2, shall be used with this MAU.

NRZ bit encoding is combined with TIA-485-A:1998 signaling targeted to low cost line couplers. Line terminators are required.

In all devices connected to the fieldbus the bus interface circuit shall be galvanically isolated from all other electrical circuits. Separation distances and insulation voltages between intrinsically safe circuits and/or non-intrinsically safe circuits shall meet the relevant applicable standards (e.g. IEC 60079-11).

Table 146 shows the required characteristics.

**Table 146 – Characteristics for intrinsic safety**

| Characteristic | Constraints |
|---|---|
| Topology | Linear bus, terminated at both ends, stubs ≤ 0,3 m, no branches |
| Medium | Shielded twisted pair cable recommended, see 22.2.2 "Medium specifications" |
| Line Length: | ≤ 1 200 m, depending on the data rate |
| Number of stations: | 32 (Master stations, Slave stations or fieldbus isolating repeaters and additionally 2 external bus terminators) |
| Data rates | 9,6 kbit/s / 19,2 kbit/s / 45,45 kbit/s / 93,75 kbit/s / 187,5 kbit/s / 500 kbit/s / 1 500 kbit/s |

The linear structure, as in Figure 125, permits connection points along the field bus segment similar to the installation of power supply circuits. The field bus cable should be looped through the individual field devices in order to avoid stubs.

A fieldbus isolating repeater or a comparable device normally forms the beginning of an intrinsically safe fieldbus segment. This fieldbus isolating repeater connects a non-intrinsically safe fieldbus segment with the intrinsically safe fieldbus segment and simultaneously ensures reliable galvanic isolation between the two. The intrinsically safe fieldbus segment is terminated at both ends with an active bus termination. Up to 32 bus participants (field devices, fieldbus isolating repeater, external bus terminators etc.) can be arranged along the fieldbus segment. The bus participants are connected to a segment of the fieldbus in an electrically floating arrangement.

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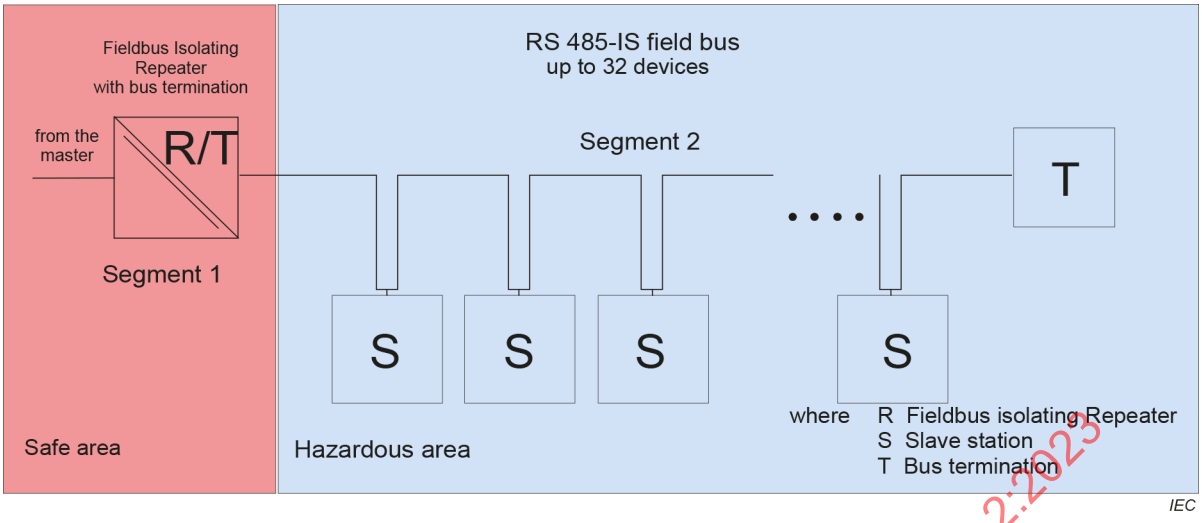


**Figure 125 – Linear structure of an intrinsically safe segment**

Figure 126 shows an example of the set-up and the segmentation of a fieldbus system with fieldbus isolating repeaters. The fieldbus segments 2 and 3 are intrinsically safe. The fieldbus isolating repeater between the intrinsically safe segments 2 and 3 shall maintain galvanic isolation. The number of cascadable repeaters depends on the signal distortion and the delay of the signal (pay attention to the manufacturer's specifications).

Segment 3 in Figure 126 is started by means of a fieldbus isolating repeater in the middle of segment 3. Bus termination is provided at one end by means of an active bus termination and at the other end by means of another fieldbus isolating repeater which opens segment 4 into the safe area.

The bus terminations of an fieldbus segment can be located in a fieldbus isolating repeater, field device, in an active bus termination (as a stand-alone device), or in a connector powered from a filedbus isolating repeater or field device.

The repeater between segments 2 and 3 in Figure 126 shall be installed outside of the hazardous area, as associated apparatus. The installation in the hazardous area requires additional explosion protection measures (e.g. Ex e, Ex d, Ex I, etc., in accordance with IEC 60079-0).

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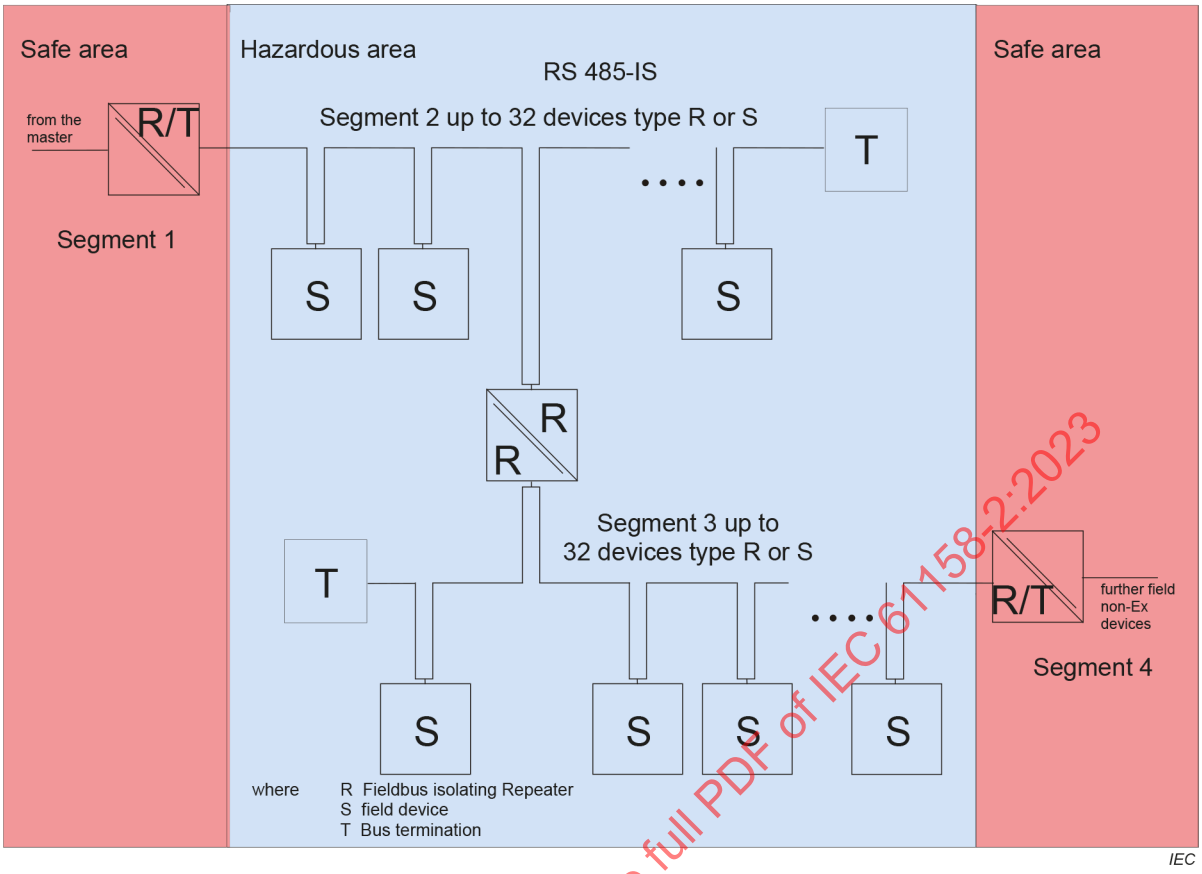


**Figure 126 – Topology example extended by repeaters**

### 22.2.2 Medium specifications

#### 22.2.2.1 Connector

The connector is specified in I.2.2.

#### 22.2.2.2 Cable

Table 147 shows the specified cable parameters related to function and intrinsic safety.

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**Table 147 – Cable specification (function- and safety-related)**

| Cable parameter | Cable type A [a] | Limiting safety values |
|---|---|---|
| Surge impedance (Ω) | 135…165 at a frequency of 3…20 MHz | Not relevant |
| Working capacitance (nF/km) | ≤ 30 | Not relevant |
| Wire diameter (mm) | > 0,64 | > 0,1 single wire for a fine-stranded conductor [b]<br>> 0,35 [c] |
| Core cross-sectional area (mm²) | > 0,34 | > 0,096 2 [c] |
| Loop resistance (Ω/km) | ≤ 110 | Not relevant |
| L/R ratio (µH/Ω) | ≤ 15 | ≤ 15 for the lowest ambient temperature (see Note) |
| Colour of sheath IS | Light blue | If colour is used for marking |
| Colour of inner cable conductor A (RxD/TxD-N) | Green | |
| Colour inner cable conductor B (RxD/TxD-P) | Red | |

NOTE Cable type A fulfils this requirement for a ambient temperature above –40 °C.

[a] In accordance with IEC 60079-14. The cable shall fulfil the requirements for cables.

[b] In accordance with IEC 60079-14. The wire ends of fine-stranded conductors shall be protected against separation of the strands, e.g. by means of cable lugs or core end sleeves.

[c] This minimum value applies for a maximum ambient temperature of 40 °C and the temperature class T6 for a total current in the field bus cable of max. 4,8 A. According to IEC 60079-11 To get information on the ampacity at other ambient temperatures, this shall be deduced from the existing requirements. In the case of the RS 485-IS, a maximum current of 4,8 A occurs in the field bus cable. This necessitates a wire cross section of ≥ 0,096 2 mm2 (diameter: ≥ 0,35 mm) for a cable used in T6 and for a maximum ambient temperature of 40 °C. Because the permissible surface temperature of the cable shall not exceed 80 °C in the case of T6, the maximum temperature rise is 40 K for 4,8 A and the above-specified wire cross section. For cables deployed in T4 and higher ambient temperatures than 40 °C, the sum of the ambient temperature and the cable's temperature rise shall not exceed 130 °C for a current of 4,8 A. In all cases, the insulation of the cable shall be suitable for the maximum expected cable temperatures.

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Table 148 shows the permissible maximum cable length depending on the transmission speeds.

**Table 148 – Maximum cable length for the different transmission speeds**

| Item | Unit | Value | | | | | |
|---|---|---|---|---|---|---|---|
| **Data rate** | kbit/s | 9,6 | 19,2 | 93,75 | 187,5 | 500 | 1 500 |
| **Cable type A** | m | 1 200 | 1 200 | 1 200 | 1 000 | 400 | 200 |

### 22.2.2.3 Grounding and shielding rules

NOTE Grounding means permanently connected to earth through a sufficiently low impedance and with sufficient current-carrying capability to prevent voltage build-up which might result in undue hazard to connected equipment or persons.

Zero volts (common) lines may be connected to ground where they are galvanically isolated from the fieldbus trunk.

Fieldbus devices shall not connect either conductor of the twisted pair to ground at any point in the network. Signals shall be applied and preserved differentially throughout the network.

The fieldbus devices should allow DC isolation of the cable shield from ground.

For intrinsically safe installations, the grounding shall be in accordance with IEC 60079-14.

For shielding, see 12.8.6.

#### 22.2.2.4 Bus terminator

The bus cable type A shall be terminated at both ends with $R_t$. The termination resistor $R_t$ specified in TIA-485-A:1998 shall be complemented by a pulldown resistor $R_d$ (connected to Bus termination ground ISGND) and by a pullup resistor $R_u$ (connected to Bus termination plus ISP), as shown in Figure 127. This supplement forces the differential mode voltage (that is, the voltage between the conductors) to a well-defined value when no station is transmitting (during the idle periods).

The termination of this MAU specification for explosion protection type Ex i differs from the specification of the non-intrinsic safe MAU on account of the modified electrical specification. In this context, the resistance values of the bus termination (see Figure 127) and the modified arrangement of the bus termination (see I.2.2) shall be paid attention when integrated into communication devices or plug connectors.

Each station that is destined to terminate the line (in common with a bus terminator) shall make an internal supply voltage U+ of + 3,3 V with a tolerance of ± 5 % available.

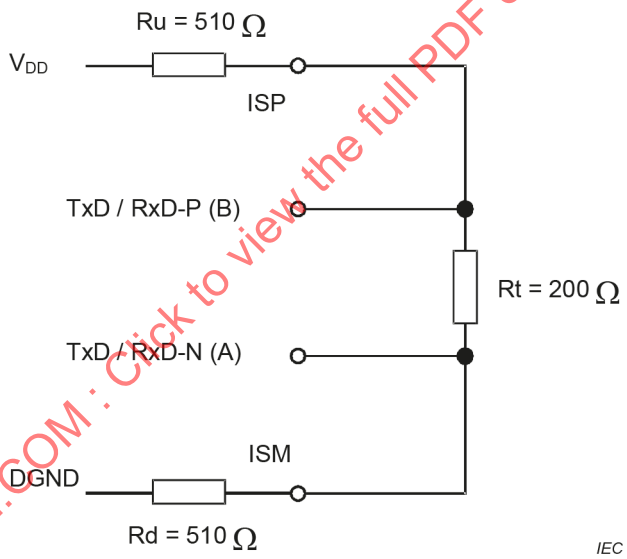


**Figure 127 – Bus terminator**

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### 22.2.3 Transmission method

#### 22.2.3.1 Bit coding

See 22.1.3.1.

#### 22.2.3.2 Transceiver control

See 22.1.3.2.

#### 22.2.3.3 Signal characteristics

##### 22.2.3.3.1 Signal specification

A typical voltage waveform on the intrinsically safe fieldbus is shown in Figure 128. Three phases are defined in which characteristic signal levels are generated on the bus:

– idle state with $V_{ODidle}$

– low phase with $V_{ODlow}$

– high phase with $V_{ODhigh}$

The noise margin plays a crucial role in the definition of signal levels. The noise margin of a signal level is always the difference between the voltage corresponding to this level and the threshold voltage. The threshold voltage $U_{TH}$ is an attribute of the TIA-485-A receiver and is defined in the range of ±0,2 V. For reliable data transmission the noise margin shall be as large as possible. In the case of the MAU for intrinsically safe fieldbus, a minimum noise margin of 0,2 V shall be assured under "worst case" conditions.

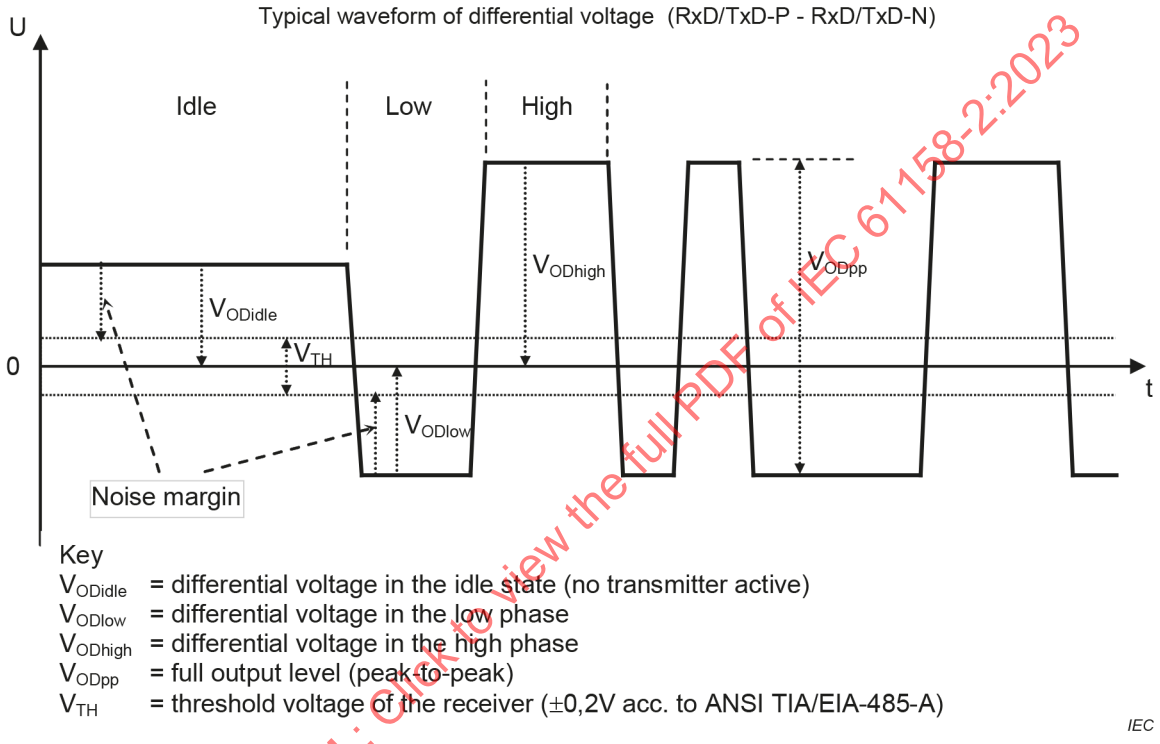


**Figure 128 – Waveform of the differential voltage**

The parameters listed in Table 149 are mandatory for the communication devices.

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**Table 149 – Electrical characteristics of the intrinsically safe interface**

| Parameter | Description | Value | Remark |
|---|---|---|---|
| Minimum idle level | $V_{ODidle}$ [V] | 0,50 | Only relevant for devices with an integrated or a connectable bus termination |
| Transmission level on the bus connection (peak-to-peak) | $V_{ODss}$ [V] | ≥ 2,7 | For the worst-case bus configuration and maximum load on the transmitter |
| Positive and negative transmission level on the bus connection | $V_{ODhigh}$ [V] | ≥ 1,5 | For the worst-case bus configuration and maximum load on the transmitter |
| | $V_{ODlow}$ [V] | ≤ −1,1 | |
| Signal level on the receiver input | $V_{IDhigh}$ [V] | ≥ 0,8 | For the worst-case bus configuration |
| | $V_{Idlow}$ [V] | ≤ −0,4 | |
| Data transmission rates | kbit/s | 9,6;<br>19,2;<br>45,45;<br>93,75;<br>187,5;<br>500;<br>1 500 | A field device can be designed with limited data transmission rate |
| Input impedance (receiver) | $R_{IN}$ [kOhm]<br>$C_{IN}$ [pF]<br>$L_{IN}$ | ≥ 12<br>≤ 40<br>≈ 0 | For a device supplied or not supplied |
| Supply voltage RS 485 driver and bus termination | $V_{DD}$ [V] | 3,3 ±5 % | |

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#### 22.2.3.3.2 Test circuits

##### 22.2.3.3.2.1 General

The purpose of these measurements is the verification of the signal levels required by Table 149. The measurements should be performed statically at a low data transmission rate so that the existing reactances, such as input capacitances, do not influence the measurement results. Furthermore, the bus cable is substituted by an equivalent resistance corresponding to the loop resistance for the maximum length of the bus cable.

NOTE Only the measurements which are specific for the intrinsically safe interface are described here.

Additionally, the compliance with TIA-485-A:1998 should be verified.

##### 22.2.3.3.2.2 Measurement of the idle level

This measurement determines the characteristics of the termination resistance. For this reason, this measurement shall only be performed on devices under test which are either equipped with a bus termination, see Figure 129, or provide a power supply for an external bus termination (the connections ISM and ISP are realised), see Figure 130.

The additional components as well as switch and resistors should be connected directly to the DUT terminals (5 cm to 15 cm). When a connecting cable shall be used, the length of the cable shall not exceed 1 m.

The measurement is undertaken in two steps:

Step 1: the open circuit voltage V1 is measured and shall be greater than specified in Table 149, line 1.

Step 2: the voltage V2 is measured under load conditions (330 Ω load). V2 shall be in a specified range (0,65 × V1 ≤ V2 ≤ 0,72 × V1). That guarantees that the termination resistor is in the range 130 Ω to 180 Ω.

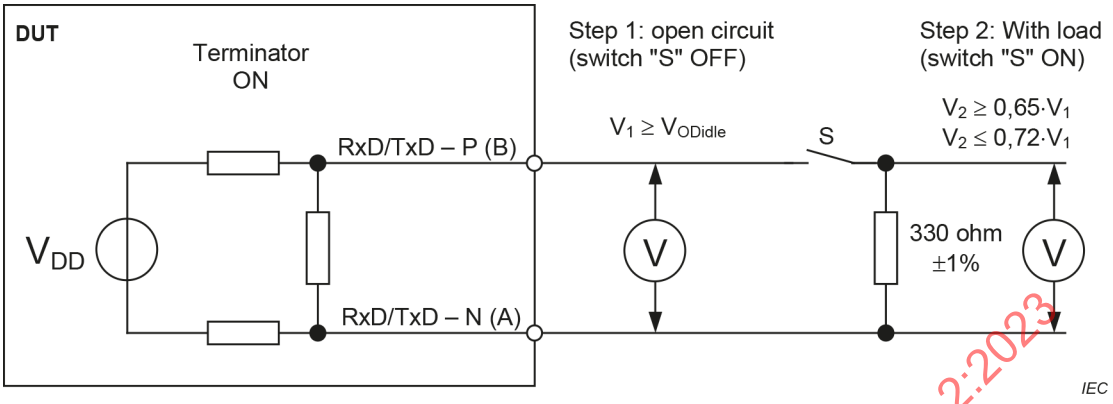


**Figure 129 – Test set-up for the measurement of the idle level for devices with an integrated termination resistor**

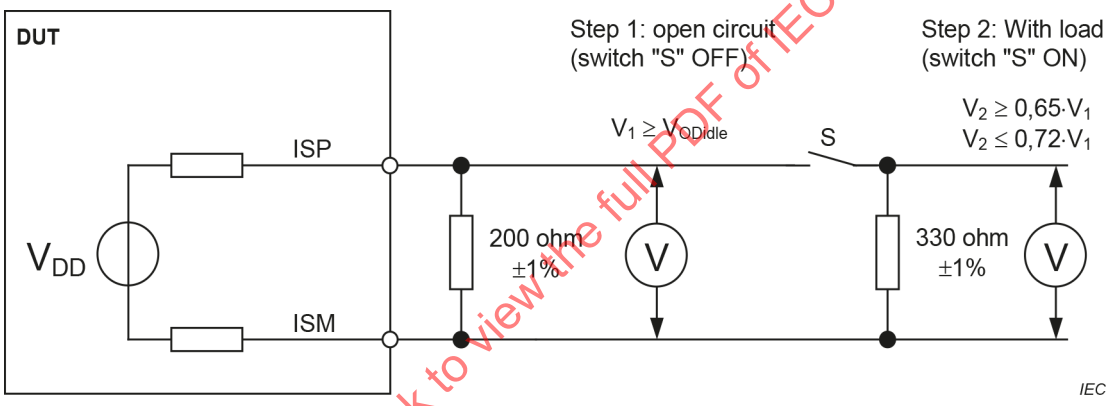


**Figure 130 – Test set-up for the measurement of the idle level for devices with a connectable termination resistor**

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#### 22.2.3.3.2.3 Measurement of the signal levels

For the measurement set-ups below A compliant fieldbus isolating repeater shall be employed for connection on the master system. During the test, the intrinsically safe fieldbus shall be terminated at both ends in accordance with 22.2.2.4. If the bus termination is not integrated in the device under test, then an external compliant bus termination shall be used.

In order to measure the signals on the intrinsically safe fieldbus without external influences, it is necessary to connect an electrically isolated oscilloscope (e.g. a hand-held with a battery supply).

The additional components as well as resistor and resistor network should be connected as short as possible to the terminals of the DUT and the fieldbus isolating repeater. When a connecting cable shall be used, the entire length of the cable(s) shall not exceed 2 m. The oscilloscope can be attached to any suitable terminals according to set-up.

The measurement shown in Figure 131 determines the transmission levels on the transmitter connections and for a worst-case load. This is the case for a fieldbus cable length equal to zero. In this case, the output current of the transmitter and consequently the load is at maximum. The rated values for the transmission levels are shown in Table 149, lines 2 and 3.

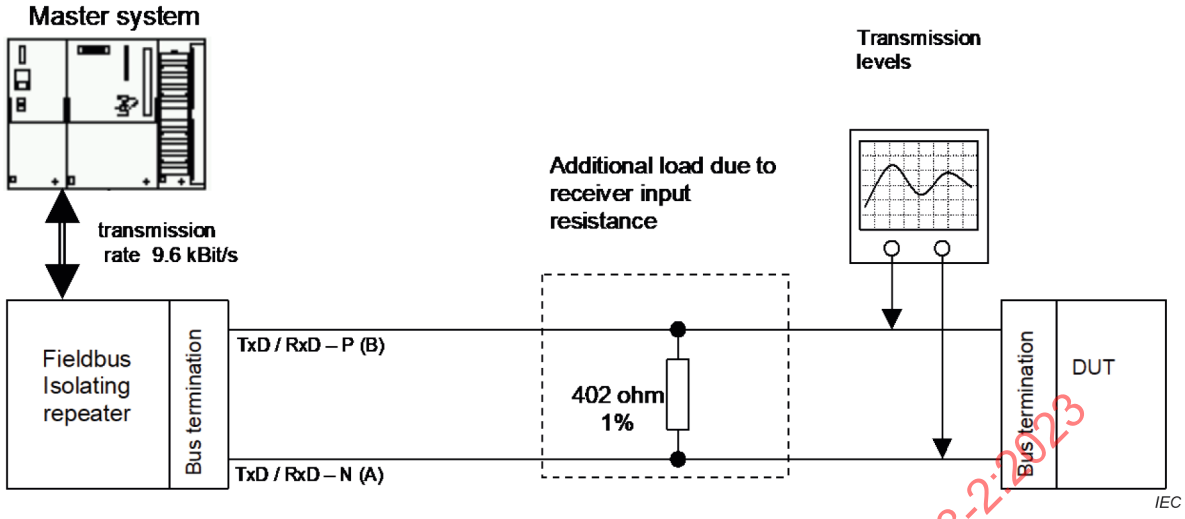


**Figure 131 – Test set-up for measurement of the transmission levels**

The measurement shown in Figure 132 attempts to verify the capability of the transmitter to generate a sufficient level for every receiver for a worst-case load. For a maximum fieldbus cable length of 1 200 m and additional load, this is the case roughly in the middle of the cable. The measurement values shall fulfill the requirements of Table 149, line 4.

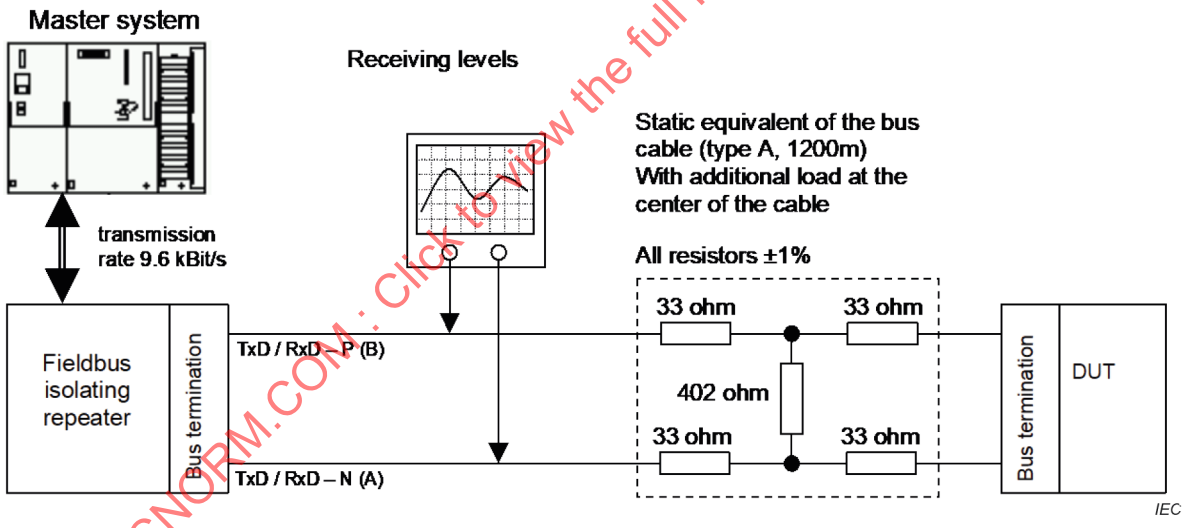


**Figure 132 – Test set-up for the measurement of the receiving levels**

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### 22.2.4 Intrinsic safety

#### 22.2.4.1 General

This document does not attempt to list the requirements by which an item of equipment may be certified as intrinsically safe nor does it require equipment to be intrinsically safe. Rather, it seeks to exclude conditions or situations that would prevent intrinsic safety certification.

#### 22.2.4.2 Fieldbus model for intrinsic safety

The intrinsically safe fieldbus is based on a model, in which all devices are active. All devices are supplied from outside and can provide power to the field bus. In an intrinsically safe circuit, only a maximum amount of energy is permissible when considering the inductances and capacitances which exist. This maximum amount of energy is described by the ignition curves.

NOTE The analysis carried out by the PTB (Physikalisch-Technische Bundesanstalt) forms the basis for the intrinsically safe fieldbus. PTB-Mitteilungen, 113 Jahrgang, Heft 2/2003, Die Bewertung der Zündfähigkeit eigensicherer Stromkreise anhand eines Rechenverfahrens. Abschnitt: Der eigensichere RS 485 Feldbus als Anwendungsbeispiel.

A basic set-up of the fieldbus model is shown in Figure 133. A fieldbus isolating repeater is (usually) located in the non-hazardous area for the safe separation of the intrinsically safe bus segment from the non-intrinsically safe bus segment. Other connected communications devices are located in the hazardous area. The bus cable is terminated at both ends by means of an external active bus termination or a bus termination integrated in a field device. All communications devices are supplied by external voltage sources and possess the means of safely limiting the current and voltage on the bus.

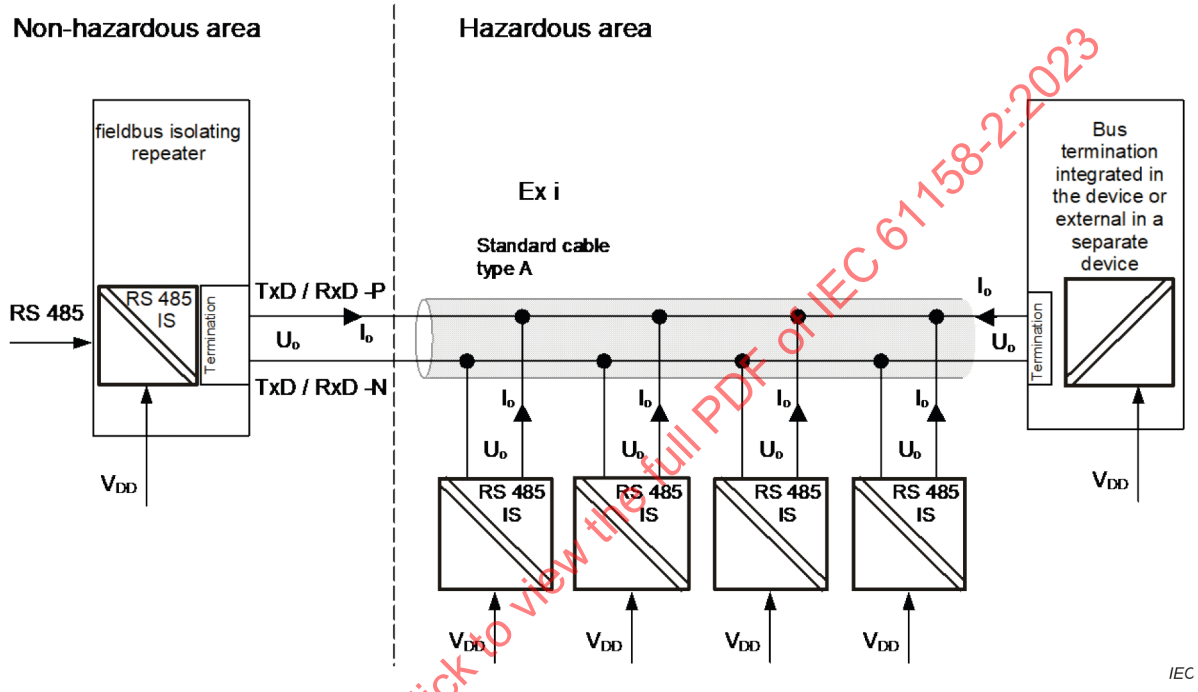


**Figure 133 – Fieldbus model for intrinsic safety**

Under certain circumstances, devices which are installed in the hazardous area shall be protected with additional explosion measures (e.g. Ex e, d, m in accordance with IEC 60079-0).

### 22.2.4.3 Model of a communication device

A circuit diagram for the RS 485-IS interface is described in Figure 134. The interface is composed of the components for galvanic isolation, voltage limitation, current limitation and an RS 485 transceiver.

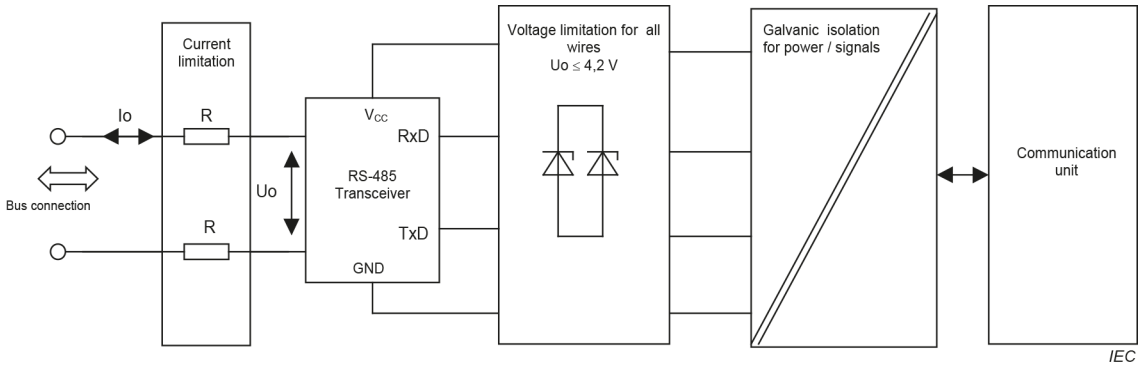


**Figure 134 – Communication device model for intrinsic safety**

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To meet the limit for $U_o$ given in Table 150 all connections to the bus interface (power supply and data lines) shall be limited by appropriate voltage limiting components. In this context, the tolerances and the maximum power rating of the components shall be taken into account. Under certain circumstances, suitable measures for power limitation should be introduced in the communications unit / power supply.

In all devices connected to the intrinsically safe the bus interface circuit shall be galvanically isolated from all other electrical circuits.

Separation distances and insulation voltages between intrinsically safe circuits and/or non-intrinsically safe circuits shall meet IEC 60079-11.

NOTE Current limitation is determined by the maximum output voltage and the sum of the internal resistance. The internal resistance is formed by the series resistors of the data lines RxD/TxD-N and RxD/TxD-P and series resistors Ru and Rd for the supply of the bus terminator.

In this context, the tolerances and power ratings of the resistances shall also be taken into account. Detailed requirements for the current- and voltage-limiting components are outlined in IEC 60079-11.

#### 22.2.4.4 Maximum safety values

Table 150 shows the safety relevant parameters and their values for the entire fieldbus system.

**Table 150 – Maximum safety values**

| Parameter | Description | Value | Remark |
|---|---|---|---|
| **Bus system** | | | |
| Maximum input voltage | $U_i$ [V] | \|±4,2\| | |
| Maximum input current | $I_i$ [A] | 4,8 | The characteristic of the circuit is linear Rs = Uo/Io |
| Maximum inductance to resistance ratio (see Note) | L'/R' [µH/Ω] | 15 | For the whole operation temperature range of the bus system |
| Number of devices | $N_{TN}$ | ≤ 32 | A field device can be designed with limited data transmission rate |
| **Communication Device** | | | |
| Maximum output voltage | Uo [V] | \|±4,2\| | |
| Maximum output current | Io [mA] | 149 | Total current from wires A, B and supply for bus termination |
| Maximum input voltage | $U_i$ [V] | \|±4,2\| | |
| Maximum internal inductance | $L_i$ [H] | 0 | No concentrated inductances are permissible along the fieldbus |
| Maximum internal capacitance | $C_i$ [nF] | N/A | Insignificant for safety |
| **External active bus termination** | | | |
| Maximum output voltage | Uo [V] | \|±4,2\| | |
| Maximum output current | Io [mA] | 16 | |
| Maximum input voltage | $U_i$ [V] | \|±4,2\| | |
| Maximum internal inductance | $L_i$ [H] | 0 | No concentrated inductances are permissible along the fieldbus |
| Maximum internal capacitance | $C_i$ [nF] | N/A | Insignificant for safety |

NOTE For a voltage less than 10 V, the cable capacitance does not cause any additional danger. However, for functional reasons, the cable capacitance for the bus cable is limited to C' < 40 nF/km.

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For functional reasons, the current limitation resistance should be subdivided symmetrically.

#### 22.2.4.5 Fieldbus isolating repeater

In order to create or connect intrinsically safe fieldbus segments, fieldbus isolating repeaters (see Figure 125 and Figure 126) are required. The intrinsically safe fieldbus interfaces of these devices shall also be implemented in accordance with this MAU specification. In particular, the maximum safety data (see 22.2.4.4) and the galvanic isolation from all other circuits (see 22.2.1) shall be considered from the safety point of view.

The fieldbus isolating repeater shall be designed as associated apparatus. If the fieldbus isolating repeaters are to be installed in the hazardous area, additional explosion-protection measures are necessary.

## 23 Type 3: Medium attachment unit: asynchronous transmission, optical medium

### 23.1 Characteristic features of optical data transmission

Table 151 shows the characteristic features of an optical data transmission.

**Table 151 – Characteristic features**

| Item | Feature |
|---|---|
| Transfer medium | Fiber optic cable (FOC) manufactured from quartz or plastic |
| Characteristics | - Large range, independent of the transmission speed<br>- Insensitivity to electromagnetic disturbance<br>- Galvanic isolation between the connected nodes<br>- Non-reacting connection - even to existing implementations<br>- Configuration of the optical components with economical, standard components |
| Network structure | Star, ring, line and mixed topologies (tree)<br>Connection to electrical network segments |
| Network components | Active star coupler<br>Repeater<br>Opto-electrical converter } with or without retiming |
| Data rates | 9,6 kbit/s; 19,2 kbit/s; 45,45 kbit/s; 93,75 kbit/s; 187,5 kbit/s; 500 kbit/s; 1,5 Mbit/s; 3 Mbit/s; 6 Mbit/s; 12 Mbit/s |
| Network range and number of nodes | Dependent on the number and type of network components used<br>EXAMPLE 1 Network segment with 1 active star coupler and glass fiber optic cable (multimode):<br>- 3 400 m (independent of the number of nodes).<br>EXAMPLE 2 Network segment with 1 active star coupler and plastic fiber optic cable:<br>- 88 m (independent of the number of nodes).<br>NOTE Increasing of ranges and numbers of nodes is possible through linking network segments. |

Figure 135 shows the optical MAU beside a TIA-485-A:1998 MAU. This means that the optical MAU shall be connected over a DL-Ph interface to a DLL in the same manner as an TIA-485-A:1998 MAU. The mentioned interface is described in 5.4.2.

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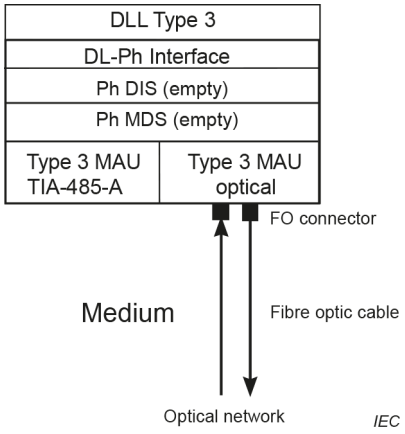


**Figure 135 – Connection to the optical network**

### 23.2 Basic characteristics of an optical data transmission medium

An optical data transmission medium is characterized by:

– Insensitivity to electromagnetic interference, i.e.:
  a) no cross talk between different fiber optic signal lines,
  b) immunity to interference injection from and to electrical lines,
  c) immunity to interference from electromagnetic fields which can occur e.g. when switching large electrical loads.
– Galvanic isolation between the connected nodes, i.e.:
  d) no equalizing currents between differing ground potentials
  e) no special lightning protection measures are required for the transmission link.
– The capability to use fiber optics to bridge large distances at high transmission speeds.
– Simple and economical installation of shorter networks based on plastic fibers.
– Low weight.
– No corrosion.
– Simplified standard cabling of buildings through identical reference fibers for many other communication standards.

### 23.3 Optical network

Significant components of the optical MAU of a node are the electro-optical converters that interface the electrical part of the MAU and an optical network medium.

An optical transmitter converts electrical signals into optical ones and feeds these signals into the optical medium. Conversely, an optical receiver converts the received optical signals from the optical medium into electrical signals.

Figure 136 shows the principle structure of an optical network.

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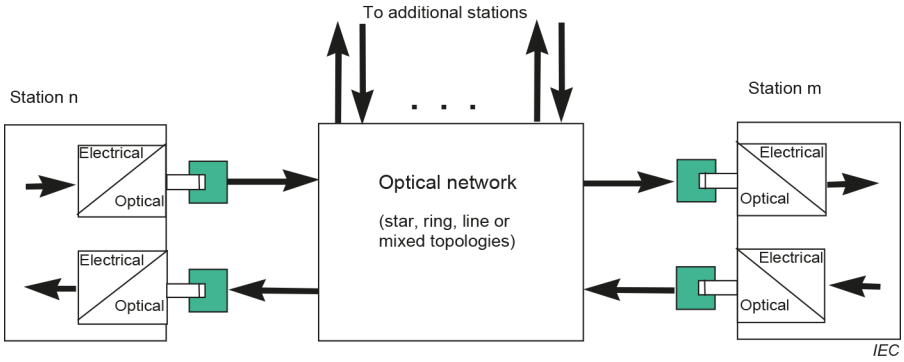


**Figure 136 – Principle structure of optical networking**

Electrical-optical converters with a specific signal level budget that take into account of the physical differences between glass and plastic fibers are specified for each fiber type.

The user can "consume" the signal level budget as attenuation along the optical link.

### 23.4 Standard optical link

The standard optical link is a theoretical construction that is used to specify the admissible range of signal levels and signal distortions, see Figure 137.

Network topologies of any complexity can be calculated from the standard optical link. The standard optical link consists of

– an electro-optical converter (transmitter) that converts an electrical signal into an optical signal which lies within the admissible limits specified by the signal template (see Figure 138);

– a passive optical link consisting of a fiber optic cable and characterized by signal amplitude attenuation and signal timing distortion;

– an opto-electrical converter (receiver) that detects the received optical signal as described in 23.7.3 and converts this signal to an electrical signal with characteristics specified in 23.8.

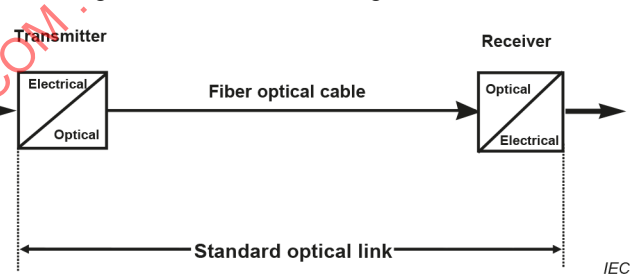


**Figure 137 – Definition of the standard optical link**

### 23.5 Network structures built from a combination of standard optical links

According to the definition above, a standard optical link forms an end-to-end connection. Standard optical links can be interconnected (chained) to build complex networks by interconnecting the electric interfaces. Chaining rules are specified in 23.8.3.

The user can thus specify the network structure by choosing the signal distribution to best meet the requirements of the system to be networked.

The following topologies are supported: star, ring or linear topologies, as well as their combination to form a mixed topology. Coupling of optical and electrical segments of the network (such as TIA-485-A:1998 MAU) is both possible and permissible.

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### 23.6 Bit coding

NRZ bit coding (non return to zero) from the DLL is represented with optical signals as follows:

– binary "1" (DL_symbol = "ONE") means no light on the FOC,
– binary "0" (DL_symbol = "ZERO") means light on the FOC.

The idle state (DL_symbol = "SILENCE") has the "1" binary state, i.e. no light.

### 23.7 Optical signal level

#### 23.7.1 General

Taking into account the physical differences between glass and plastic fibers, a specific level budget is applicable for both fiber types.

#### 23.7.2 Characteristics of optical transmitters

The transmitted power is specified in dBm.

The specified levels are defined at the end of a 1 m long glass fiber optic cable or a 0,5 m long plastic fiber optic cable and measured with a large detector area. Cladding modes shall not be included in the measured value. The fiber optic cable shall be connected to the transmitter using the connector specified in 23.10. That is, the attenuation of the connector at the optical transmitter is included in the measured value.

The signal level tolerances are applicable for the entire operating temperature range (ambient temperature of the transmitter element).

All values specified in the following Table 152 to Table 155 are based on the shape of the transmit signal specified by the signal template in Figure 138. The technical terms used in the table (peak wavelength, etc.) are explained in IEC 60050-731.

**Table 152 – Characteristics of optical transmitters for multi-mode glass fiber**

| Quantity | Value | Unit |
|---|---|---|
| Peak wavelength | 790 to 910 | nm |
| Spectral width | ≤ 75 | nm |
| Operating temperature | 0 to 70 | °C |
| Test fiber (graded index) (see Note) | 62,5/125 | µm |
| NA (numerical aperture of the test fiber) | 0,275 ± 0,015 | |
| $P_{Smax"0"}$ (max. transmit power for binary "0") | −10 | dBm |
| $P_{Smin"0"}$ (min. transmit power for binary "0") | −15 | dBm |
| $P_{Smax"1"}$ (max. transmit power for binary "1") | −40 | dBm |
| $P_{Sost}$ (max. overshoot, transmit power for binary "0") | −8,8 | dBm |
| NOTE Test fiber as specified in IEC 60793, Type A1b. | | |

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**Table 153 – Characteristics of optical transmitters for single-mode glass fiber**

| Quantity | Value | Unit |
|---|---|---|
| Peak wavelength | 1 260 to 1 380 | nm |
| Spectral width | ≤ 120 | nm |
| Operating temperature | 0 to 70 | °C |
| Test fiber (graded index) (see Note) | 9/125 | µm |
| NA (numerical aperture of the test fiber) | 0,113 ± 0,02 | |
| $P_{Smax"0"}$ (max. transmit power for binary "0") | −10 | dBm |
| $P_{Smin"0"}$ (min. transmit power for binary "0") | −20 | dBm |
| $P_{Smax"1"}$ (max. transmit power for binary "1") | −40 | dBm |
| $P_{Sost}$ (max. overshoot, tx power for "0") | −8,8 | dBm |
| NOTE Test fiber as specified in IEC 60793, Type B1.1, B3. | | |

**Table 154 – Characteristics of optical transmitters for plastic fiber**

| Quantity | Value | | Unit |
|---|---|---|---|
| Peak wavelength | 640 to 675 | | nm |
| Spectral width | ≤ 35 | | nm |
| Operating temperature | 0 to 70 | | °C |
| Test fiber (graded index) (see Note) | 980/1 000 | | µm |
| NA (numerical aperture of the test fiber) | 0,5 ± 0,15 | | |
| Transmitter power level | Standard | Increased | |
| $P_{Smax"0"}$ (max. transmit power for binary "0") | −5,0 | 0 | dBm |
| $P_{Smin"0"}$ (min. transmit power for binary "0") | −11 | −6 | dBm |
| $P_{Smax"1"}$ (max. transmit power for binary "1") | −42 | −42 | dBm |
| $P_{Sost}$ (max. overshoot, transmit power for binary "0") | −4,3 | 2,3 | dBm |
| NOTE Test fiber as specified in IEC 60793, Type A4a. | | | |

**Table 155 – Characteristics of optical transmitters for 200/230 µm glass fiber**

| Quantity | Value | Unit |
|---|---|---|
| Peak wavelength | 640 to 675 | nm |
| Spectral width | ≤ 35 | nm |
| Operating temperature | 0 to 70 | °C |
| Test fiber (stepped index) (see Note) | 200/230 | µm |
| NA (numerical aperture of the test fiber) | 0,37 ± 0,02 | |
| $P_{Smax"0"}$ (max. transmit power for binary "0") | −8 | dBm |
| $P_{Smin"0"}$ (min. transmit power for binary "0") | −17 | dBm |
| $P_{Smax"1"}$ (max. transmit power for binary "1") | −44 | dBm |
| $P_{Sost}$ (max. overshoot, transmit power for binary "0") | −6,8 | dBm |
| NOTE Test fiber in IEC 60793, Type A3c: NA = 0,4 ± 0,04. | | |

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### 23.7.3 Characteristics of optical receivers

The input sensitivity of receivers is also specified in dBm see Table 156 to Table 159. The input sensitivity is measured at the end of the specified reference fiber with a large detector area. Cladding modes shall not be included in the measured value.

The signal level tolerances are applicable for the entire operating temperature range (ambient temperature of the receiver element). They shall be maintained throughout the specified lifetime of the receive element. The shape of the receive signal is based on the shape of the transmit signal shown in the signal template in Figure 138.

The receiver shall tolerate an overshoot of the input signal at the beginning of a binary "0" pulse. However, the receiver shall not require an overshoot, e.g. to maintain a required signal distortion.

**Table 156 – Characteristics of optical receivers for multi-mode glass fiber**

| Quantity | Value | Unit |
|---|---|---|
| Peak wavelength | 790 to 910 | nm |
| Operating temperature | 0 to 70 | °C |
| $P_{Emax"0"}$ (max. receive power for binary "0") | −10 | dBm |
| $P_{Emin"0"}$ (min. receive power for binary "0") | −24 | dBm |
| $P_{Emax"1"}$ (max. receive power for binary "1") | −42 | dBm |

**Table 157 – Characteristics of optical receivers for single-mode glass fiber**

| Quantity | Value | Unit |
|---|---|---|
| Peak wavelength | 1 260 to 1 380 | nm |
| Operating temperature | 0 to 70 | °C |
| $P_{Emax"0"}$ (max. receive power for binary "0") | −10 | dBm |
| $P_{Emin"0"}$ (min. receive power for binary "0") | −27 | dBm |
| $P_{Emax"1"}$ (max. receive power for binary "1") | −40 | dBm |

**Table 158 – Characteristics of optical receivers for plastic fiber**

| Quantity | Value | | Unit |
|---|---|---|---|
| Peak wavelength | 640 to 675 | | nm |
| Operating temperature | 0 to 70 | | °C |
| Receiver for tx performance level | Standard | Increased | |
| $P_{Emax"0"}$ (max. receive power for binary "0") | −5 | 0 | dBm |
| $P_{Emin"0"}$ (min. receive power for binary "0") | −20 | | dBm |
| $P_{Emax"1"}$ (max. receive power for binary "1") | −42 | | dBm |

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**Table 159 – Characteristics of optical receivers for 200/230 µm glass fiber**

| Quantity | Value | Unit |
|---|---|---|
| Peak wavelength | 640 to 675 | nm |
| Operating temperature | 0 to 70 | °C |
| $P_{Emax"0"}$ (max. receive power for binary "0") | −8 | dBm |
| $P_{Emin"0"}$ (min. receive power for binary "0") | −22 | dBm |
| $P_{Emax"1"}$ (max. receive power for binary "1") | −44 | dBm |

## 23.8 Temporal signal distortion

### 23.8.1 General

The following sections describe the signal distortion due to each of the elements in the transmission link.

Evaluation of the electrical digital signals always takes place at the intersection with 50 % of the signal amplitude.

### 23.8.2 Signal shape at the electrical input of the optical transmitter

The permissible signal distortion at the electrical input of the optical transmitter of a station or a component with retiming is shown in Table 160.

**Table 160 – Permissible signal distortion at the electrical input of the optical transmitter**

| Signal | Limits for data rates < 1,5 Mbit/s | Limits for data rates ≥ 1,5 Mbit/s [a] |
|---|---|---|
| $t_{BIT}$ [b] | 1/ Data_rate × (1 ± 0,3 %) | 1/ Data_rate × (1 % ± 0,03 %) |
| $t_{SBIT}$ (only for stop bit) [c] | $t_{BIT}$ × (1 ± 6,25 %) | |

[a] Data rate is the nominal data rate specified in Table 151.

[b] $t_{BIT}$ is the time, which elapses during the transmission of one bit. It is equivalent to the reciprocal value of the transmission rate.

[c] $t_{SBIT}$ is the extended tolerance for the permissible bit duration in the optical network that applies exclusively to the transmitted stop bit. This extension of the tolerance allows repeaters with retiming to equalize deviations in the receive and transmit clocks.

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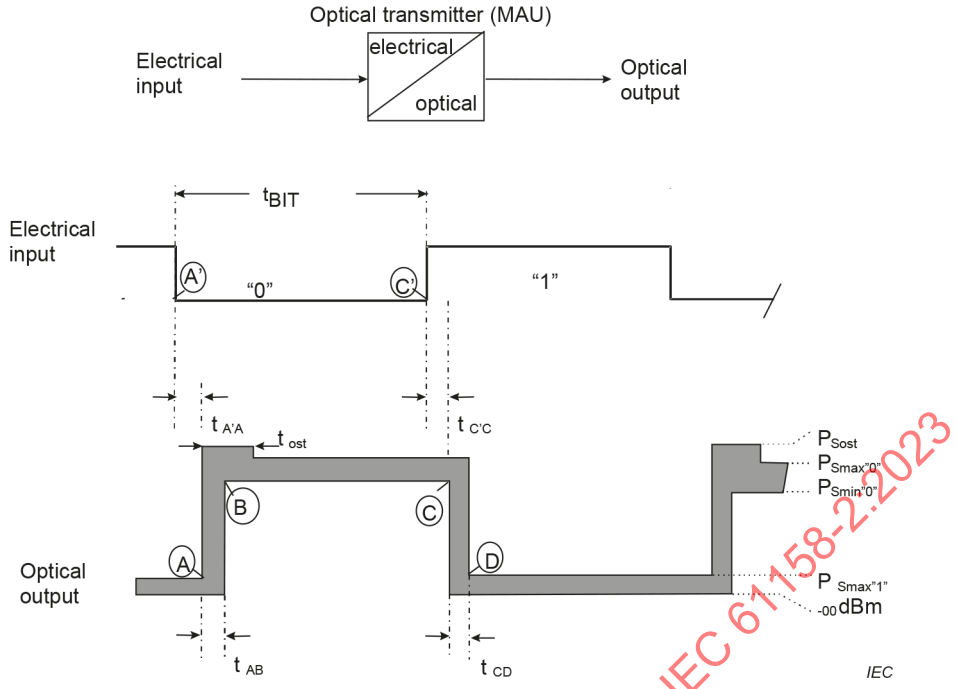
### 23.8.3 Signal distortion due to the optical transmitter

To meet the specified requirements, the transmit signal of the optical transmitter shall be within the shaded section of the signal template in Table 138, with parameters as given in Table 161.




where

$t_{ost}$ = the maximum duration that the maximum optical transmit power can be exceeded dynamically.

$t_{AB}$ = the rising edge of the optical signal shall pass through $P_{Smax"1"}$ to $P_{Smin"0"}$ within this time.

$t_{CD}$ the falling edge of the optical signal shall pass through $P_{Smin"0"}$ to $P_{Smax"1"}$ within this time.

$t_{A'A}$ the shortest duration signal delay due to the electro-optical converter for a level change from "1" to "0" (rising optical edge).

$t_{C'C}$ the shortest duration signal delay due to the electro-optical converter for a level change from "0" to "1" (falling optical edge).

**Figure 138 – Signal template for the optical transmitter**

The optical transmitter shall meet the template specifications at ≤ 1,5 Mbit/s and 3 Mbit/s to 12 Mbit/s as shown in Table 161.

**Table 161 – Permissible signal distortion due to the optical transmitter**

| Time | ≤ 1,5 Mbit/s | 3 Mbit/s to 12 Mbit/s | Unit |
|---|---|---|---|
| $t_{ost}$ | 200 | 20 | ns |
| $t_{AB}$ | 40 | 25 | ns |
| $t_{CD}$ | 95 | 25 | ns |
| $t_{A'A} - t_{C'C}$ | 65 | 5 | ns |

### 23.8.4 Signal distortion due to the optical receiver

The maximum distortion of the receiver's electrical output signal compared to the optical input signal is specified in Table 162. This applies to the entire input level range specified in 23.7.3.

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**Table 162 – Permissible signal distortion due to the optical receiver**

| Time | ≤ 1,5 Mbit/s | 3 Mbit/s to 12 Mbit/s | Unit |
|---|---|---|---|
| $t_{dis"0"}$ [a] | −20 to 95 | −25 to 25 | ns |

[a] $t_{dis"0"}$ describes the permissible limits of the bit duration distortion for a "0" bit.

### 23.8.5 Signal influence due to coupling components

Coupling components, such as active star couplers, TIA-485-A:1998/optical-MAU converters or repeaters contain internal logic that influences the propagated signal beyond that due to the electro-optical converter that was described above.

The maximum influence shall be within the limits specified in Table 163

**Table 163 – Permissible signal influence due to internal electronic circuits of a coupling component**

| Time | ≤ 1,5 Mbit/s | 3 Mbit/s to 12 Mbit/s | Unit |
|---|---|---|---|
| $t_{log}$ [a] | −0 to 10 | −0 to 10 | ns |
| $t_{delay}$ [b] | ≤ 3 $t_{BIT}$ | ≤ 8 $t_{BIT}$ | ns |

[a] $t_{log}$ describes the maximum permissible signal distortion due to the internal logic of a coupling component (for example an active star coupler) with no retiming. This factor is relevant when chaining standard optical links and is already taken into account in Table 164.

[b] $t_{delay}$ describes the maximum permissible signal delay between any input and output when passing through a coupling component (for example an active star coupler).

### 23.8.6 Chaining standard optical links

If the network consists of standard optical links connected in series (chaining), the sum of the distortions of individual links shall not exceed the overall permissible bit duration distortion of a node interface, which is 25 % (≤ 1,5 Mbit/s) or 30 % (12 Mbit/s).

Since the distortions of the electro-optical converters represent absolute values, they become increasingly important at higher data transmission rates.

If standard optical links are chained without a retiming device, the calculated maximum number of links between two nodes and/or retiming components shall not exceed the values shown in Table 164.

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**Table 164 – Maximum chaining of standard optical links without retiming**

| Data rate | Number of links in series (≤ 1,5 Mbit/s, [a]) | Number of links in series (3 Mbit/s to 12 Mbit/s, [b]) |
|---|---|---|
| 12 Mbit/s | - | 1 |
| 6 Mbit/s | - | 2 |
| 3 Mbit/s | - | 4 |
| 1,5 Mbit/s | 1 | 8 |
| 500 kbit/s | 3 | 24 |
| 187,5 kbit/s | 8 | 64 |
| 93,75 kbit/s | 16 | 128 |
| 45,45 kbit/s | 33 | 264 |
| 19,2 kbit/s | 78 | 625 |
| 9,6 kbit/s | 156 | 1 250 |

[a] Devices designed for max. data transmission rate of 1,5 Mbit/s.

[b] Devices designed for max. data transmission rate of 12 Mbit/s.

Any required degree of chaining is possible if the coupling components re-establish the timing between the optical links (retiming).

### 23.9 Bit error rate

A maximum bit error rate (BER) of $10^{-9}$ is permitted at the electrical output of a standard optical link.

### 23.10 Connectors for fiber optic cable

The connectors are specified in I.2.2.

### 23.11 Redundancy in optical transmission networks

A redundant optical link analogous to the Type 3 electrical transmission technology is also possible. The functional principle is described in Annex J.

## 24 Type 4: Medium attachment unit: RS-485

### 24.1 General

The RS-485 MAU can be used to connect up to 125 fieldbus devices on the same cable. The length of the cable can be up to 1 200 m, and the Baud rate can be 9 600, 19 200, 38 400 or 76 800.

### 24.2 Overview of the services

The MDS-MAU interface makes services available to connect the MDS with a corresponding MAU. The TxS and RxS services are defined as logical signals that the MAU sublayer directly converts into physical signals. The TxE service is defined as a logical signal that is used internally in the MAU. The services of the RS-485 MDS-MAU interface are shown in Table 165.

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**Table 165 – Services of the MDS-MAU interface, RS-485, Type 4**

| Signal name | Mnemonic | Direction |
|---|---|---|
| Transmit Signal | TxS | To MAU |
| Transmit Enable | TxE | To MAU |
| Receive Signal | RxS | From MAU |

## 24.3 Description of the services

### 24.3.1 Transmit signal (TxS)

This service transmits the PhPDU from the MDS to the MAU, where it shall be transmitted on to the medium if Transmit Enable (TxE) is set to logic 1 (high level).

### 24.3.2 Transmit enable (TxE)

The Transmit Enable service (TxE) shall provide the MDS with the facility to enable the MAU to transmit. TxE shall be set to logic 1 (high level) by the MDS immediately before the transmission begins, and to logic 0 (low level) minimum 3, maximum 10 bit periods after transmission ends.

### 24.3.3 Receive signal (RxS)

This service transmits the PhPDU from the MAU to the MDS.

## 24.4 Network

### 24.4.1 General

This MAU operates in a network that consists of the following components:

– cable;
– connectors;
– devices (containing at least one communication element).

### 24.4.2 Topology

This MAU shall operate in a bus structure organized as a physical ring without termination. Up to 125 fieldbus devices are connected directly or via stubs of maximum length 2 m. The total length of the cable shall not exceed 1 200 m.

## 24.5 Electrical specification

The voltage levels of the transmitter and receiver can be taken from TIA-485-A:1998.

## 24.6 Time response

The time response of the transmitter and receiver can be taken from TIA-485-A:1998.

## 24.7 Interface to the transmission medium

A recommended circuit for coupling to the transmission medium is shown in Figure 139.

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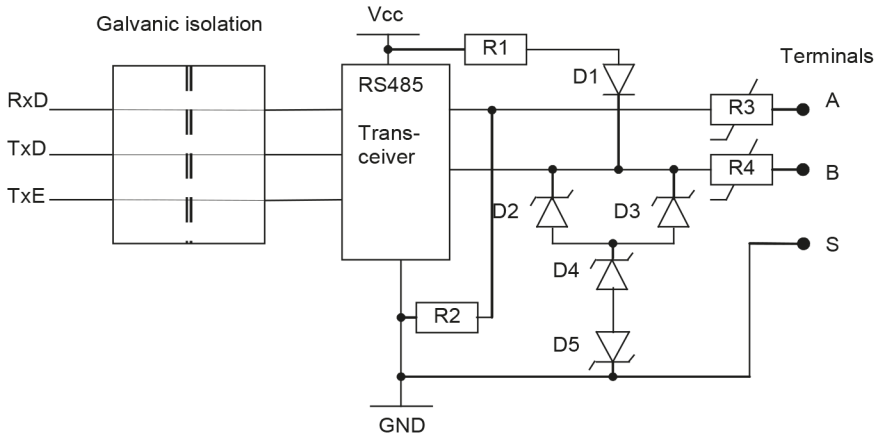


Component values:

| | |
|---|---|
| R1, R2 | 15 kΩ |
| R3, R4 | PTC, max 13 Ω; hold current 100 mA |
| D1 | 100 mA small signal diode |
| D2, D3, D4, D5 | 3.9 V / 1 W Voltage regulator diode |

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**Figure 139 – Recommended interface circuit**

### 24.8 Specification of the transmission medium

#### 24.8.1 Cable connectors

Normally, fieldbus devices are equipped with screw terminals marked A, B and S for shield.

#### 24.8.2 Cable

A shielded twisted pair cable with conductors with minimum 0,22 $mm^2$ cross section and a characteristic impedance of 100 Ω to 120 Ω.

## 25 Void

NOTE Clause 25 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the clause numbering of the prior edition.

## 26 Void

NOTE Clause 26 is a placeholder in this edition to minimize the disruption to existing national and multi-national standards and consortia documents that reference the clause numbering of the prior edition.

## 27 Type 8: Medium attachment unit: twisted-pair wire medium

### 27.1 MAU signals

A MAU of an outgoing and incoming interface is shown in Figure 140 and Figure 141.

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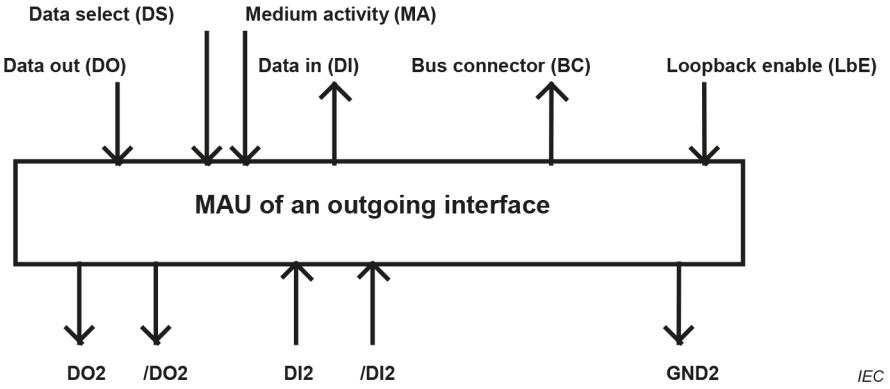


**Figure 140 – MAU of an outgoing interface**

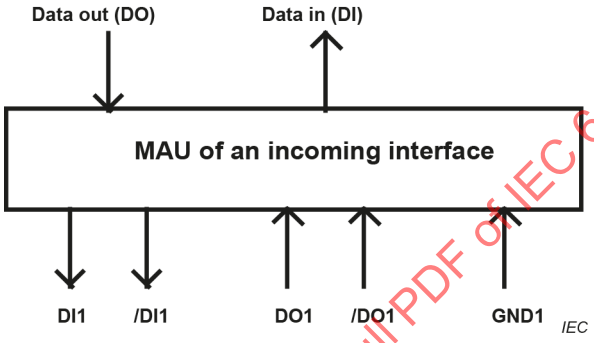


**Figure 141 – MAU of an incoming interface**

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### 27.2 Transmission bit rate dependent quantities

Four bit rates are defined for the twisted pair wire medium attachment unit (MAU). A given MAU shall support at least one of these bit rates. Table 166 defines the bit rates and bit rate dependent quantities.

**Table 166 – Bit rate dependent quantities twisted pair wire medium MAU**

| Quantity | Value | | | | Unit |
|---|---|---|---|---|---|
| Nominal bit rate (see Note) | 0,5 | 2 | 8 | 16 | Mbit/s |
| Maximum deviation from bit rate | ± 0,1 % | ± 0,1 % | ± 0,1 % | ± 0,1 % | — |
| Nominal bit duration (T) | 2 000 | 500 | 125 | 62,5 | ns |
| Minimum remote bus length | 0 | 0 | 0 | 0 | m |
| Maximum remote bus length | 400 | 150 | 125 | 100 | m |
| Maximum transmitted bit cell jitter | ± 240 | ± 60 | ± 15 | ± 7,5 | ns |
| NOTE Average transmission bit rate for 13 bits. | | | | | |

### 27.3 Network

#### 27.3.1 General

A twisted-pair wire medium MAU operates in a network that consists of the following components:

– cable;

– connectors;

– electrical isolation;
– devices (with at least one communication element).

### 27.3.2 Topology

The twisted-pair wire medium MAU shall operate in one remote bus with one further device. A remote bus link (see Figure 142) consists of two point-to point connections. The connections are unidirectional. Thus each MAU has one transmitter and one receiver.

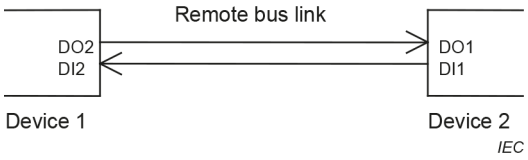


**Figure 142 – Remote bus link**

A remote bus link shall be between 0 and the maximum length for a given bit rate (see Table 166).

### 27.4 Electrical specification

The voltage levels of the transmitter and receiver shall be taken from TIA-422-B:1994.

### 27.5 Time response

The time response of the transmitter and the receiver shall be taken from TIA-422-B:1994.

### 27.6 Interface to the transmission medium

#### 27.6.1 General

The coupling to the transmission medium is effected via one incoming (optional) and one or several outgoing interfaces which are independent of the medium (see Figure 143).

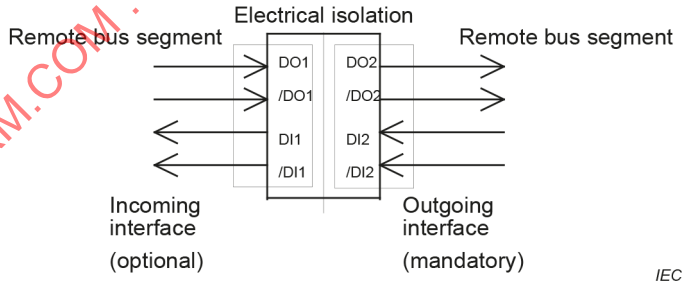


**Figure 143 – Interface to the transmission medium**

### 27.6.2 Incoming interface

The incoming interface comprises five signal lines (see Table 167) for the connection to the network. These signal lines have to be electrically isolated from the device. The isolation voltage shall amount to ≥ 500 V (direct voltage).

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**Table 167 – Incoming interface signals**

| Short name | Name |
|---|---|
| DO1 | Receive data line + |
| /DO1 | Receive data line − |
| DI1 | Send data line + |
| /DI1 | Send data line − |
| GND1 | Ground line |

### 27.6.3 Outgoing interface

The outgoing interface comprises five signal lines (see Table 168) for the connection to the network.

**Table 168 – Outgoing interface signals**

| Short name | Name |
|---|---|
| DO2 | Send data line + |
| /DO2 | Send data line − |
| DI2 | Receive data line + |
| /DI2 | Receive data line − |
| GND2 | Ground line |

## 27.7 Specification of the transmission medium

### 27.7.1 Cable connectors

If used, the 9-position subminiature D connectors shall use a standard connector pin assignment (see M.1.1).

Field termination elements such as screw-clamp or flat-type connectors and fixed connectors, can also be used. In this case the connector pin assignment given in M.1.2 should be used.

### 27.7.2 Cable

A shielded cable with two twisted cable pairs is to be used as a bus cable. The shielding is to improve the electromagnetic compatibility (EMC). The remote bus cable should at least fulfil the requirements indicated in Table 169.

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**Table 169 – Remote bus cable characteristics**

| Characteristic quantity (20 °C) | Value | Test method |
|---|---|---|
| Number of wires (twisted pairs) | 3 × 2, twisted pair | |
| Cross section | Min. 0,20 $mm^2$ | |
| Direct current conductor resistance/100 m | Max. 9,6 Ω | IEC 60189-1:2018, 8.1 |
| Characteristic impedance | 120 Ω ± 24 Ω at f = 0,064 MHz | |
| | 100 Ω ± 15 Ω at f > 1 MHz | IEC 61156-1, 6.3.1 |
| Dielectric strength | | |
| - Conductor/conductor | 1 $kV_{RMS}$, 1 min | IEC 60189-1:2018, 8.2 |
| - Conductor/shield | 1 $kV_{RMS}$, 1 min | |
| Insulation resistance<br>(after dielectric strength test) | Min 150 MΩ for a cable of 1 km in length | IEC 60189-1:2018, 8.3 |
| Maximum transfer impedance | | |
| - at 30 MHz | 250 mΩ/m | |
| Mutual capacitance (at 800 Hz) | Max. 60 nF for a cable of 1 km in length | IEC 60189-1:2018, 8.4 |
| Min. near end cross talk loss (NEXT) for a cable of 100 m | | IEC 61156-1, 6.3.5 |
| - at 0,772 MHz | 61 dB | |
| - at 1 MHz | 59 dB | |
| - at 2 MHz | 55 dB | |
| - at 4 MHz | 50 dB | |
| - at 8 MHz | 46 dB | |
| - at 10 MHz | 44 dB | |
| - at 16 MHz | 41 dB | |
| - at 20 MHz | 40 dB | |
| Max. attenuation for a cable of 100 m | | IEC 61156-1, 6.3.3. |
| - at 0,256 MHz | 1,5 dB | |
| - at 0,772 MHz | 2,4 dB | |
| - at 1 MHz | 2,7 dB | |
| - at 4 MHz | 5,2 dB | |
| - at 10 MHz | 8,4 dB | |
| - at 16 MHz | 11,2 dB | |
| - at 20 MHz | 11,9 dB | |

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The minimum wiring with a shield between two communicating devices is shown in Figure 144.

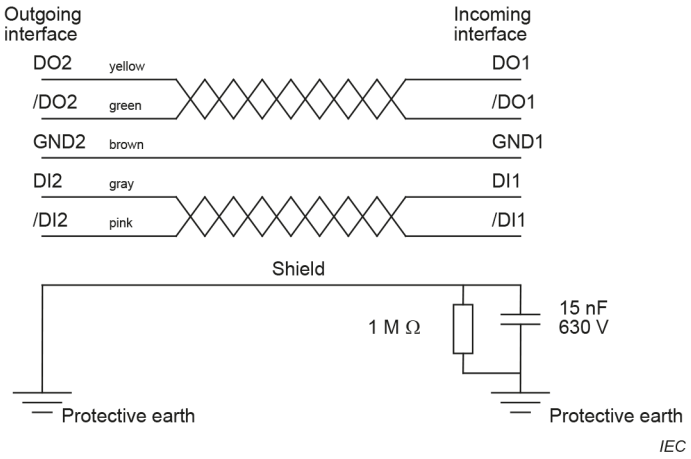


**Figure 144 – Wiring**

### 27.7.3 Terminal resistor

The cable pair of the receive line is to be connected with a resistor network (see Figure 145) directly before the receiver of the MAU. The circuit can be used for the polarisation of the MAU, for the detection of a short or open circuit on a wire. It shall be observed that the resulting equivalent resistance is at least 100 Ω.

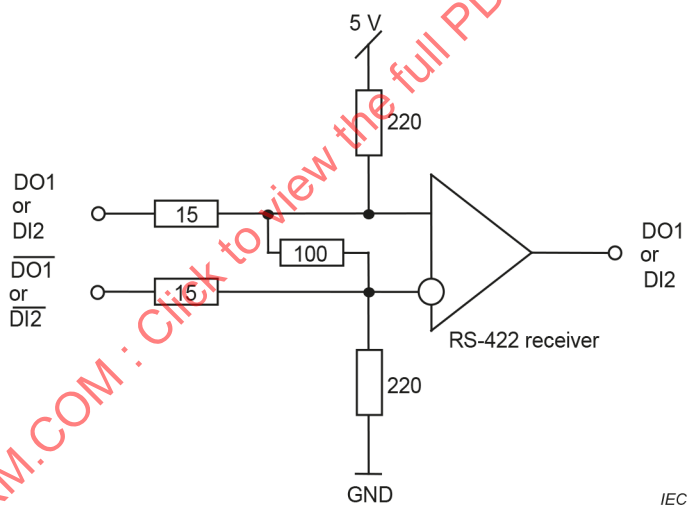


**Figure 145 – Terminal resistor network**

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## 28 Type 8: Medium attachment unit: optical media

### 28.1 General

The object of Clause 28 is to give the operating and optical specifications of the duplex fiber mode optical MAU.

The fiber optic remote bus cable consists of a pair of optical fiber (see Figure 146) waveguides providing bidirectionality by use of a separate fiber for each direction of signal propagation. These dual fibers connect to the CPIC of a network device.

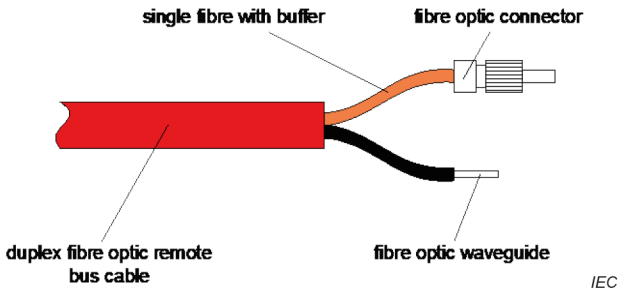


**Figure 146 – Fiber optic remote bus cable**

Two optical fiber types are supported:

– polymer optical fiber;
– plastic clad silica fiber.

### 28.2 Transmission bit rate dependent quantities

Four bit rates are defined for the optical medium attachment unit (MAU). A given MAU shall support at least one of these bit rates. Table 170 defines the bit rates and bit rate dependent quantities.

**Table 170 – Bit rate dependent quantities optical MAU**

| Transmit timing characteristics | Value | | | | Unit |
|---|---|---|---|---|---|
| Nominal bit rate | 0,5 | 2 | 8 | 16 | Mbit/s |
| Maximum deviation from bit rate | ± 0,1 % | ± 0,1 % | ± 0,1 % | ± 0,1 % | |
| Nominal bit duration (T) | 2 000 | 500 | 125 | 62,5 | ns |

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### 28.3 Network topology

An optical MAU operates in a network that consists of the following components:

– optical cable;
– connectors;
– devices (containing at least one communication element).

An optical MAU shall operate in one remote bus with one further device. A remote bus link (see Figure 147) consists of two point-to-point connections. The connections are unidirectional. Thus each MAU has one fiber optic transmitter and one fiber optic receiver.

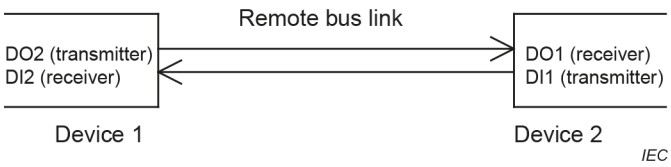


**Figure 147 – Optical fiber remote bus link**

The cable length shall be in the range specified in Table 171.

**Table 171 – Remote bus fiber optic cable length**

| Fiber type | Minimum length | Maximum length |
|---|---|---|
| Polymer optical fiber | 1 m | 50 m [a] [b] |
| Plastic clad silica fiber | 1 m | 300 m [a] [b] |

[a] This does not exclude longer distances between two devices, e.g. by using receive circuits with a lower minimum optical receiver sensitivity than specified in 28.5.2.

[b] The maximum length can be reduced in cases where special cables with higher attenuation than the standard cables specified in 28.6.2 are used.

## 28.4 Transmit circuit specifications

### 28.4.1 Data encoding rules

NRZ Coding is specified for the optical transmission following the encoding rules given in Table 172.

**Table 172 – Encoding rules**

| Logical symbol bit | Encoding |
|---|---|
| 1 | Low optical output level |
| 0 | High optical output level |

In the case of no bus activity an idle state of logic 0 shall be used.

### 28.4.2 Test configuration

The output level, spectral and timing specifications are measured at the end of a standard test fiber (as specified in 28.6.4) connected to the CPIC.

The requirements relative to 28.4 are summarized in Table 173 and Table 170.

### 28.4.3 Output level specification

An optical MAU transmit circuit shall conform to the following output level and spectral requirements. The specified level and spectral characteristics shall be maintained over the whole temperature range specified for the network device. Output level is the effective launch power of logic 0. The output level specification is shown in Table 173.

**Table 173 – Transmit level and spectral specification summary for an optical MAU**

| Transmit level and spectral characteristics (values referred to CPIC with standard test fiber) | Polymer optical fiber (980/1 000 µm fiber) | | Plastic-clad silica fiber (200/230 µm fiber) |
|---|---|---|---|
| Maximum peak emission wavelength ($\lambda p$) | 660 nm | 520 nm | 660 nm |
| Typical spectral full width half maximum ($\Delta\lambda$) | < 30 nm | | < 30 nm |
| Maximum output level | −2,0 dBm | | −8 dBm |
| Minimum output level | −6,2 dBm | | −16,9 dBm |
| Maximum effective launch power of a logic 1 | −43 dBm | −41 dBm | −45 dBm |

NOTE Standard test fiber specification, see 28.6.4.

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### 28.4.4 Output timing specification

An optical MAU transmit circuit shall conform to the following output timing requirements (see Figure 148). Timing characteristics shall be maintained over the whole temperature range specified for the network device.

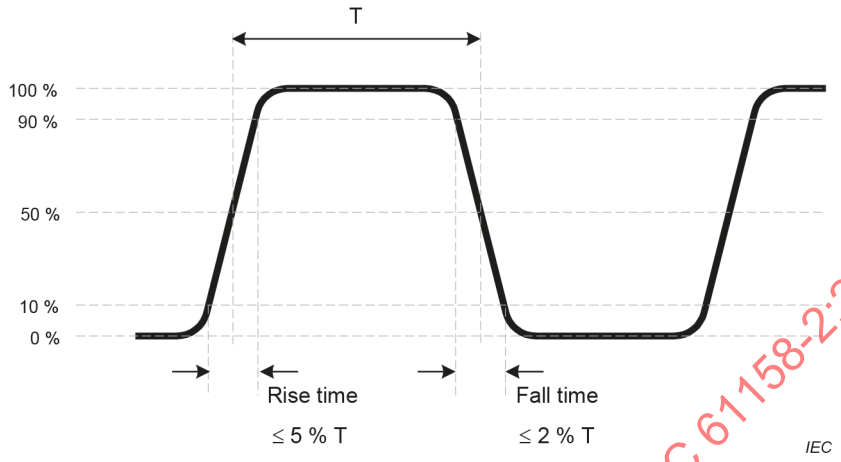


**Figure 148 – Optical wave shape template optical MAU**

NOTE 1 For ease of reference, the requirements of 28.4.4are summarized in Table 170.

NOTE 2 0 % effective power is the low optical output power state (logic 1).

NOTE 3 100 % effective power is the high optical output power state (logic 0).

Rise time, fall time and bit cell jitter shall be chosen in that manner, that the electrical output timing specifications of the optical MAU receive circuit given in Table 174 are still fulfilled.

## 28.5 Receive circuit specifications

### 28.5.1 Decoding rules

Decoding rules according to Table 172 shall be used.

### 28.5.2 Fiber optic receiver operating range

An optical MAU receive circuit shall have the minimum optical receiver sensitivity defined in Table 174 over the whole temperature range specified for the network device. The maximum optical power for logic 0, measured with a standard test fiber specified in 28.6.4, of an optical MAU receive circuit shall not exceed the value defined in Table 174.

The fiber optic receive circuit used for 0,5 Mbit/s and 2 Mbit/s systems shall be capable of detecting a 01010 bit stream after a 200 ms long idle state where the optical power level of the second logical 0 is reduced by up to 65 % against the others. This capability shall be maintained over the whole fiber optic receiver operating range.

### 28.5.3 Maximum received bit cell jitter

The receive circuit shall accept a NRZ encoded signal transmitted in accordance with 28.4. In addition, the fiber optic receiver shall accept signals with the time variation between any two adjacent signal transition points (50 % crossing) of ± 25 %.

The requirements relative to 28.5 are summarized in Table 174.

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**Table 174 – Optical MAU receive circuit specification summary**

| Receive circuit characteristics (values referred to the CPIC) | Polymer optical fiber (980/1 000 µm fiber) | Plastic-clad silica fiber (200/230 µm fiber) |
|---|---|---|
| Minimum optical receiver sensitivity | ≤ −21,6 dBm | ≤ −23 dBm |
| Maximum optical power for logic 0 | −2,0 dBm | −8 dBm |
| Maximum received bit cell jitter | ± 25 % of nominal bit time | ± 25 % of nominal bit time |

## 28.6 Specification of the transmission medium

### 28.6.1 Connector

Cable connectors, if used, shall be in accordance with the specification given in Clause M.2.

### 28.6.2 Fiber optic cable specification: polymer optical fiber cable

#### 28.6.2.1 General

A polymer optical fiber cable for fixed routing in indoor installations shall be compatible to the following specifications. Special fiber optic cables used for special environmental or physical applications where e.g. high flexibility of the cable is essential may differ from the following specification concerning the cable attenuation.

#### 28.6.2.2 Fiber optic waveguide

A fiber optic waveguide of a polymer optical fiber cable for a network optical MAU shall fulfil the following requirements given in Table 175.

**Table 175 – Specification of the fiber optic waveguide**

| Parameter | Value |
|---|---|
| Core diameter | (980 ± 60) µm |
| Cladding diameter | (1 000 ± 60) µm |
| Cladding non-circularity | ≤ 6 % |
| Core material | Polymethylmethacrylate (PMMA) |
| Numerical aperture | 0,47 ± 0,03 |
| Refractive index profile | Step index |
| Bandwidth at 660 nm | ≥ 10 MHz × 100 m |
| Attenuation at 650 nm (monochromatic) | ≤ 160 dB/km |
| Attenuation at 660 nm (measured with LED and 50 m cable length) | ≤ 230 dB/km |

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#### 28.6.2.3 Single fiber

A single fiber of a polymer optical fiber cable for an optical MAU shall conform to the following requirements given in Table 176.

**Table 176 – Specification of the single fiber**

| Parameter | Value |
|---|---|
| Buffer material | Polyamide (PA) |
| Buffer color | Black or orange |
| External diameter | 2,20 mm ± 0,07 mm |
| Minimum long-term bending radius | 30 mm |

#### 28.6.2.4 Cable sheath and mechanical properties of the cable

The sheath of a polymer optical fiber cable for an optical MAU should conform to the following requirements given in Table 177.

**Table 177 – Specification of the cable sheath and mechanical properties of the cable**

| Parameter | Value |
|---|---|
| Sheath material | Polyurethane (PUR) |
| Sheath color | Red |
| Strain relief elements | Non-metallic |
| Marking | Running length in m, production date |
| Temperature range (in operation) | −20 °C to +70 °C |
| Minimum long-term bending radius | ≤ 65 mm |
| Maximum long-term tensile strength | ≥ 100 N |
| Maximum long-term lateral pressure | ≥ 20 N/cm |

#### 28.6.2.5 Material properties of the cable

The polymer optical fiber cable for an optical MAU should have the following further material properties as shown in Table 178.

**Table 178 – Recommended further material properties of the cable**

| Parameter | Value |
|---|---|
| Oil resistance | ASTM Oil No. 2, 100 °C, IEC 60811-404 |
| Halogen-free | IEC 60754-2 |
| Ozone resistance | IEC 60811-403 |
| UV resistance | ISO 4892-1 |
| Abrasion resistance | IEC 60794-1-2 method E2A<br>Minimum 5 000 cycles, 1 mm radius of the point of the steel needle, 500 g |
| NOTE Dependent on the application, other material properties can also be required, for example, free from substances impairing paint-wetting performance (chloroform test). | |

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### 28.6.3 Fiber optic cable specification: plastic clad silica fiber cable

#### 28.6.3.1 General

A plastic clad silica fiber optic cable for fixed routing in indoor installations shall be compatible to the following specifications. Special plastic clad silica fiber optic cables used for special environmental applications such as outdoor cables may differ from the following specification concerning the cable attenuation.

#### 28.6.3.2 Fiber optic waveguide

A fiber optic waveguide of a plastic clad silica fiber optic cable for an optical MAU shall fulfil the following requirements given in Table 179.

**Table 179 – Specification of the fiber optic waveguide**

| Parameter | Value |
|---|---|
| Core diameter | (200 ± 8) µm |
| Cladding diameter | (230 ± 10) µm |
| Cladding non-circularity | ≤ 6 % |
| Numerical aperture | 0,40 ± 0,04 |
| Refractive index profile | Step index |
| Bandwidth at 650 nm | ≥ 17 MHz × km |
| Attenuation at 650 nm | ≤ 10 dB/km |

#### 28.6.3.3 Single fiber

A single fiber of a plastic clad silica fiber optical cable for an optical MAU shall conform to the following requirements given in Table 180.

**Table 180 – Specification of the single fiber**

| Parameter | Value |
|---|---|
| Buffer material | FRNC material |
| Buffer color | Red or green |
| External diameter | 2,2 mm or 2,9 mm |
| Minimum long-term bending radius | 30 mm |

#### 28.6.3.4 Cable sheath and mechanical properties of the cable

The sheath of a plastic clad silica fiber optic cable for an optical MAU should conform to the following requirements given in Table 181.

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**Table 181 – Specification of the cable sheath and mechanical properties of the cable**

| Parameter | Value |
|---|---|
| Sheath color | Red |
| Strain relief elements | Non-metallic |
| Marking | Running length (m); production date |
| Temperature range (in operation) | −20 °C to +70 °C |
| Minimum long-term bending radius | ≤ 50 mm |
| Maximum long-term tensile strength | ≥ 200 N |
| Maximum long-term lateral pressure | ≥ 100 N/cm |

#### 28.6.3.5 Material properties of the cable

The plastic clad silica fiber optic cable for an optical MAU should have further material properties as shown in Table 178.

### 28.6.4 Standard test fiber

The cable used for testing network devices with an optical MAU for conformance to the requirements of the Clause 28 shall be a cable with one or more fiber optic waveguides whose characteristics are as shown in Table 182.

**Table 182 – Specification of the standard test fiber for an optical MAU**

| Parameter | Polymer optical fiber (980/1 000 µm fiber) | Plastic-clad silica fiber (200/230 µm fiber) |
|---|---|---|
| Length | 1 m | 1 m |
| Core diameter | (980 ± 60) µm | (200 ± 8) µm |
| Cladding diameter | (1 000 ± 60) µm | (230 ± 10) µm |
| Cladding non-circularity | ≤ 6 % | ≤ 6 % |
| Numerical aperture | 0,47 ± 0,03 | 0,40 ± 0,04 |
| Bandwidth for 660 nm | ≥ 10 MHz × 100 m | ≥ 17 MHz × 1 km |
| Attenuation for 660 nm (monochromatic) | ≤ 160 dB/km | ≤ 10 dB/km |
| Buffer diameter | 2,2 mm | 2,9 mm |
| Insertion loss (see Note) | 1,5 dB to 2,0 dB | 1,0 dB to 1,5 dB |
| NOTE Measured in conformance with IEC 61300-3-4 (insertion procedure B). | | |

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## 29 Type 12: Medium attachment unit: Power combined with Ethernet Physical Layer Device (PHY)

### 29.1 Electrical characteristics

#### 29.1.1 Relationship to the Ethernet architecture

This Clause 29 defines the functional and electrical characteristics of two optional power entities, a 2PP Powered Device (PD) and 2PP Power Sourcing Equipment (PSE), for use in combination with Ethernet Physical Layer Device (PHY). When used in this clause, the term PSE always means 2PP PSE, and the term PD always means 2PP PD. A PD can receive power from one or two independent channels of an Ethernet 100BASE-TX link section consisting of two twisted pairs. Both pairs can be connected to a different power source. A device that can become a powered device can have the ability to draw power from an alternate power source and do not

require power from the PI in that case. A PD is specified at the point of the physical connection to the cabling. Characteristics such as the losses due to voltage correction circuits, power supply inefficiencies, separation of internal circuits from external ground or other characteristics induced by circuits after the PI connector are not specified. Limits defined for the PD are specified at the PI, not at any point internal to the PD, unless specifically stated. These entities allow devices to draw/supply power using the same cabling that is used for data transmission. 2PP is intended to provide an Ethernet Physical Layer device with a single interface to both the data it requires and the power to process this data as shown in Figure 149. This Clause 29 specifies:

– the characteristics of a power source to add power to the 100 Ω two balanced twisted-pair cabling system;
– the characteristics of a PD's load on the power source and the cabling;
– certain electrical parameters of each MDI/PI which may be different from that specified in the PHY Clause 29 when power is simultaneously transmitted with data.

There is a differentiation between a PSE and a PD. Compliant implementations of PD and PSE systems are defined as compatible at their respective Power Interfaces (PIs) when used in accordance with the restrictions of this clause. Designers are free to implement circuitry within the PD and PSE in an application-dependent manner provided that the respective PI specifications are satisfied. MDIs that incorporate compliant 2PP PIs are compatible with their respective Physical Layer standards. The PHY specification of ISO/IEC/IEEE 8802-×:2021, Clause 25 applies. The PHY design shall be in accordance with the specifications of ISO/IEC/IEEE 8802-3:2021, 25.4.5 to ISO/IEC/IEEE 8802-3:2021, 25.4.7 regarding combinations of MDI and PI. Compatibility requires additional specifications found in 29.1.2, 29.1.3, and 29.1.4. The basic requirement is that a combined MDI/PI Interface has no significant impact on the general signal quality in regards of the operation characteristics described in this clause. There is no negotiation of this capability - a mechanical setup (connectors according to IEC 61076-2-114, M8 with P-coding) ensures the pairing of PSE - PD and further PDs.

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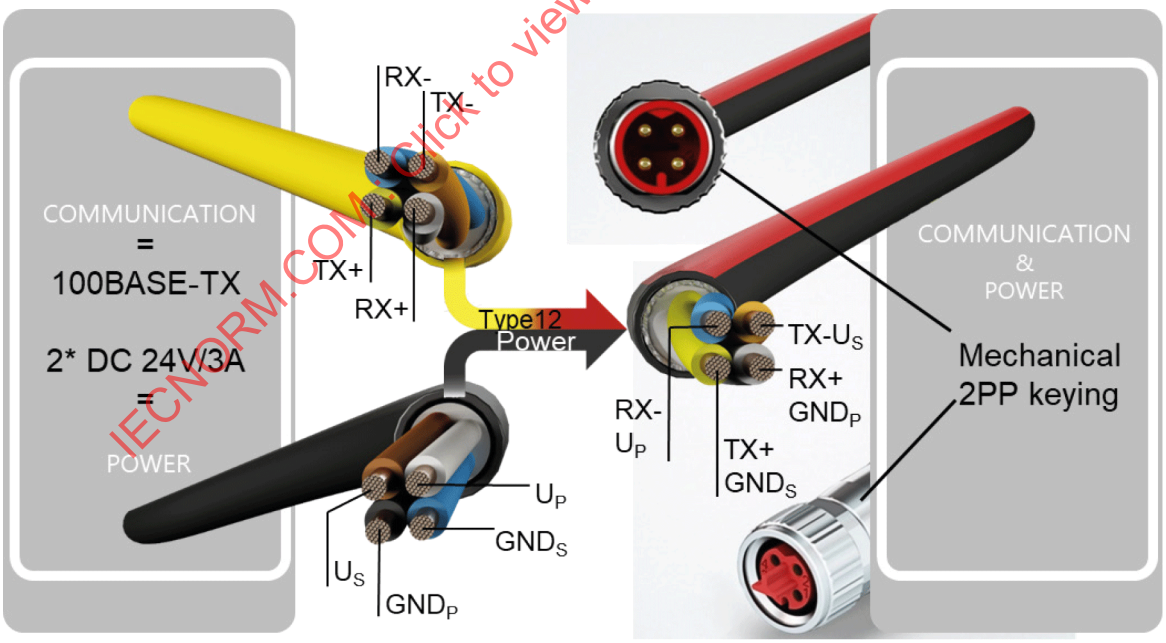



**Figure 149 – Combining Ethernet and Power**

A PSE can supply power for multiple devices. Thus, a forwarding function for Power is included in the 2PP design. A device PD1 acts as PSE proxy for a PD2 connected to a second port. A system with 2 PD is shown in Figure 150.

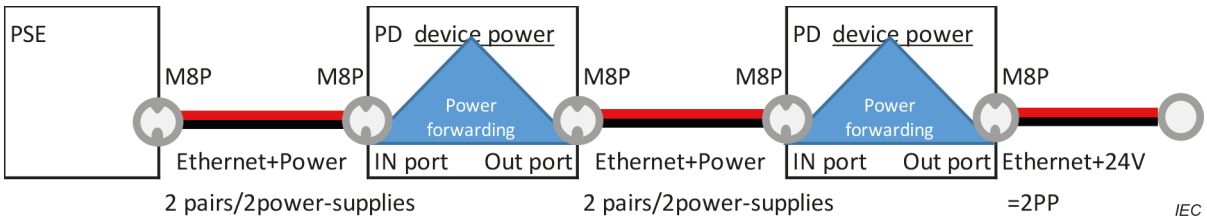
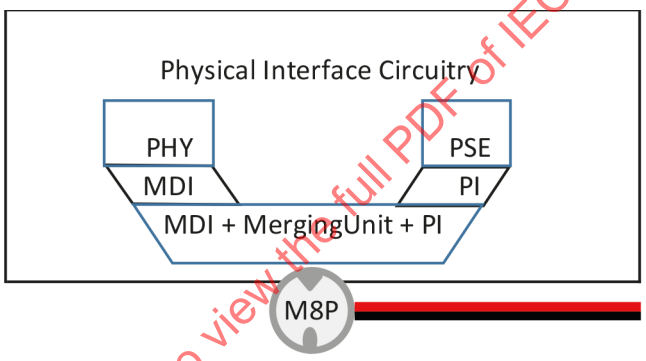



**Figure 150 – Interaction between PSE and multiple PD**

2PP is a power entity to be used in conjunction with supported two-pair Ethernet Physical Layer 100BASE-TX PHY. The topology supported is a pair of wires with exactly one sender and one receiver on a single pair.

A connection consists of two pairs of wire which connects exactly two DTE.

PHY and MDI according to the ISO/IEC/IEEE 8802-3:2021 100BASE-TX (Clause 25) specification are extended by either PSE and PI or PD and PI as shown in Figure 151 and Figure 152.




PHY Physical Layer Device
MDI Medium Dependent Interface
PSE Power Sourcing Equipment
PI Power Interface

IEC

**Figure 151 – 2PP power sourcing equipment (PSE) relationship to the physical interface circuitry and the ISO/IEC/IEEE 8802-3 model**

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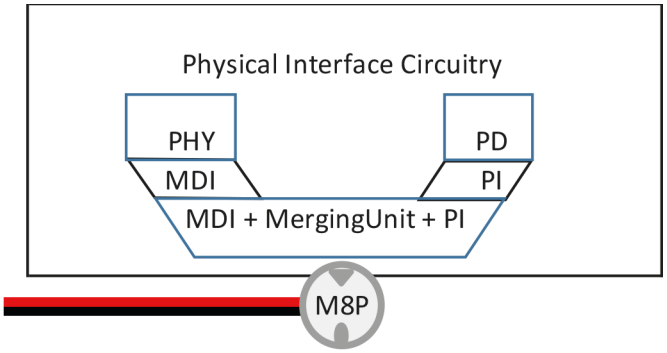


PHY Physical Layer Device
MDI Medium Dependent Interface
PD Powered Device
PI Power Interface

**Figure 152 – 2PP powered device (PD) relationship to the physical interface circuitry and the ISO/IEC/IEEE 8802-3 model**

The Power Interface (PI) is the generic term that refers to the mechanical and electrical interface between the PSE or PD and the transmission medium. The PI is encompassed within the MDI.

The PI/MDI combined interface acts as filter (see Figure 153). The PI is connected with a low pass filter to the network and the MDI is protected by a high pass filter. The cut of frequencies of both filters should have the same value or should be closely related. The impedance of both channels combined shall be the same as specified in ISO/IEC/IEEE 8802-3:2021.

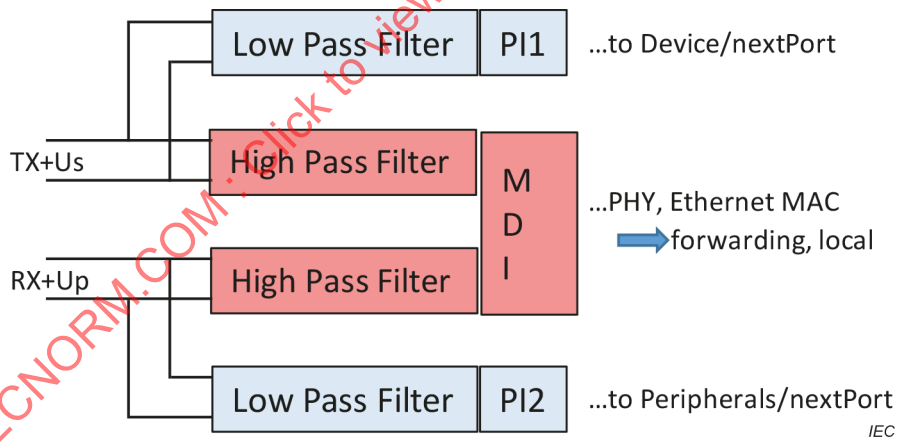


**Figure 153 – Interaction between Port, MDI and PI**

### 29.1.2 General power requirements

The default power requirements per pair are defined in Table 183. The values of $V_{StaticPSE(max)}$, $V_{RipplePSE(max)}$ and $V_{PD(min)}$ are derived from IEC 61131-2:2017, Table 16 (DC 24 V).

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**Table 183 – Power requirements for PSE, PI and PD**

| Electrical Parameter | Value | Remark |
|---|---|---|
| $V_{StaticPSE(max)}$ (V) | 24+20 % | Maximum static voltage measured at the PSE PI over the full range of operating conditions |
| $V_{RipplePSE(max)}$ (mV) | 2 400 | Maximum allowed peak to peak power feeding ripple at the PSE PI below 2,4 kHz. |
| $V_{PSE_OC(min)}$ (V) | 24 | Minimum allowed open circuit voltage measured at the PSE PI. |
| $I_{PI(max)}$ (A) | 3 | Maximum current flowing at the PSE and PD PIs except during inrush or an overload condition. |
| $V_{PD(min)}$ (V) | ≤ 19,2 | Minimum voltage (static+ ripple) to be accepted from the PD PI - the value is given as device parameter. |
| $P_{PD(max)}$ (W) | | Maximum required power at the PD PI (one pair) (device parameter). |

A PSE shall apply a voltage in the range of $V_{PSE}$ at the PI. The PI of a device feeding power to a PD shall be capable to operate with a current of $I_{PI(max)}$.

### 29.1.3 Power sourcing equipment

The 2PP PSE shall provide voltage V and current A within the nominal values and provide additional stability during the operation of the MDI by limiting parameters according to Table 184.

**Table 184 – Additional requirements for PSE**

| Electrical Parameter | Value | Remark |
|---|---|---|
| $\|dV_{PSE}/dt\|$ (max) (V/ms) | 100 | Maximum Peak-to-Peak voltage change as absolute value during operation of MDI |
| $V_{Ripple}$(f<2,4 kHz) (mV) | 2 400 | Maximum allowed power feeding ripple and noise at the PSE PI below 2,4 kHz. |
| $V_{Ripple}$(2,4 kHz ≤ f < 150 kHz) (mV) | 200 | Maximum allowed power feeding ripple and noise at the PSE PI above 2,4 kHz up to 150 kHz. |
| $V_{Ripple}$(150 kHz ≤ f < 10 MHz) (mV) | 50 | Maximum allowed power feeding ripple and noise at the PSE PI above 150 kHz up to 10 MHz. |
| $V_{Ripple}$(10 MHz ≤ f < 100 MHz) (mV) | 25 | Maximum allowed power feeding ripple and noise at the PSE PI above 10 MHz up to 100 MHz. |
| $I_{LIM}$ (short circuit max) (A) | 2,3 × $I_{PI}$ | Maximum short circuit current flowing at the PSE PI. |
| $T_{LIM}$ (short circuit max) (ms) | 15 | Maximum short circuit cut off time at the PSE PI. |
| $T_{Inrush}$ (max) (ms) | 12 | Maximum inrush time at the PSE PI. |

A PSE shall apply a voltage in the range of $V_{PSE}$ at the PI within $T_{Inrush}$ (max).

The maximum Peak-to-Peak voltage change as absolute value ($|dV_{PSE}/dt|$ (max)) is a criterion that shall be applied to all intervals up to 100 MHz.

The specification for power feeding ripple and noise shall be met for peak-to-peak noise values for power outputs ($I_{PI(max)}$ × $V_{PSE(min)}$). The limits are meant to preserve data integrity. Lower values may be needed to meet other standards such as IEC 61131-2.

During operation when the PSE is enabled, the PSE shall limit IPI at a link to less than $I_{LIM}$ as specified in Table 184 for a duration of up to $T_{LIM}$.

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Measurements of $I_{LIM}$ during a short circuit condition shall be made 1 ms after the initial transient to allow for settling.

### 29.1.4 Powered device

The 2PP PD uses voltage V and current A within the nominal values and provide additional stability during the operation of the MDI by limiting the current used as specified.

A PD is specified at the point of the physical connection to the PI. Limits defined for a PD are specified at the PI, not at any point internal to the PD, unless specifically stated.

**Table 185 – Additional requirements for PD**

| Electrical Parameter | Value | Remark |
|---|---|---|
| $I_{PD}$(max) (A) | ≤ 3 | Maximum current flowing at the PD PIs except during inrush or an overload condition (device parameter). |
| $\|dI_{PD}/dt\|$ (max) (mA/ms) | 100 | Maximum allowed current drawing ripple and noise at the PD PI for frequencies above 1 kHz and below 1 MHz. |
| Tpower_dly (ms) | ≥ 2 | Waiting time for power on after VPDon is reached (device parameter). |
| $V_{PDon}$(min) (V) | | Minimum Voltage for a device to start-up (device parameter). |
| $V_{PDoff}$(max) (V) | | Maximum Voltage for a device to stop (device parameter). |

The PD shall remain off until the input voltage reaches a value in the range of $V_{PDon}$, as specified in Table 185, and remains above that limit after a delay greater than Tpower_dly. Once the PD is turned on, the PD may remain on in the input voltage range greater than $V_{PDoff}$. When the input voltage is less than $V_{PDoff}$ as specified in Table 185, the PD shall be turned off. The PD shall turn on or off without start-up oscillation and within the first trial when a voltage in the range of $V_{PSE(max)}$ and $V_{PD(min)}$ (as defined in Table 183) is applied.

### 29.1.5 Inrush current and overload protection

Inrush current is defined as a maximum, instantaneous current drawn by PD when first turned on. Power converters have inrush currents much higher than their steady state currents, due to the charging current of the input capacitance. This situation has impact on the selection of overcurrent protection devices as well as for all components forwarding power. All PD shall be able to start with the inrush current load.

The generic inrush model specified is a capacitor C in series with a resistor R (RC-combination). The resistor R defines the worst-case current at start-up.

The formula of the maximum inrush current is

$$\max(I_{IR}) = V_{PSE}\left(maxStatic\right) / R$$

The current value of the RC-combination follows an exponential function

$$I_{IR}\left(t\right) = U / \left( R \cdot e^{\frac{t}{R \cdot C}} \right)$$

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The constant R·C determines the reduction time of the current. The starting current of 7 A will be reduced to less than 3 A after R × C (s) under ideal conditions. The worst-case inrush time shall be less than 12 ms.

The model parameters of inrush are described in Table 186 and the diagram of allowed values is described in Figure 154. The diagram shall be scaled down if the power consumption in a segment is lower.

**Table 186 – Power requirements for PSE, PI and PD**

| Electrical Parameter | Value | Remark |
|---|---|---|
| $t_{IR(max)}$ (mS) | 12 | Maximum inrush time with higher current as specified |
| $I_{IR(max)}$ (A) | 7 | Maximum current flowing at the PSE and PD PIs under inrush conditions. |

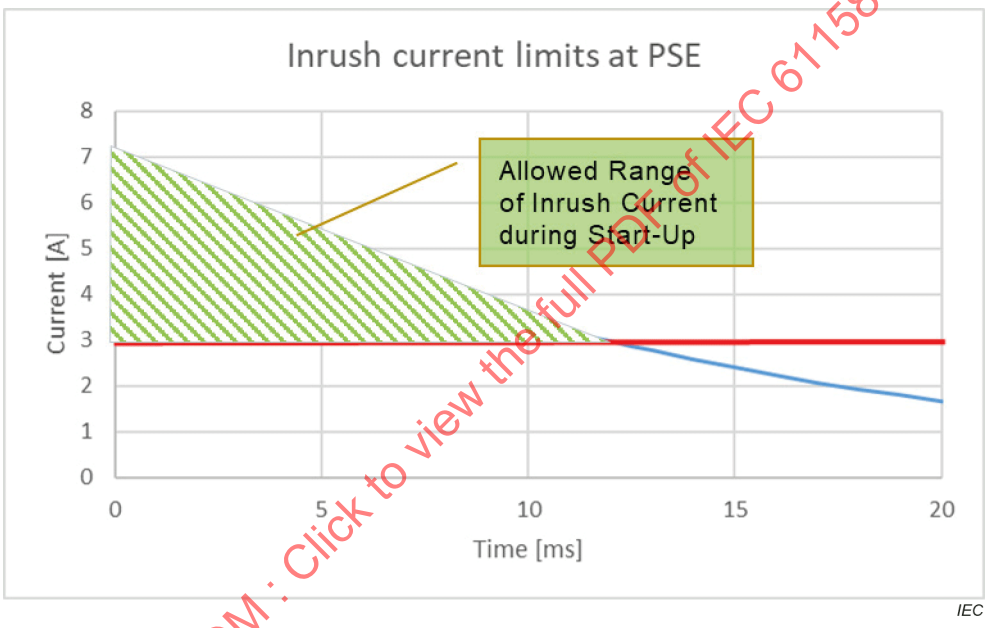


**Figure 154 – Inrush current limits above nominal current**

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### 29.1.6 Dynamic change of current

Current change combined with cable resistance cause a dynamic change of voltage at end nodes. The worst-case current change caused by a PD is directly related to a voltage change due to line resistance. Thus, the line voltage drop shall be treated as dynamic component.

The limits are related to the amount of current taken by a PD.

It is not allowed to feedback energy from a local power source at PI.

The maximum change rate shall not exceed the change of limits specified in Table 187.

**Table 187 – Power requirements for PD dynamic change of current**

| Electrical Parameter | Value | Remark |
|---|---|---|
| $\lvert dI_{PD}/dt \rvert$ (max) (mA/µs) | 20 × ($I_{PD}$ (A)/3A) | Maximum Peak-to-Peak current change of PD change as absolute value during operation of MDI |
| $\lvert dV_{PD}/dt \rvert$ (max) (mV/µs) | 100 × ($I_{PD}$ (A)/3A) | Maximum accepted additional Peak-to-Peak voltage change caused by all PD current changes as absolute value during operation of MDI |

The values are given for all PDs. The rate change of a device shall be multiplied with the ratio of consumed current to maximum current (3 A).

### 29.1.7 Changes related to worst-case droop of transformer

The worst-case droop of transformer is defined in ANSI INCITS 263:1995, 9.7.1 and was changed by ISO/IEC/IEEE 8802-3:2021, 25.4.5. The model of 25.4.5 applies. The equivalent system time constant τ, shall be greater than 140 ns measured with the MDI/PI on both ends of the test circuit.

The length of the test pattern specified in ISO/IEC/IEEE 8802-3:2021, 25.4.11 may be shortened to accommodate feasible 100BASE-TX measurements, but shall not be shorter than 200 code-groups.

### 29.1.8 Additional electrical specifications

Specific standards apply in dedicated areas of use.

In order to prevent the formation of a ground loop, a PD shall provide at least 1 MΩ DC isolation between all accessible external conductors, including grounding/PE.

The isolation requirements according to IEC 61131-2 shall apply.

A PSE can use a common ground for both pairs of power. It is recommended to use RC coupling of PSE between ground and PE.

The PI shall meet the fault tolerance requirements as specified for 100BASE-TX. A PD shall not be damaged when connected to any PSE.

The PSE PI shall withstand without damage the application of short circuits between the wires within the cable for an indefinite period of time.

The electrical characteristics of the MDI shall be extended by a protection circuit. This implies test fixtures for 100BASE-TX PHYs.

The 100BASE-TX PHY shall operate with AC coupling to the MDI. Where a load is not specified, the transmitter shall meet the requirements of this section with a 100 Ω (the value can vary within ±1 % range) resistive differential load connected to the transmitter output.

The MDI shall be protected against higher voltage of PI. A high pass filter in front of the MDI with a cutoff frequency of less than 4 MHz shall be used with an attenuation increase of at least 20 dB reducing the frequency by a factor of 10.

Insertion loss is a measure of the signal loss between the transmitter and receiver, expressed in dB relative to the MDI signal level. Insertion loss increase of MDI shall be less than 2 dB compared at MDI without high pass filtering. However, for lower frequencies (below 4 kHz) that correspond to calculated values more than 60 dB, the requirement reverts to the maximum requirement of 60 dB.

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Power forwarding results in an increase of the NEXT parameter at the PI. NEXT loss is a measure of the unwanted signal coupling from a transmitter at the near-end into neighbouring pairs measured at the near-end. NEXT loss is expressed in dB relative to the received signal level. NEXT loss at PI shall be higher than 34 dB when measured for the transmit and receive pairs from 8 MHz to 100 MHz.

### 29.2 Medium specifications

#### 29.2.1 Connector

There is a connector specified for this media. The connecting elements defined in IEC 61076-2-114, M8 with P-coding (M8P) shall be used.

#### 29.2.2 Wire

The medium is a set of two pairs of wires. Shielding should be used to improve the electromagnetic compatibility (EMC).

The cable plant shall be as defined in ISO/IEC/IEEE 8802-3:2021, 25.4.9. In addition, the wire diameter should be AWG 22 by default to meet the industrial power supply premises. For shorter distances AWG 24 wires can be used.

## 30 Type 16: Medium attachment unit: optical fiber medium at 2 Mbit/s, 4 Mbit/s, 8 Mbit/s and 16 Mbit/s

### 30.1 Structure of the transmission lines

The structure of the optical transmission line is shown in Figure 155.

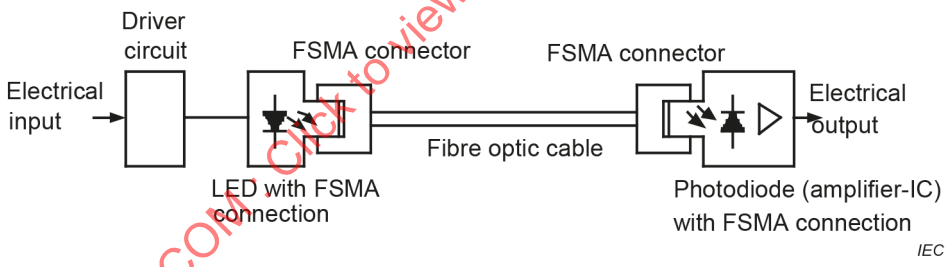


**Figure 155 – Optical transmission line**

The driver circuit for the transmitting LED shall be activated by an electrical impulse. The high-performance LED (transmitter) shall emit light of a wavelength of 650 nm. The transmission power shall be switchable between "low attenuation" and "high attenuation", using a manually operated switch.

The fiber optic cable shall be made of plastic or glass and have a step index profile or graded index profile. Fiber optic cables and cores may be used depending on application. Attenuation taking place along the transmission line is caused by the fiber optic cable and possibly other couplings. These additional couplings can become necessary when routing through a wall, for example. The factors which contribute to attenuation along the line are explained in more detail in Clause O.2.

NOTE For fiber optic materials currently in use, the attenuation is approximately 220 dB/km for plastic and 6 dB/km for glass.

The receiver component shall consist of a photodiode and an integrated amplifier circuit.

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It shall be possible that the signal is inverted while passing through a slave (i.e., a light-on signal at the optical slave input shall not necessarily lead to a light-on signal at the optical output).

## 30.2 Time performance of bit transmission

### 30.2.1 Introduction

The distance between rising and falling edges of the optical signal is specified in 30.2. An edge is a change in level between the optically low and optically high levels. The specification is based on an envelope which has been defined for the optical signal. Any optical output signal of a transmitter shall remain within this specific envelope at all times.

Furthermore, the run-time performance between optical slave input and output is specified. A slave shall be synchronized to the transmission clock of the bit stream coming into its optical input. Although the transmission clock of a slave can deviate from the clock at its input for a short time, the slave needs to be synchronized to the predetermined clock (e.g., by means of a phase locked loop). Thus, all units connected to the network are required by definition to transmit the same averaged transmission clock pulse. In other words, all units shall use the transmission clock pulse of the master.

The slave shall be synchronized to the transmission clock on its optical input by means of light-on edges (rising edges).

### 30.2.2 Master and slave in test mode

#### 30.2.2.1 Introduction

In Subclause 30.2.2, the run-time performance at the optical output of the master is specified while the master is operating both in its normal and test modes.

It shall be possible to activate the test mode externally by special means (e.g. pressing a key). Master and slave shall then be able to provide a continuous signal light, as well as a zero bit stream at the optical output, without the presence of an input signal.

#### 30.2.2.2 Continuous light signal test mode

A continuous light signal implies a logical high level without a level change at the optical output. This mode is only required for the master. The slave may generate a continuous light signal, depending on whether or not a continuous light signal comes in at the optical input. Due to its function as a repeater, the slave shall be able to echo the light at its optical output, which it receives at its optical input (or the lack thereof).

Optical signal inversion by the slave shall be possible.

#### 30.2.2.3 Zero bit stream test mode

The zero bit stream test mode implies that the transmitter shall transmit consecutive zeros which, based on the NRZI code, result in continuous level changes in the signaling pattern of the transmission clock (this results in a 1 MHz signal for a data rate at 2 Mbit/s). A slave shall use its local clock to synchronize the transmitting clock at its optical output signal. No clock adjustments may occur at the optical output (e.g., due to the phase locked loop, $\rightarrow t_{cad}$) and only statistically distributed jitter of the optical signal is allowed. This requirement is important because it allows the system to isolate and separate jitter noise ($\rightarrow J_{noise}$) from possible clock adjustments due to the phase locked loop ($\rightarrow t_{cad}$), as will be discussed later. The curve shapes of optical signals which are generated while the system is in the zero bit stream test mode, are not allowed to deviate from the signals during normal mode near the rising and falling edges (e.g. different rise and fall times, different excess levels during the test mode). Specifically, the

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same driver circuit shall be used during the zero bit stream test mode as is used during normal mode.

The following parameters shall be used to specify the optical output signal of the master and slave (see Figure 156 and Figure 157):

$t_r$: This is the time delay between points 1 and 2 (= 1-1' or 2-2'). It shall be the upper limit of the time required by the optical signal to pass through $P_{TmaxL}$ to $P_{TminH}$ on the rising edge. This time does not correspond to the rise time of the transmitter which is given between 10 % and 90 % of the optical signal in the data sheet.

$t_f$: This is the time delay between points 3 and 4 (= 3-3' or 4-4'). It shall be the upper limit of the time required by the optical signal to pass through $P_{TminH}$ to $P_{TmaxL}$ on the falling edge. This time does not correspond to the fall time of the transmitter, which is given between 10 % and 90 % of the optical signal in the data sheet.

NOTE See item remark below regarding $t_r$ and $t_f$.

$t_{os}$: This parameter indicates length of time the maximum optical transmission power may be exceeded dynamically. This interval shall start at time ① (see Figure 156).

$t_{BIT}$: This is the arithmetic mean value (measured over several seconds) of the transmission clock period (duration of a bit cell) by the master (not in test mode) and shall correspond to the reciprocal value of the data rate. The nominal duration shall be described by $t_{BITnom}$. $t_{BIT}$ shall be measured between edges with the same direction (= 2 × $t_{BIT}$) at optical power levels of 0,5 × $P_{TminH}$ ± 20 %. $t_{BIT}$ shall be considered to be constant in the range of seconds. Only fluctuations due to noise are allowed. Relatively long measurement duration of $t_{BIT}$ ensures that the influence of short-term deviations of the delays between edges (jitter → $J_{noise}$) is negligible. Hence, $t_{BIT}$ shall describe the time between points 1 and 3, as well as the time between points 3 and 5 (which shall correspond to point 1 of the next period) (see Figure 156).

$t_{BITtest}$: This is the arithmetic mean value measured over several seconds of the master or slave transmission clock period (duration of a bit cell) in the zero bit stream test mode. All measurements and properties of $t_{BITtest}$ shall correspond to $t_{BIT}$.

$J_{noise}$: This parameter describes the jitter of the optical signal. It shall be the purely statistical deviation of the distance between both edges, compared with the value $t_{BITtest}$ measured over a long time interval. $J_{noise}$ shall be obtained by overlaying the signals of several periods (e.g. on an oscilloscope) such that they come together at one optical power level (e.g. $P_{TmaxL}$ on the falling or rising edge). The jitter of the optical signal is then determined by the width of the overlaid optical signals (which gives a time). This width shall not exceed the value $J_{noise}$ in the power region between $P_{TmaxL}$ and $P_{TminH}$ vice versa. By this definition, the jitter of the optical signals is limited, that is, the signal curve shapes shall be reproducible in the power region $P_{TmaxL}$ through $P_{TminH}$ vice versa.

The times $t_r$ and $t_f$ are not fully available as rise time and fall time. Due to non-symmetrical ON/OFF performance of the driver circuit (duty cycle, propagation delay), the falling edge can be time-shifted with respect to the rising edge, resulting in a remaining difference for $t_{BITtest}$. In this case, the high level can be extended by some time interval and the low level could be shortened by the same interval. This extending/shortening interval is not considered part of the rising and falling interval. In addition, the signal with added $J_{noise}$ shall remain completely within the envelope, which implies that the jitter shall be taken into consideration for the times $t_r$ and $t_f$.

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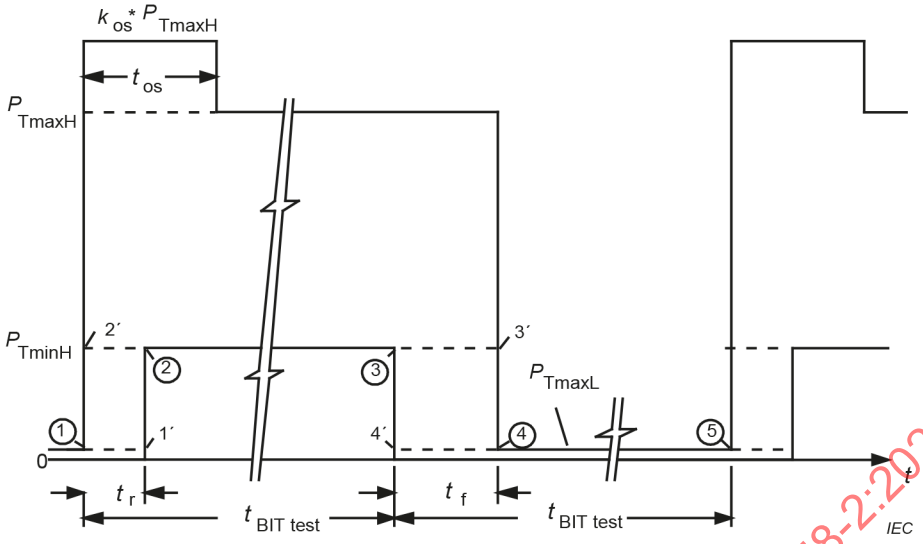


**Figure 156 – Optical signal envelope**

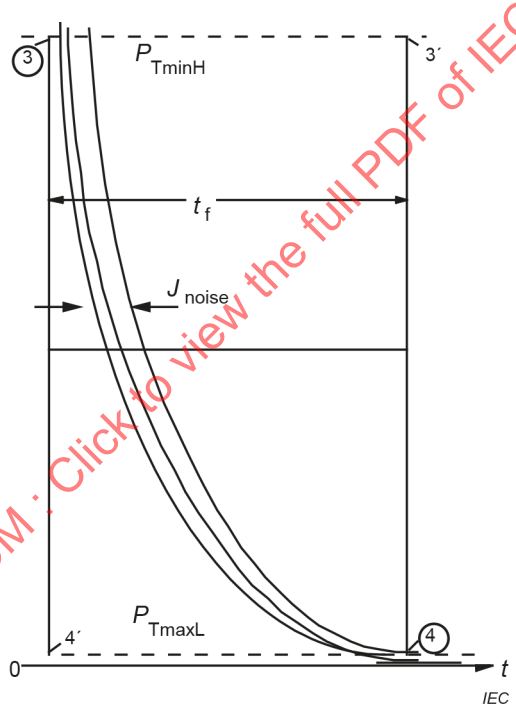


**Figure 157 – Display of jitter ($J_{noise}$)**

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### 30.2.3 Data rate

The data rate is the baud rate measured at the optical output of the master. Its nominal value shall be 2 Mbit/s, 4 Mbit/s, 8 Mbit/s or 16 Mbit/s. The measured value is allowed to deviate by ±0,01 %. The data rate is a time average measured over several seconds. The short-term performance (nanoseconds range) may deviate slightly and is specified through $J_{noise}$ (see Table 189).

Table 188 specifies which data rates shall be supported by Type16, and the way baud rate shall be selected, for two performance classes called CP16/1 and CP16/2.

**Table 188 – Transmission rate support**

| Performance class | CP16/1 | CP16/2 |
|---|---|---|
| 2 Mbit/s | Mandatory | Mandatory |
| 4 Mbit/s | Optional | Optional |
| 8 Mbit/s | No | Optional |
| 16 Mbit/s | No | Optional |
| Baud rate | Manual setting (e.g. switch) | Manual setting (e.g. switch), or automatic baud rate recognition |

**Table 189 – Transmission data parameters**

| Transmission rate (data rate) | Bit times | | | |
|---|---|---|---|---|
| | 2 Mbit/s ± 0,2 kbit/s | 4 Mbit/s ± 0,4 kbit/s | 8 Mbit/s ± 0,8 kbit/s | 16 Mbit/s ± 1,6 kbit/s |
| $t_{BIT}$ [ns] | 500 ± 0,05 | 250 ± 0,025 | 125 ± 0,012 5 | 62,5 ± 0,006 25 |
| $t_{BITnom}$ [ns] | 500 | 250 | 125 | 62,5 |
| $t_{BITtest}$ [ns] | 500 ± 0,05 | 250 ± 0,025 | 125 ± 0,012 5 | 62,5 ± 0,006 25 |
| Data frequency (max.) | 1 MHz | 2 MHz | 4 MHz | 8 MHz |
| **Times for curve shapes** | | | | |
| $t_{os}$ [ns] | 200 | 100 | 50 | 25 |
| $t_r$ [ns] | 100 | 40 | 20 | 10 |
| $t_f$ [ns] | 150 | 110 | 25 | 15 |
| Jitter [ns] | $0 \le J_{noise} \le 10$ | $0 \le J_{noise} \le 10$ | $0 \le J_{noise} \le 5$ | $0 \le J_{noise} \le 5$ |

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### 30.2.4 Input-output performance of the slave

#### 30.2.4.1 General

In Subclause 30.2.4, the input-output performance of the slave synchronization performance is specified. A slave shall receive a signal with a certain clock at its optical input. The mean value of this clock is equal to the transmitting clock of the master. In the long run, a slave shall be synchronized to this clock (by evaluation of one of the rising or falling edges).

The slave shall generate its own local clock. This local clock shall be used to receive and to transmit data. The local clock of a slave shall run freely between the synchronizing edges of the incoming bit stream. During synchronization, the slave shall adjust the phases of the local clock (phase locked loop). This performance can be observed at the optical output because the duration of the high or low level becomes shortened or lengthened with respect to the average bit duration ($t_{BIT}$). The amount of shortening or lengthening shall be called clock adjustment time $t_{cad}$.

Clock adjustment time shall not exceed a specific value ($t_{cadmax}$). In addition, the implemented maximum clock adjustment time ($t_{cadreal}$) of every slave shall be specified by the manufacturer (e.g. $t_{BIT}/16$).

The optical signal shall run through the range $P_{TmaxL} - P_{TminH}$ resp. vice versa of the envelope always at the same position (taking $J_{noise}$ into account). The envelope can be shifted over the optical signal (due to short rise and fall times), but this possible shift shall not be taken into account as a "bonus" to the clock adjustment.

A slave shall be able to receive signals correctly if its clock adjustment time is smaller or equal to the maximum clock adjustment time, $t_{cadreal}$, implemented in that slave. If the slaves are physically located in the ring in an ascending $t_{cadreal}$ sequence, the system shall make sure that correct receiving conditions are established for any slave. The receiver of the master, being the last unit in the ring, shall be able to process the maximum allowable clock adjustment time $t_{cadmax}$.

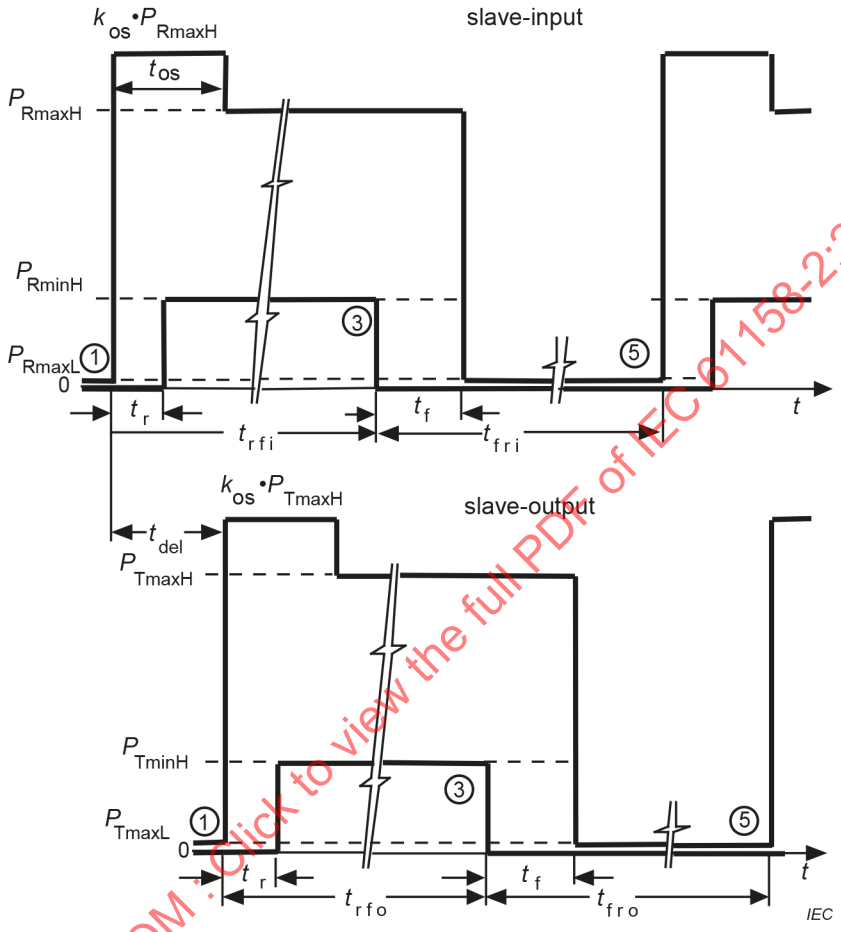


**Figure 158 – Input-output performance of a slave**

In addition to the clock adjustment time just described, a minimum clock adjustment time ($t_{cadmin}$) shall be specified. Every slave shall be able to process data if the clock has been adjusted by $t_{cadmin}$ at its input. The input/output performance of a slave is specified by the following parameters.

$t_{rfi}$: this is the time between points 1 and 3 in Figure 158 on the receiver input.

$t_{fri}$: this is the time between points 3 and 5 in Figure 158 on the receiver input.

$t_{cadreal}$: This is the maximum clock adjustment time (shortening or lengthening a level) which a slave generates at its optical output. This value shall be specified by the manufacturer. The slave shall also be able to correctly process this maximum clock adjustment time at its input, within the scope of the specified bit error rate.

$t_{cadmin}$: this is the minimum clock adjustment time which a slave shall be able to process correctly within the scope of the specified bit error rate.

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$t_{cadmax}$: this is the upper limit for $t_{cadreal}$ and also describes the maximum clock adjustment time that the master shall be able to process correctly within the scope of the specified bit error rate.

$t_{rfo}$: this is the time between points 1 and 3 in Figure 158 at the transmitter output.

$t_{fro}$: this is the time between points 3 and 5 in Figure 158 at the transmitter output.

$t_{del}$: this is the time delay of the envelope between the optical input and output, measured at the slave (see Figure 158). This parameter describes the signal delay (run-time) of the optical signal through a slave in a repeater mode (see also Table 194). The delay shall be measured between the light-ON edge at the optical input and the associated light signal edge at the optical output (in non-inverting slaves, this is the light-ON edge; in inverting slaves, this is the light-OFF edge).

$t_{del}$-optic: max. delay in the electro-optical elements of receiver and transmitter.

$t_{del}$-electric: max. delay of the electric signal routing through the slave (e.g. using an ASIC).

A receiver shall be provided with an input signal as defined by cases a) or b) of Table 190. Changing between cases a) and b) is not allowed. Thus the clock adjustment time will shorten or lengthen only the high level, or only the low level.

**Table 190 – Possible slave input signals**

| Case | $t_{rfi}$ | $t_{fri}$ |
|---|---|---|
| a) | $i \times t_{BIT} - t_{cadreal} \le t_{rfi} \le i \times t_{BIT} + t_{cadreal}$ | $j \times t_{BIT}$ |
| b) | $i \times t_{BIT}$ | $j \times t_{BIT} - t_{cadreal} \le t_{rfi} \le j \times t_{BIT} + t_{cadreal}$ |
| NOTE 1 i and j are ordinary digits; i is not identical to the sequence of networks as given in the abbreviations.<br>NOTE 2 For normal operation i = 1 to 8 and j = 1 to 8, so that I + j = 2 to 16. When switching from telegram to fill signal and vice versa, i = 1 to 12 and j = 1 to 12, but I + j = 2 to 20. | | |

With these specific input signals, the slave shall be able to perform following tasks:

a) receiving and processing data correctly within the scope of the bit error rate;

b) generating valid output signals.

Valid output signals shall have a signal timing within the specified limits and be generated according to cases c) or d) of Table 191. The slave shall be able to either shorten or lengthen only the high level or only the low level through clock adjustment. Alternating between the two is not allowed.

**Table 191 – Possible slave output signals**

| Case | $t_{rfo}$ | $t_{fro}$ |
|---|---|---|
| c) | $m \times t_{BIT} - t_{cadreal} \le t_{rfo} \le m \times t_{BIT} + t_{cadreal}$ | $n \times t_{BIT}$ |
| d) | $m \times t_{BIT}$ | $n \times t_{BIT} - t_{cadreal} \le t_{rfo} \le n \times t_{BIT} + t_{cadreal}$ |
| NOTE m and n are ordinary digits. They are not identical to the explanation given in the abbreviations. | | |

Four cases (shown in Table 192) shall be distinguished for the allowable values m and n:

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**Table 192 – Valid slave output signals**

| Status / slave | Non-inverting slave | | Inverting slave | |
|---|---|---|---|---|
| **Repeater** | **i = m; j = n** | | **i = n; j = m** | |
| Slave transmits own telegram | Normal operation | When switching from telegram to fill signal | Normal operation | When switching from telegram to fill signal |
| | i, j = 8 | | i, j =8 | |
| | m, n = 1 .. 8 | (1 .. 12) | m, n = 1 .. 8 | (1 .. 12) |
| | m + n = 2 .. 16 | (2 .. 20) | m + n = 2 .. 16 | (2 .. 20) |
| NOTE Numbers in brackets represent values which can occur when switching from telegram to fill signal. | | | | |

#### 30.2.4.2 Clock adjustment

The limit values of clock adjustment times are specified in Table 193.

**Table 193 – Specifications of the clock adjustment times**

| Time | Value |
|---|---|
| $t_{cadmin}$ | = $t_{BITnom}$ / 64 |
| $t_{cadmax}$ | = $t_{BITnom}$ / 11 |
| $t_{cadreal}$ | $0 \leq t_{cadreal} \leq t_{cadmax}$ |

#### 30.2.4.3 Signal delay due to the slave

Signal delay due to the slave (in repeater mode) is specified in Table 194.

**Table 194 – Optical signal delay in a slave**

| Baud rate | $t_{del}$-max | $t_{del}$-electric | $t_{del}$-optic |
|---|---|---|---|
| 2 Mbit/s | 750 ns | 400 ns | 350 ns |
| 4 Mbit/s | 375 ns | 200 ns | 175 ns |
| 8 Mbit/s | 250 ns | 100 ns | 150 ns |
| 16 Mbit/s | 200 ns | 50 ns | 150 ns |

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### 30.2.5 Idealized waveform

The idealized waveform is characterized by status changes of the optical signal. The optical signal is replaced by rectangular wave shapes of equal height and infinitely short rise and fall times. The status change (edge) of the idealized waveform (rectangle) is defined at the transmitter output as the instant of time at which the optical power is 0,5 × $P_{TminH}$ with a tolerance of ± 20 %. Both threshold levels (low attenuation and high attenuation) shall always fall within the interval $P_{TmaxL}$ and $P_{TminH}$.

All subsequent times shall be measured between the status changes defined above.

## 30.3 Connection to the optical fiber

### 30.3.1 Introduction

In Subclause 30.3, the connections to the optical fiber for master and slave as well as their interaction are described in more detail.

Table 195 shows all basic functions that shall be performed by a connection.

**Table 195 – Basic functions of the connection**

| Function to be performed by → | | Master | Slave |
|---|---|---|---|
| 1 | Retrieve clock from received signal | x | x |
| 2 | Regenerate and transmit received signal | | x |
| 3 | Transmit 0111 1111 as fill signal | x | |
| 4 | Transmit own telegram | x | x |
| 5 | Phase-correct and spike-free transition between numbers | 4 → 3<br>3 → 4 | 4 → 2<br>2 → 4 |

### 30.3.2 Master connection

#### 30.3.2.1 Function

Figure 159 shows the functions that a master connection shall have.

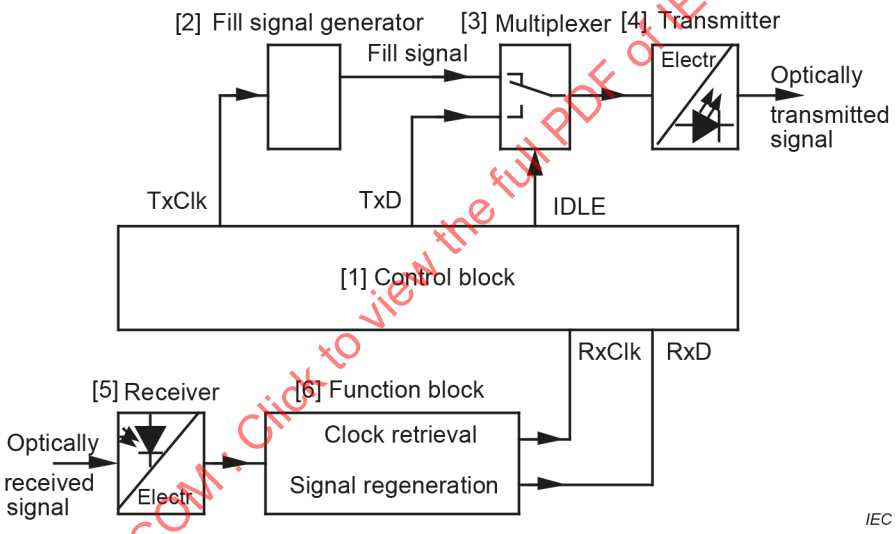


**Figure 159 – Functions of a master connection**

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The control block - [1] in Figure 159 - shall construct the telegram to be sent according to Figure 159 and convert it into a NRZI-coded signal. When receiving a telegram, the master's control block shall recognize the NRZI-coded and regenerated telegram as one for the master based upon its telegram delimiters and the address field. In addition, the control block [1] shall check the telegram and transmit only correct data fields to the signal processing unit.

Except for NRZI coding/decoding and the generation/recognition of the telegram delimiters, the functions above will be discussed with higher protocol layers.

#### 30.3.2.2 Generating a fill signal

According to Figure 159, the control block [1] shall generate the transmitting clock (TxClk) for the master. This shall be sent to the fill signal generator - [2] in Figure 159 -, where the fill signal is generated according to 9.10.2, Figure 67.

When the master is transmitting the fill signal (IDLE = 1), the signal shall reach the electro-optical converter [4] via the switch [3]. The switch shall work in such a way that a signal change at its output always coincides with the pattern of the transmitting clock. In this way, subsequent

units can use phase locked loops for clock retrieval. Thus, they can always be synchronized to the transmitting clock of the master.

Function block [6] is discussed in 30.3.3.

#### 30.3.2.3 Switching from fill signal to telegram delimiters and vice versa

During transitions from fill signal 0111 1111 to telegram delimiters:

a) it shall be possible to interrupt the bit string 0111 1111 at any point;
b) it shall be possible to insert up to two arbitrary (transitioning) bits xx (e.g., for simplifying implementation).

All signal changes generated this way, however, shall be synchronized with the transmitting clock.

Figure 160 shows some examples of valid signal patterns of the transmitting signal during transitions from fill signal to a telegram to be sent, where occasionally inserted (transitioning) bits are shaded.

As shown in Figure 160, bit sequences having several delimiters can be generated. The receiver shall be able to recognize the highlighted, double-lined signal as the leading telegram delimiter.

During the transition from telegram delimiters to fill signals, i.e. after the bit sequence $01111110_B$ (delimiter):

a) up to four arbitrary transitioning bits can be inserted;
b) followed by switching to an arbitrary point in the bit sequence 0111 1111 (fill bits).

All generated signal changes shall be synchronized to the transmitting clock. Figure 161 shows some examples. Occasionally inserted (transitioning) bits are shaded. It is possible to have several delimiters appear. A receiver shall be able to recognize the first delimiter as an enclosing telegram delimiter.

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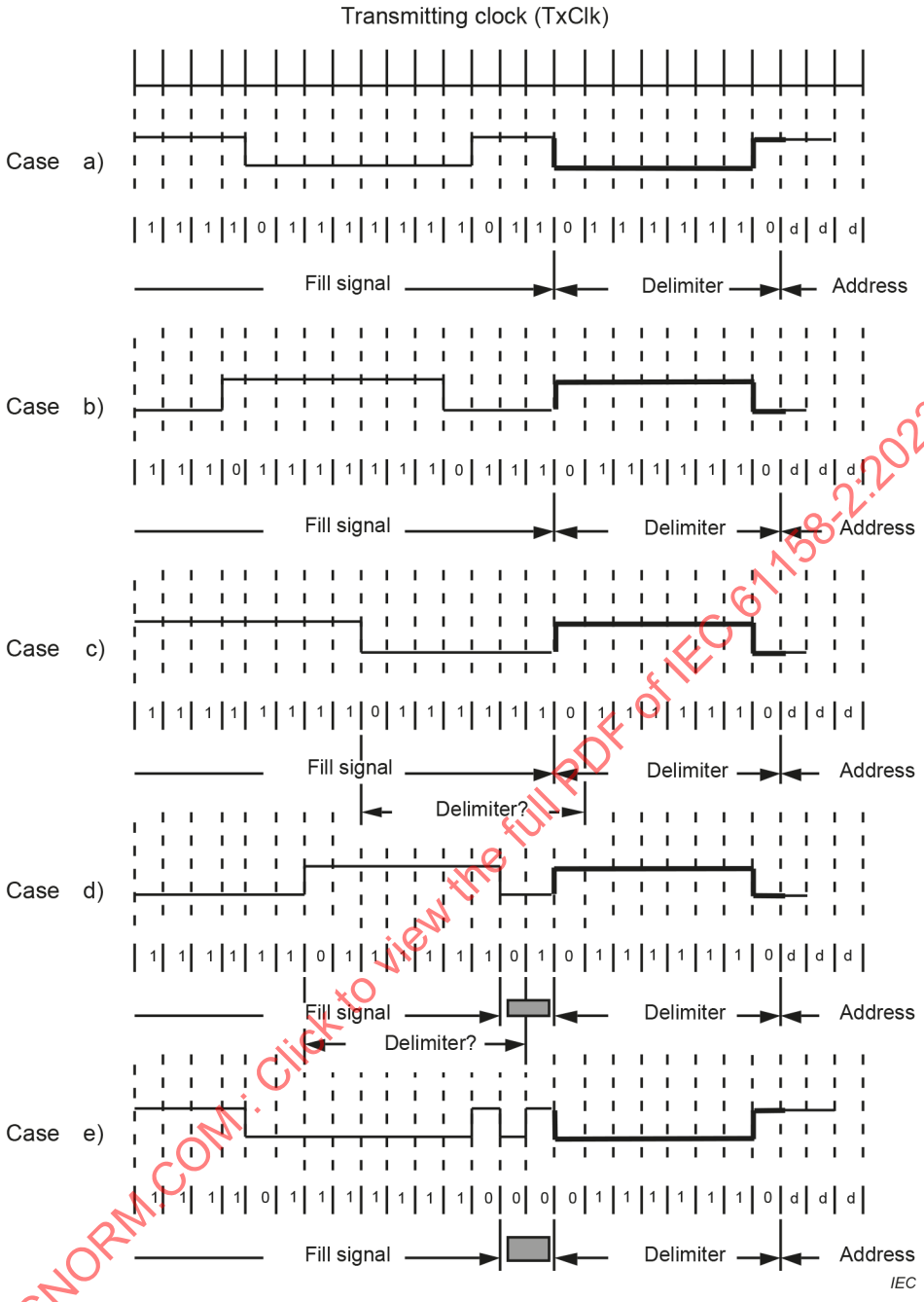


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**Figure 160 – Valid transmitting signals during the transition from fill signal to telegram delimiters**

In Figure 161, case e) is identified by the fact that two consecutive edges of opposite directions shall be separated by a maximum of 12 transmitting clock cycles ($t_{BIT}$) and two sequential edges with the same direction shall be separated by a maximum of 20 transmitting clock cycles ($t_{BIT}$). This is important for the proper operation of a DPLL.

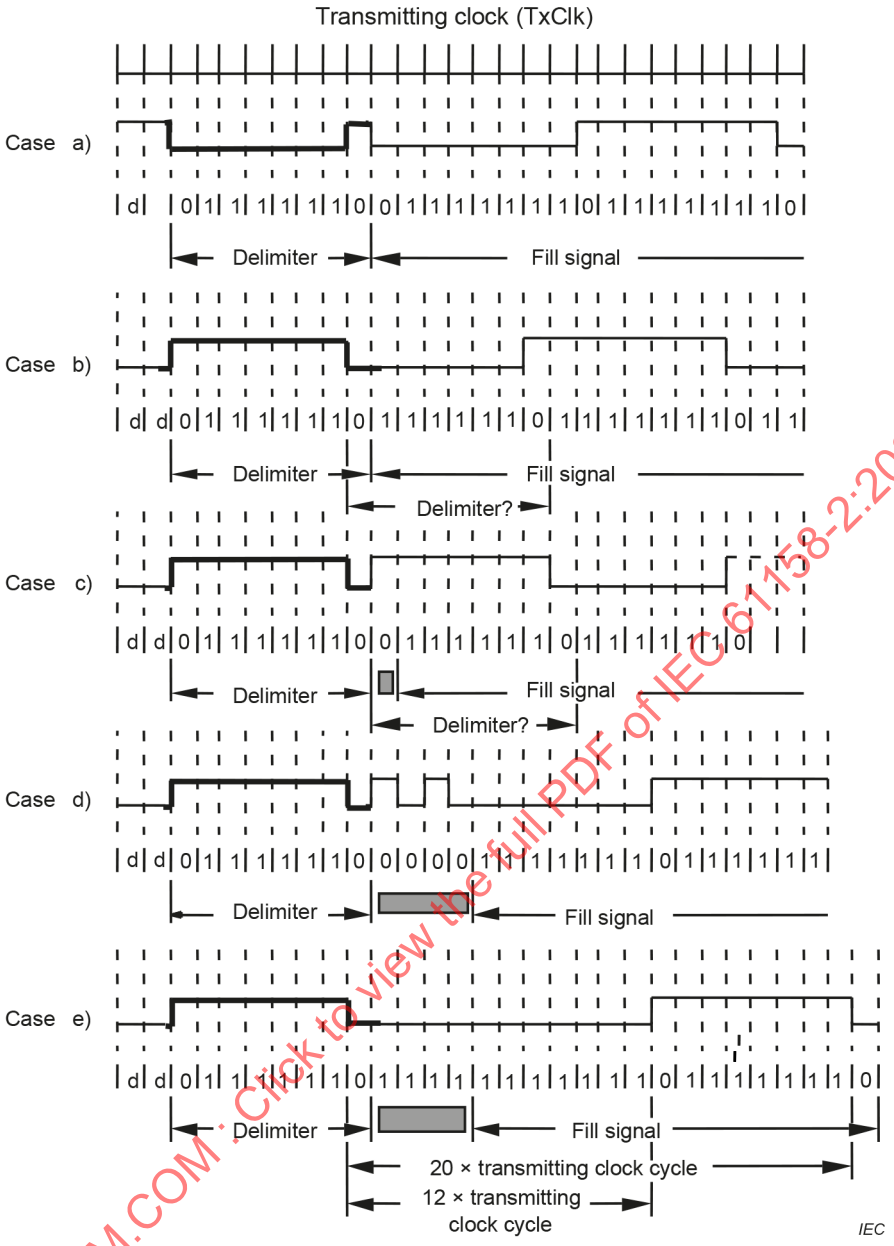


**Figure 161 – Valid transmitting signals during the transition from telegram delimiter to fill signal**

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### 30.3.3 Slave connection

Figure 162 shows the functions that a slave connection shall have.

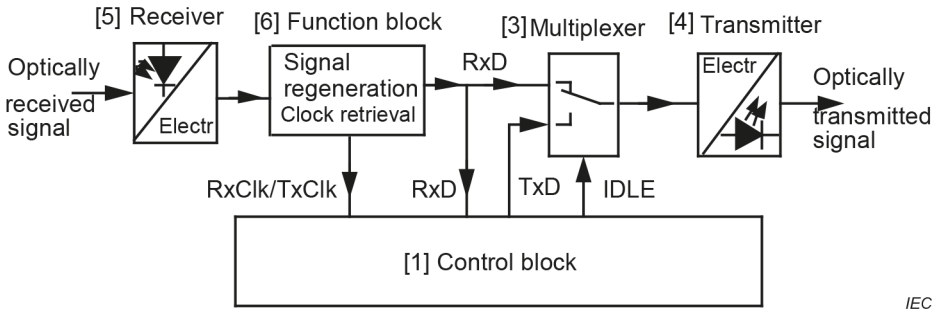


**Figure 162 – Functions of a slave connection**

The function block [6] has the following tasks:

a) Retrieving the clock from the electrical received signal (clock retrieval, possibly with DPLL). The clock retrieved in [6] shall be used as transmitting and receiving clock for [1] (for the master, transmitting and receiving clocks are different signals);

b) Regenerating the received signal, care shall be taken that any signal changes occur synchronously with the clock retrieved in a). If the slave does not need to transmit its own telegram, the regenerated received signal shall be sent (repeater mode, IDLE = 1).

The multiplexer [3] shall work according to the transitioning parameters as shown in 30.3.2.3.

Power supply:

In order to perform the above functions, the electronic components shall continue to work (e.g. during start-up and diagnostics), even if the power supply of the associated devices is shut down. The slaves shall at least be able to regenerate the stream of data and to function as repeaters by transmitting the data.

### 30.3.4 Interactions of the connections

In Figure 163, the interaction of the connection of two slaves in a network is illustrated. The assumption is made that slave 1 is in the process of transmitting a telegram to the master. The multiplexer [3] in the master shall pass the fill signal so that the function block [6] of slave 1 can retrieve the clock. Slave 2 multiplexer [3] shall pass its regenerated received signal (i.e., the slave 1 telegram) to the master. The master, in turn, shall retrieve the receiver clock from the received signal by means of its function block [6]. All three phase locked loops in Figure 163 shall be synchronized at any time. This synchronization shall always be maintained, even if a transition [3] is activated. During switch over of [3], it is important to avoid any signal edges which do not follow the clock pattern.

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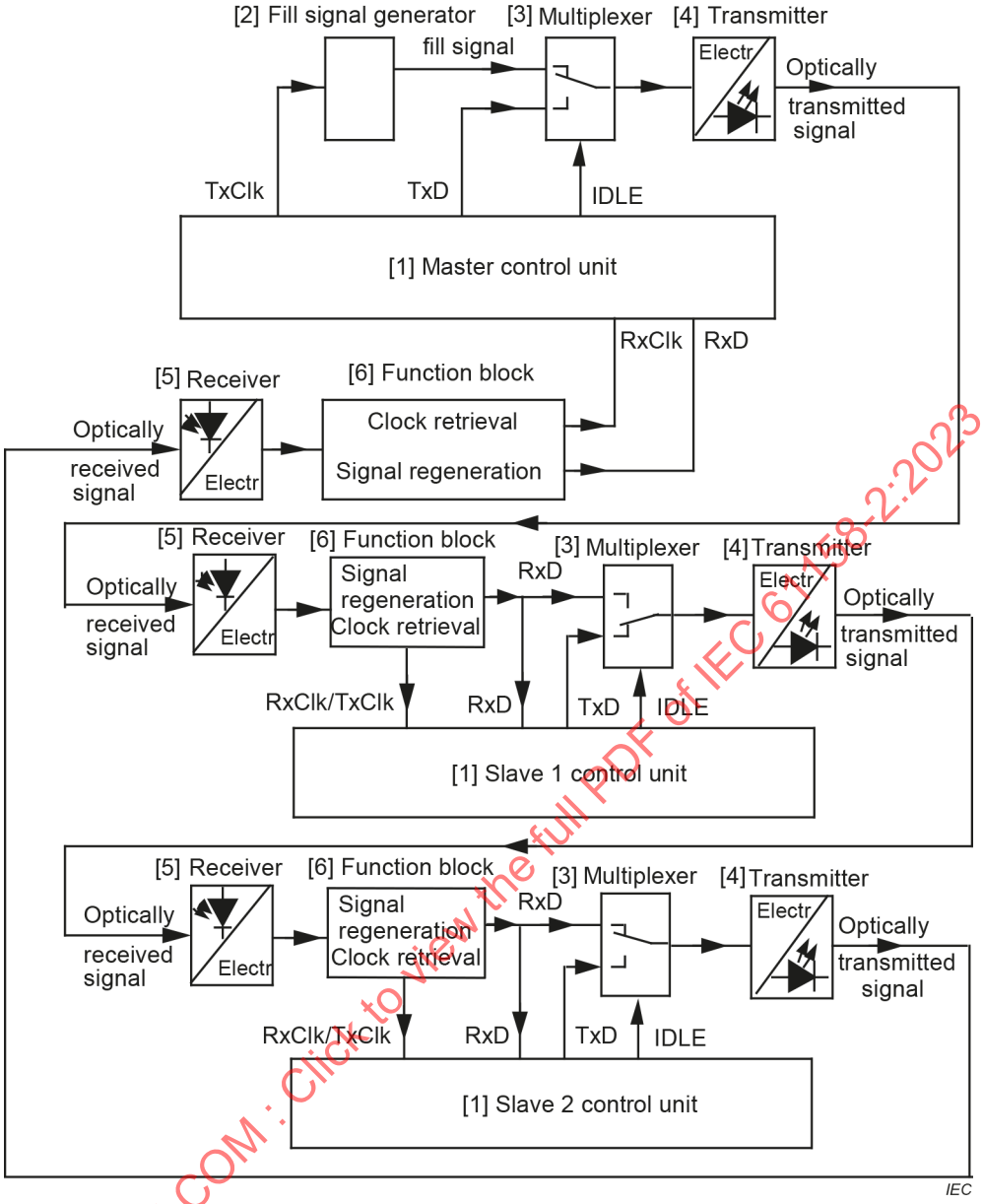


**Figure 163 – Network with two slaves**

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## 31 Type 18: Medium attachment unit: basic medium

### 31.1 General

Type 18-PhL-B implements an MAU compliant with ISO/IEC 8482 twisted pair multipoint interconnections, named TPMI throughout the remainder of Clause 31, and is a derivative of TIA-485-A:1998.

Added to the TPMI requirements are the following:

- data signal encoding specifications
- MAU bus signal loading
- signal conveyance requirements
- media specifications
  - topology descriptions

  - cable specifications
  - transmission line termination specifications
- endpoint and branch trunk cable connectors
- recommended interface circuitry

The resulting Type 18-PhL-B bus can support bit rates as high as 10 Mbit/s and transmission lengths as long as 1,2 km.

NOTE Throughout Clause 31, the term *station* refers to a network device and is used for consistency with the Type 18 DLL and AL where various types of stations are defined.

### 31.2 Data signal encoding

Type 18-PhL-B specifies NRZI (Non-Return to Zero Inverted) data signal encoding as defined by ISO/IEC 9314-1. Accordingly, a Mark-to-Space transition or a Space-to-Mark transition represents a PhPDU logical one; and a lack of transition (Mark-to-Mark or Space-to-Space) presents a PhPDU zero.

### 31.3 Signal loading

A Type 18-PhL-B MAU communication element implementation requires transceiver devices that are specified not to exceed 0,5 Unit Loads (UL). Thus, the maximum number of connected devices is 64.

### 31.4 Signal conveyance requirements

The minimum wiring between communicating devices is shown in Figure 164.

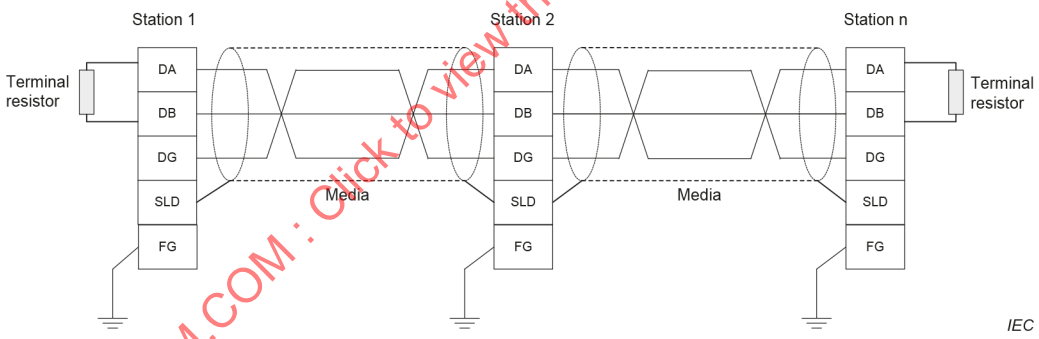


**Figure 164 – Minimum interconnecting wiring**

It is recommended to connect the SLD (shield) to the FG (field ground) at both ends of the trunk line cable via low impedance (that is, low inductance) connections. This is necessary to achieve a reasonable electromagnetic compatibility.

### 31.5 Media

#### 31.5.1 General

The medium of each bus segment (trunk) and spurs (branches) is a shielded twisted-pair cable. The shield helps to improve the electromagnetic compatibility (EMC).

#### 31.5.2 Topology

##### 31.5.2.1 Pass-through topology

A dedicated cable is configured with a pass-through type connector for each device as shown in Figure 165.

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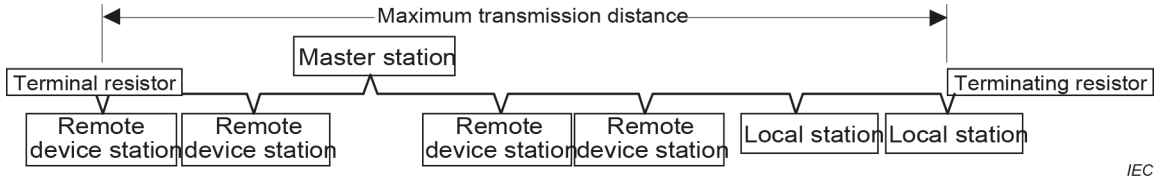


**Figure 165 – Dedicated cable topology**

### 31.5.2.2 T-branch topology

A T-branch topology is configured with T-connectors as couplers to provide node points for spurs (branches) as shown in Figure 166.

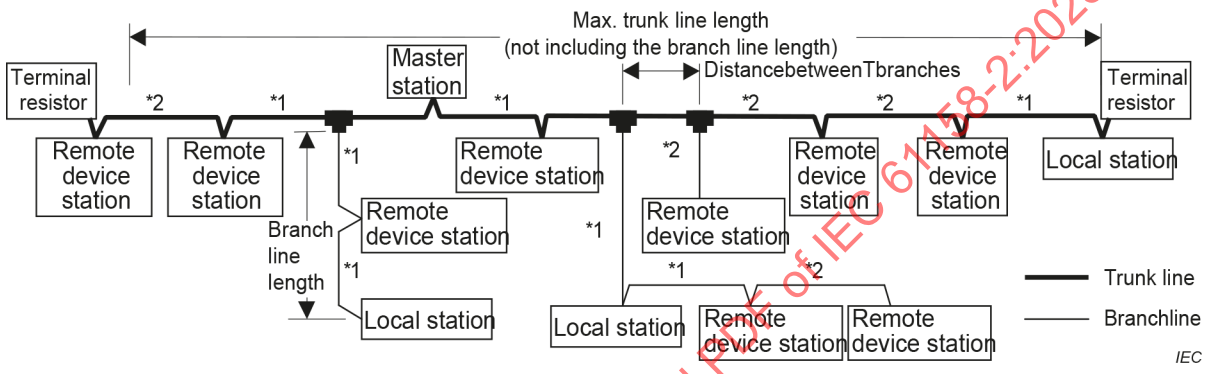


**Figure 166 – T-branch topology**

### 31.5.2.3 Topology requirements

#### 31.5.2.3.1 Pass-through topology

The maximum cable length as a function of bit-rate is specified in Table 196. The minimum cable distance device-to-device is 20 cm.

**Table 196 – Pass-through topology limits**

| Bit rate kbit/s | Max. cable length m |
|---|---|
| 10 000 | 100 |
| 5 000 | 160 |
| 2 500 | 400 |
| 625 | 900 |
| 156 | 1 200 |

#### 31.5.2.3.2 T-branch topology

The only allowable bit rates for the T-branch topology are 156 kbit/s and 625 kbit/s. The maximum cable lengths (as a function of bit-rate) and other topology limitations are specified in Table 197. See Figure 166 for a description of the referenced bus components.

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**Table 197 – T-branch topology limits**

| Parameter | | Value | Comment |
|---|---|---|---|
| Max. trunk length | 625 kbit/s | 100 m | |
| | 156 kbit/s | 500 m | |
| Max. branch length | 625 kbit/s | 50 cm | Cable length per branch (spur) |
| | 156 kbit/s | 200 cm | |
| Max. overall branch length | | 8 m | Total length of all branch lines combined |
| Max. distance between T-branches | | No limit | This distance measured on trunk line |
| Max. number of stations connected per branch | | 6 | |
| Min. distance to master station | | 2 m | See ***1** in Figure 166.<br>This parameter is reduced to 1 m for systems configured without Local Stations or Intelligent Device Stations |
| Min. distance between stations | | 30 cm | See ***2** in Figure 166. |
| NOTE Station types (e.g., master station) are defined in Type 18 DLL and AP. | | | |

### 31.5.3 Signal cable specifications

The 3-core twisted-pair cable Type 18-PhL-B medium is specified in Clause R.1.

### 31.5.4 Media termination

The trunk line segment shall be terminated at each end with its characteristic impedance. Requirements for these two transmission line terminating resistors are specified in Table 198.

**Table 198 – Terminating resistor requirements**

| Parameter | Value |
|---|---|
| Resistance | 110 Ω |
| Power | 0,5 W |
| Tolerance | < 5 % |

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## 31.6 Endpoint and branch trunk cable connectors

There is no physical connector specified for use with Type 18-PhL-B.

The type of connector shall be a screw-compression type with each terminal able to accommodate two conductors of the type specified for the media cable. It is also required that sufficient terminals are provided for all five connection points, or alternatively, four connection points with a separate connection point provided for the FG circuit.

It is recommended that two-piece connectors be implemented for disconnecting online devices. It is further recommended that the implementer evaluate appropriate industry partnership associations and consortia for commonly implemented connector solutions for the industry of targeted application. See the IEC 61784 series for references to these and other related specifications.

## 31.7 Recommended type 18-PhL-B MAU circuitry

Galvanic isolation of the communications element is not required, but it is recommended and strongly encouraged for stable performance. It is minimally recommended that the

communications element be configured with galvanic isolation as shown in Figure 167. It is further recommended that the input/output element be configured with its own galvanic isolation as shown in Figure 168.

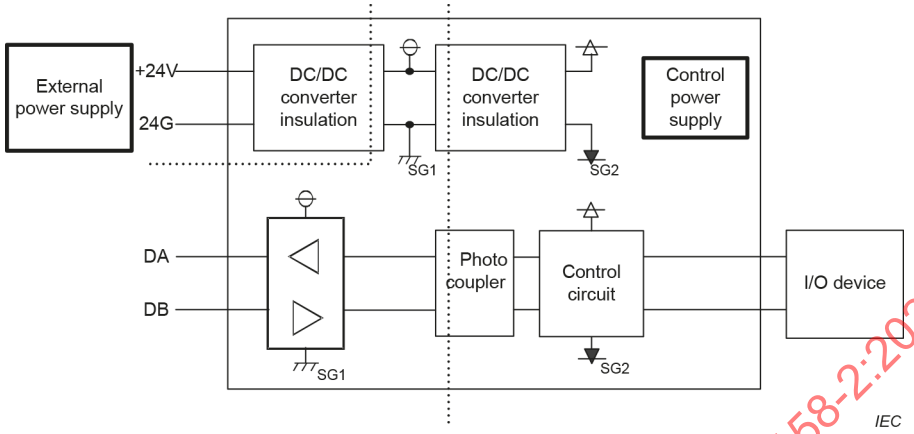


**Figure 167 – Communication element isolation**

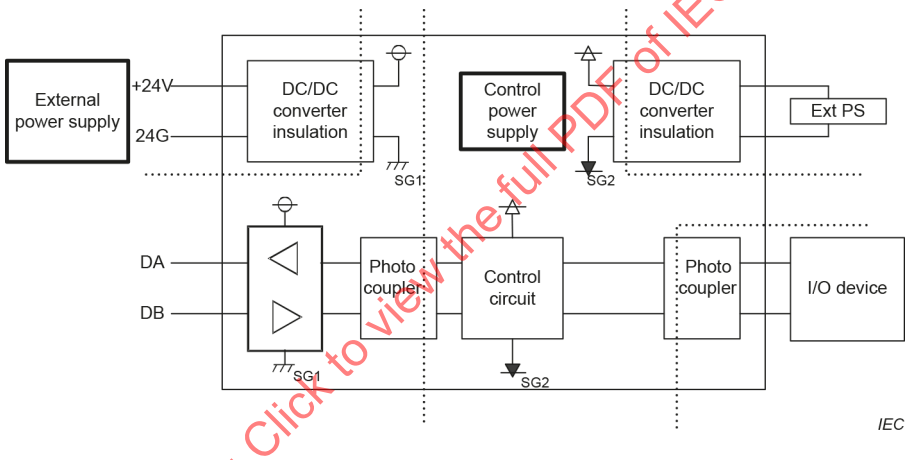


**Figure 168 – Communication element and I/O isolation**

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## 32 Type 18: Medium attachment unit: powered medium

### 32.1 General

Type 18-PhL-P implements a MAU compliant with ISO/IEC 8482 twisted pair multipoint interconnections, named TPMI throughout the remainder of Clause 32, and is a derivative of TIA-485-A:1998.

Added to the TPMI requirements are the following:

- data signal encoding specifications
- MAU bus signal loading
- signal conveyance requirements
- media specifications
  - topology descriptions
  - cable specifications
  - transmission line termination specifications

- endpoint and branch trunk cable connectors
- embedded power distribution
- recommended interface circuitry

The resulting Type 18-PhL-P bus can support bit rates as high as 2,5 Mbit/s and transmission lengths as long as 500 m.

NOTE Throughout Clause 32, the term *station* refers to a network device and is used for consistency with the Type 18 DLL and AL where various types of stations are defined.

## 32.2 Data signal encoding

Type 18-PhL-U specifies NRZI (Non-Return to Zero Inverted) data signal encoding as defined by ISO/IEC 9314-1. Accordingly, a Mark-to-Space transition or a Space-to-Mark transition represents a PhPDU logical one; and a lack of transition (Mark-to-Mark or Space-to-Space) presents a PhPDU zero.

## 32.3 Signal loading

Type 18-PhL-U MAU communication element implementation requires transceiver devices that are specified not to exceed 0,5 Unit Loads (UL). Thus, the maximum number of node devices is 64.

## 32.4 Signal conveyance requirements

The minimum wiring between two communicating devices is shown in Figure 169.

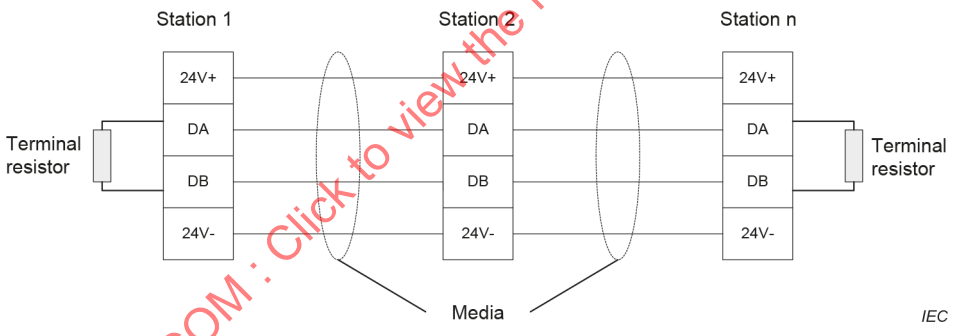


**Figure 169 – Minimum interconnecting wiring**

## 32.5 Media

### 32.5.1 General

The medium of each bus segment (trunks) and spurs (branches) is a 4-core unshielded cable. These cables are specified in both flat cable and round cable configurations with conductors for both communications and embedded power distribution.

### 32.5.2 Topology

#### 32.5.2.1 General

An example flat cable configuration with embedded power distribution is shown in Figure 170. The bus contains a trunk and may contain spurs (branches).

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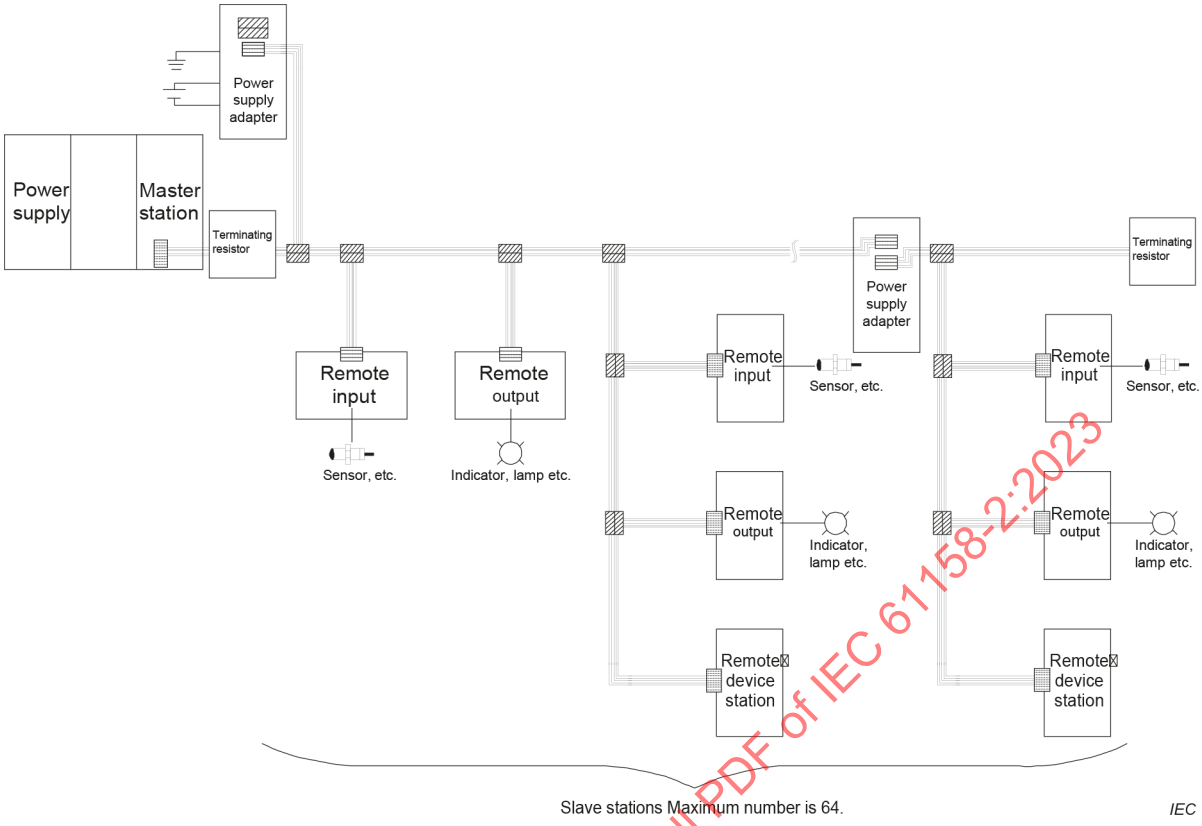


**Figure 170 – Flat cable topology**

### 32.5.2.2 Pass-through topology

A dedicated cable is configured with a pass-through type connector for each device as shown in Figure 171.

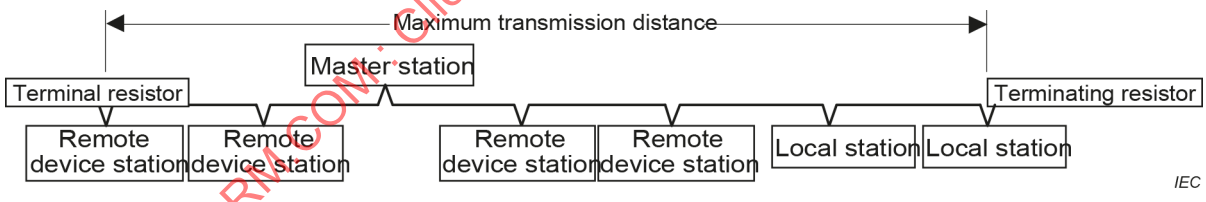


**Figure 171 – Dedicated cable topology**

### 32.5.2.3 T-branch topology

A T-branch topology is shown in Figure 172. The cable types can be mixed in the network, but shall remain consistent for a given branch of trunk segment.

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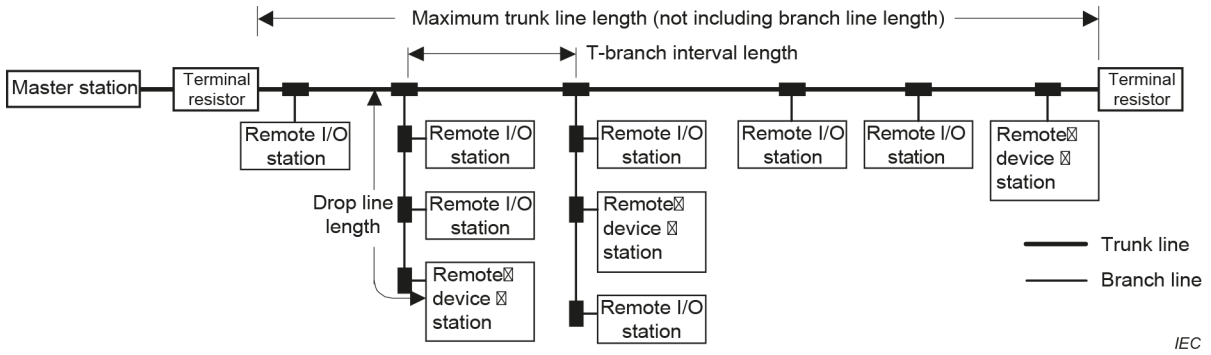


**Figure 172 – T-branch topology**

### 32.5.3 Topology requirements

#### 32.5.3.1 Pass-through topology

The maximum cable length, as a function of bit-rate, is specified in Table 199.

**Table 199 – Pass-through topology limits**

| Bit rate kbit/s | Max. cable length m |
|---|---|
| 2 500 | 35 |
| 625 | 100 |
| 156 | 500 |

#### 32.5.3.2 T-branch topology

The type 18-PhL-P topological implementation is restricted in that the trunk segment shall be constructed using only one type of cable (flat, round preferred, or round alternate). Similarly, each branch (spur) shall be self-consistent, that is, constructed of only one type of cable. However, branch cable types need not match the trunk cable type or that of other branches in the PhL-segment bus.

The only allowable bit rates for the T-branch topology are 156 kbit/s, 625 kbit/s and 2,5 Mbit/s.

The maximum cable lengths as a function of bit-rate and other topology limitation are specified in Table 200.

**Table 200 – T-branch topology limits**

| Parameter | Value | | | Comment |
|---|---|---|---|---|
| | 156 kbit/s | 625 kbit/s | 2 500 kbit/s | |
| Max. trunk segment length | 500 m | 100 m | 35 m | Not including branch line length |
| Max. branch length | 60 m | 16 m | 4 m | Cable length per branch (spur) |
| Max. overall branch length | 200 m | 50 m | 15 m | Total length of all branch lines combined |
| Max. cable length between connected devices | 500 m | 100 m | 35 m | |
| Max. cable length between T-branches | No limit | | | This distance measured on trunk line |
| Max. number of devices connected per branch | 8 | | | |

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### 32.5.4 Signal cable specifications

#### 32.5.4.1 Flat cable

The 4-core unshielded flat cable Type-18-PhL-P medium is specified in R.2.1.

#### 32.5.4.2 Round cable – preferred

The preferred 4-core unshielded round cable for the Type-18-PhL-P medium is specified in R.2.2. This cable type is also known as VCTF cord.

#### 32.5.4.3 Round cable – alternate

The alternate 4-core unshielded round cable for the Type-18-PhL-P medium is specified in R.2.3.

### 32.5.5 Media termination

The trunk line segment shall be terminated at each end with its characteristic impedance. Requirements for these two-transmission line terminating resistors are specified in Table 201 for flat cable and Table 202 for round cable.

**Table 201 – Terminating resistor requirements – flat cable**

| Parameter | Value |
|---|---|
| Resistance | 680 Ω |
| Power | 0,5 W |
| Tolerance | <10 % |

**Table 202 – Terminating resistor requirements – round cable**

| Parameter | Value |
|---|---|
| Resistance | 680 Ω |
| Power | 0,5 W |
| Tolerance | <10 % |

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## 32.6 Endpoint and branch trunk cable connectors

### 32.6.1 Device connector

The required dimensions of the Type 18-PhL-P device connector are specified in Clause Q.2.

### 32.6.2 Flat-cable connector

The required dimensions of the Type 18-PhL-P flat cable connector are specified in Clause Q.3.

### 32.6.3 Round cable connector

The required dimensions of the Type 18-PhL-P round cable connector are specified in Clause Q.4. This connector is applicable to both styles of Type 18-PhL-P round cable.

### 32.6.4 Round cable alternate connector

The required dimensions of the Type 18-PhL-P round cable alternate connector is specified in Clause Q.5.

### 32.6.5 T-branch coupler

There are no required dimensions for the Type 18-PhL-P T-branch coupler. Any suitable commercially available terminal block can be used.

## 32.7 Embedded power distribution

### 32.7.1 General

Type 18-PhL-P includes specifications for network embedded power distribution. The power component of a PhL-segment can be either a single interconnected power distribution system or partitioned into more than one power allocation segments. The example block diagram in Figure 173 demonstrates a PhL-segment with two power allocation segments.

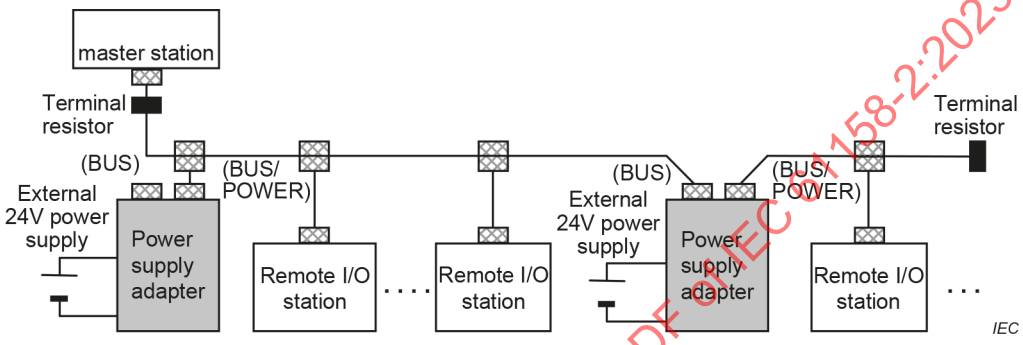


**Figure 173 – Type 18-PhL-P power distribution**

### 32.7.2 Power source

Power supply devices shall be implemented with two device bus connectors that provide pass-through connectivity for the data signals but power sourced to only one connector. The circuit diagram in Figure 174 shows the interconnection for the power source.

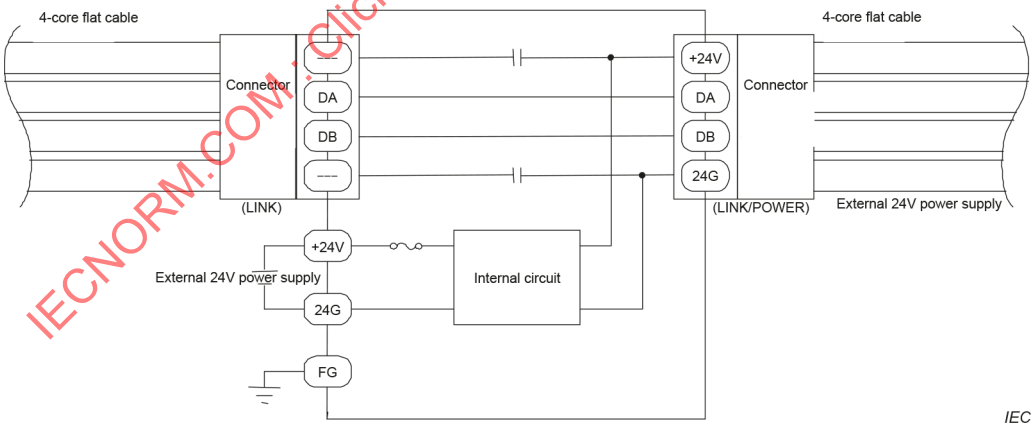


**Figure 174 – Type 18-PhL-P power distribution**

The 24 V power supply for the Type 18-PhL-P shall comply with the specifications given in Table 203.

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**Table 203 – 24 V power supply specifications**

| Parameter | Specification |
|---|---|
| Max. operating voltage | 28,8 V |
| Min. operating voltage | 20,4 V |
| Max. current | 5 A |
| Isolation - power to data signals | 500 V RMS |
| Reverse over voltage protection | 95 V |
| Current surge tolerance | Output voltage within 19,2 V to 30,0 V for ±5 A/1 ms pulse |

### 32.7.3 Power loading

Each device connected to the Type 18-PhL-P bus that also consumes power shall comply with the requirements specified in Table 204.

**Table 204 – 24 V power consumption specifications**

| Parameter | Specification |
|---|---|
| Max. operating voltage | 30,0 V |
| Min. operating voltage | 19,2 V |
| Max. current | 5 A [a] |
| Start current | 1,33 times operating current [b] |
| Reverse current protection | no damage to device or network from reverse wired power |

[a] For full transmission distances, it is necessary to limit power consumption to 0,1 A per device.

[b] This does not include the inrush current required to charge the input bypass capacitors. When these are included, it is necessary to limit the overall inrush current such that the bus power shall not droop to less than 19,2 V for more than 1 ms when a device is plugged into an operating network.

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The specifications for start current and inrush current (Table 204, Note 2) are required to support hot-pluggable devices, that is, devices that can be plugged into, or removed from, an operating network without harm to the network or the devices.

Filtering of the power input circuitry and protecting against reverse power connection is also required for stable performance at the higher bit rates. The filter parameters are not specified. A typical filter and protection circuit is shown in Figure 175 with critical components labelled.

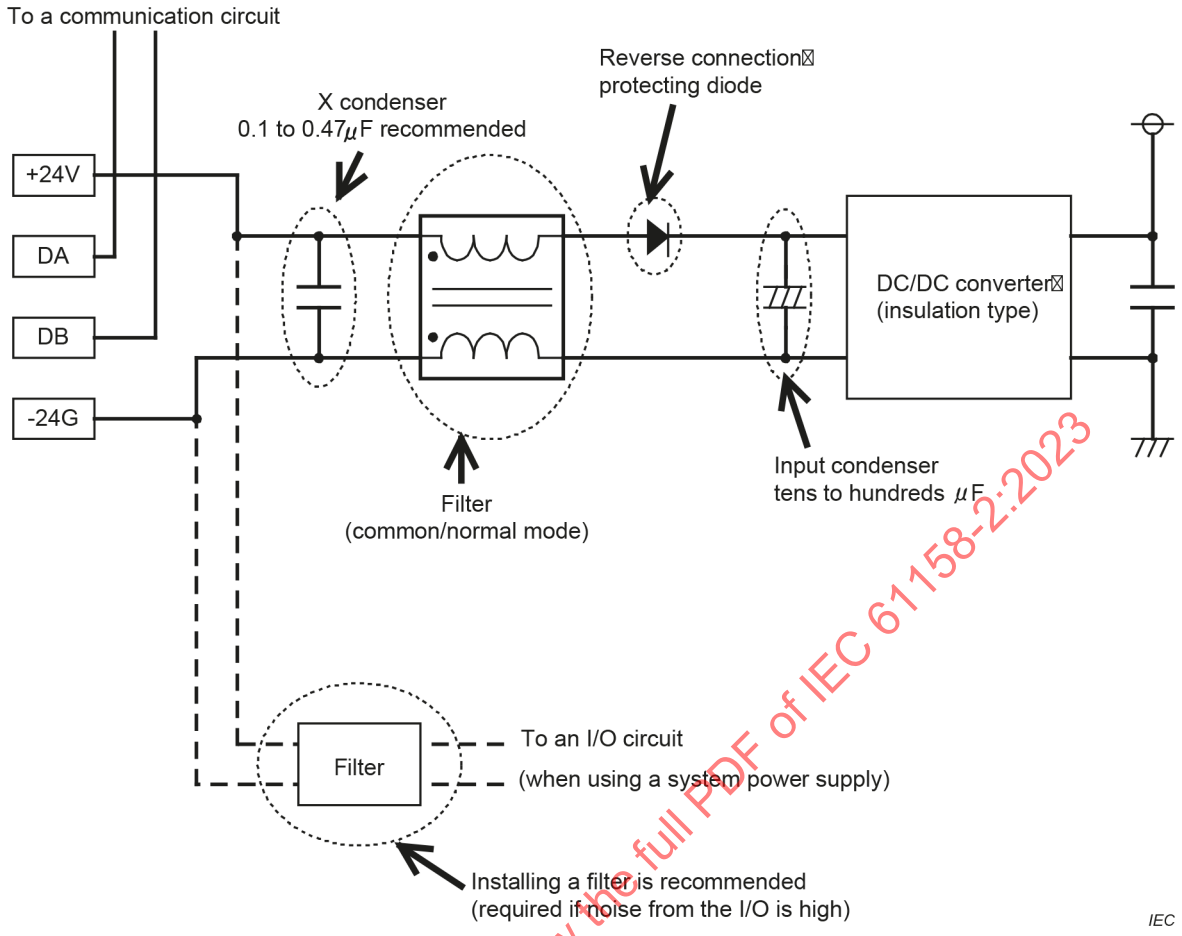


**Figure 175 – Type 18-PhL-P power supply filtering and protection**

## 32.8 Recommended type 18-PhL-P MAU circuitry

### 32.8.1 General

The circuit diagrams in 32.8.2 and 32.8.3 are included for informational purposes.

### 32.8.2 Communications element galvanic isolation

Galvanic isolation of the communications element is not required, but it is recommended and strongly encouraged for stable performance. It is minimally recommended that the communications element be configured with galvanic isolation as shown in Figure 176. It is further recommended that the input/output element be configured with its own galvanic isolation as shown in Figure 177.

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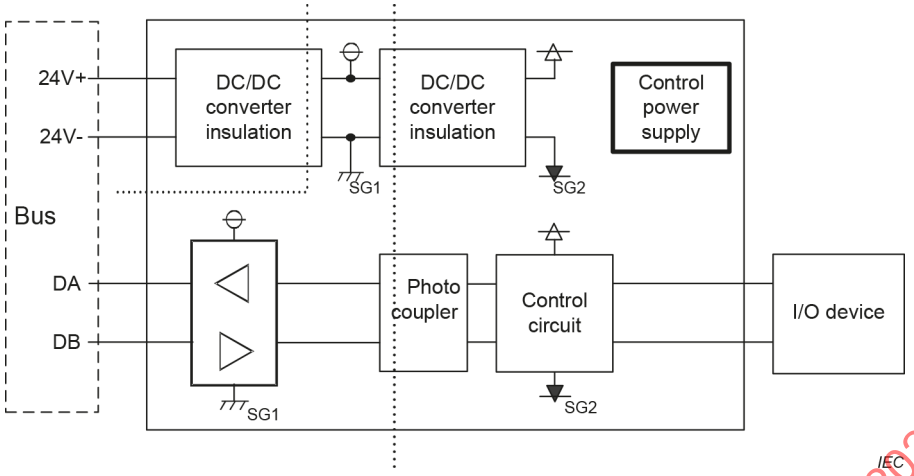


**Figure 176 – Communication element isolation**

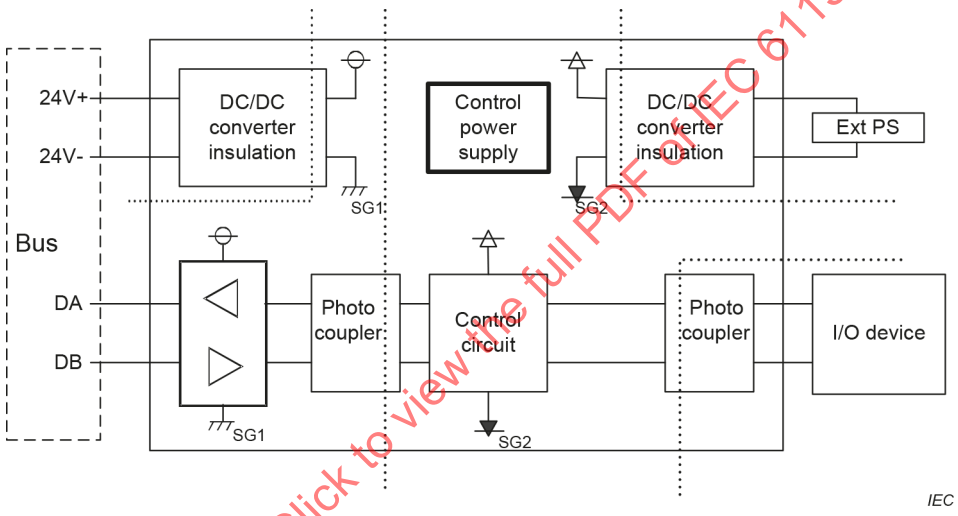


**Figure 177 – Communication element and i/o isolation**

### 32.8.3 Power

A complete power conditioning circuit is shown in Figure 178. This diagram serves as an informative guide for a recommended implementation of Type 18-PhL-P power supply components.

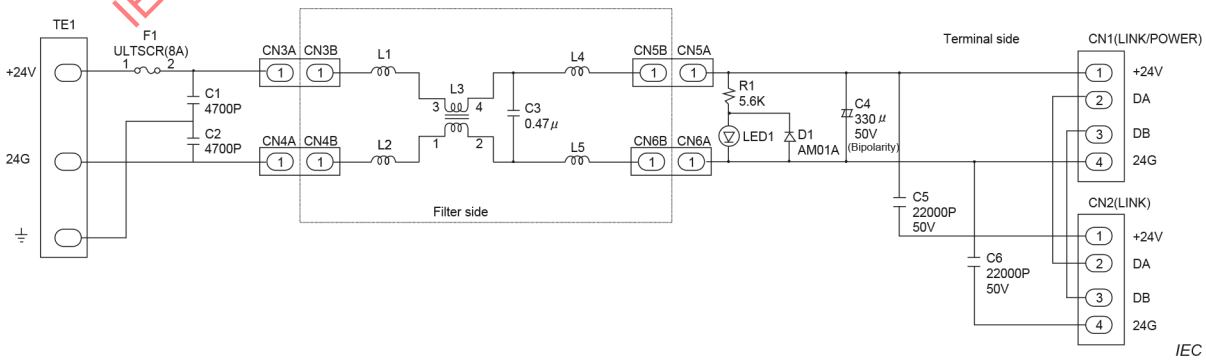


**Figure 178 – PhL-P power supply circuit**

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# 33 Type 24: Medium attachment unit: twisted-pair wire medium

## 33.1 General

This MAU specification describes a balanced line transmission corresponding to TIA-485-A:1998. In Table 205, MAU characteristics are summarized.

**Table 205 – MAU summary**

| | Characteristic | Constraints |
|---|---|---|
| Type 24-1 | Topology | Linear bus, terminated at both ends, no branches |
| | Medium | Shielded twisted pair cable, see 33.4.2 |
| | Line Length | ≤ 50 m |
| | Number of devices | 17 (Line Length ≤ 30 m)<br>16 (Line Length >30 m and ≤ 50 m) |
| | Data rate | 10 Mbit/s |
| Type 24-3 | Topology | Linear, T-branch, and combination of Linear and T-branch |
| | Medium | Shielded twisted pair cable, see Annex U |
| | Line Length | >0,1 m and ≤ 50 m, between devices |
| | Number of devices | ≤15 |
| | Data rate | 4 Mbit/s, 8 Mbit/s, 16 Mbit/s, 24 Mbit/s, 32 Mbit/s |

## 33.2 Network

### 33.2.1 Component

This MAU operates in a network that consists of the following components:

– cable;
– connectors;
– devices (containing at least one communication element).

### 33.2.2 Topology

In Type 24-1, MAU shall operate in a linear bus topology with terminators at both ends. Up to 17 fieldbus devices are connected directly. The total length of the cable shall not exceed 50 m. The maximum number of connected devices varies with the line length as shown in Table 205. The line length and number of devices can be increased by using a repeater. Only one repeater is permissible. Figure 179 shows an example of expanded network using a repeater.

See Annex U for Type 24-3 MAU Topology.

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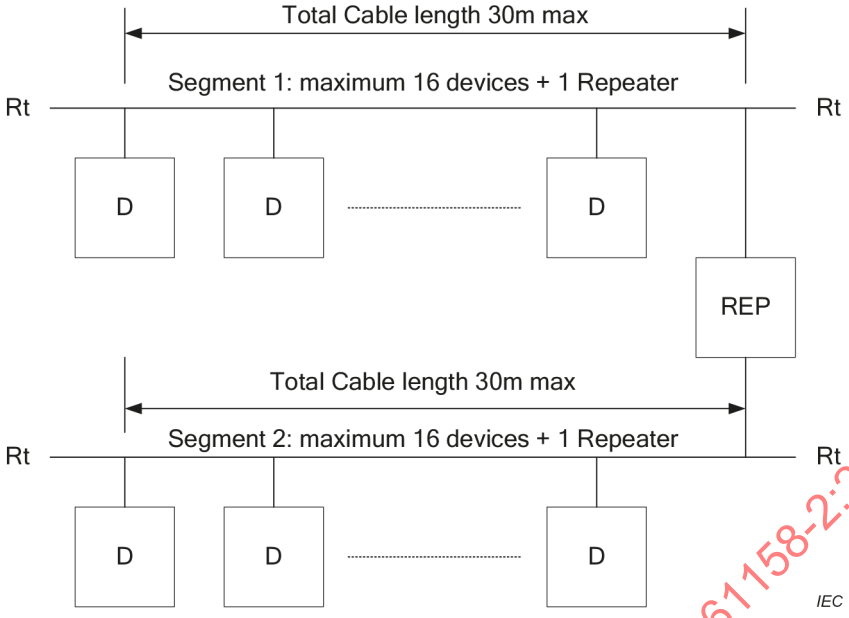


**Key**

| | |
|---|---|
| D | Device |
| REP | Repeater |
| Rt | Bus Terminator |

**Figure 179 – Expanded Type 24-1 network using repeater**

### 33.3 Electrical specification

The voltage levels of the transmitter output and receiver input are according to TIA-485-A:1998. In Type 24-1, transmitter output and receiver input are galvanic isolated by a pulse transformer. In Type 24-3, transmitter output and receiver input are without galvanic isolated by a pulse transformer.

### 33.4 Medium specifications

#### 33.4.1 Connector

For the Type 24-1 connectors are specified in Figure S.1, Figure S.2, and Figure S.3. In Type 24-1, to take the impedance matching with the transmission line, the inductor of 100 nH shall be mounted in the cable side connector as shown in Figure 180. For the Type 24-3 connectors are specified in Figure S.4, Figure S.5, Figure S.6, Figure S.7, Figure S.8, Figure S.9, Figure S.10, Figure S.11, Figure S.12, and Figure S.13.

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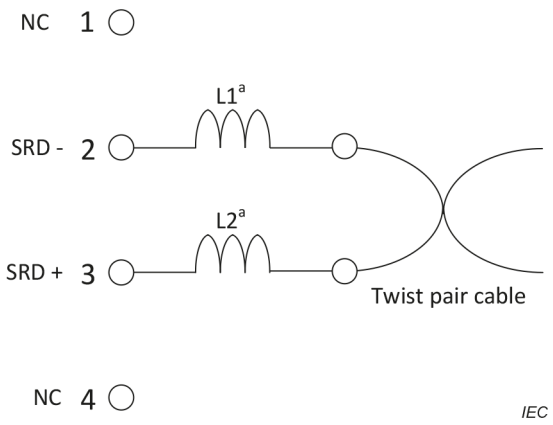


**Key**

[a] L1, L2: (100±5) nH

**Figure 180 – Connector with inductor**

### 33.4.2 Cable

The bus medium is a shielded twisted-pair cable. The shield helps to improve the electromagnetic compatibility (EMC). In Type 24-1, the structure and specification of the cable are shown in Figure 181 and Table 206 respectively.

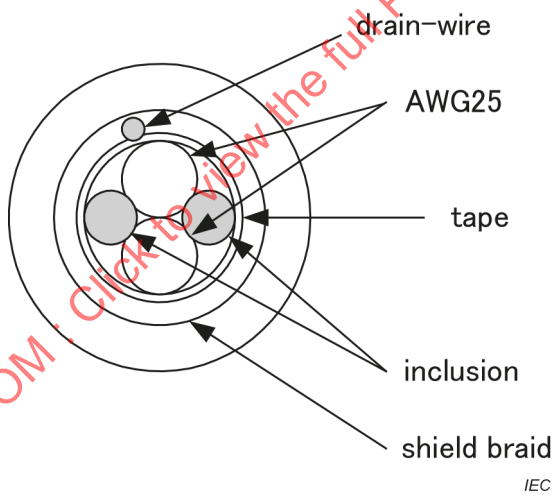


**Figure 181 – Type 24-1 Cable structure**

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**Table 206 – Type 24-1 Cable specification**

| Characteristic | Constraints |
|---|---|
| Overall diameter | 4,8 mm ± 0,2 mm |
| Conductor | Tinned annealed copper |
| Electrical resistance of conductor | ≤ 114,4 Ω/km |
| Withstand voltage | AC 1 000 V, 1 min |
| Insulation resistance | ≥ 100 MΩ/km |
| Impedance | 130 Ω |
| Capacity | 110 nF/km |
| Attenuation | 40 dB/km (at 4 MHz)<br>60 dB/km (at 10 MHz) |
| Color code | Black / Red |

The wiring between two devices is shown in Figure 182.

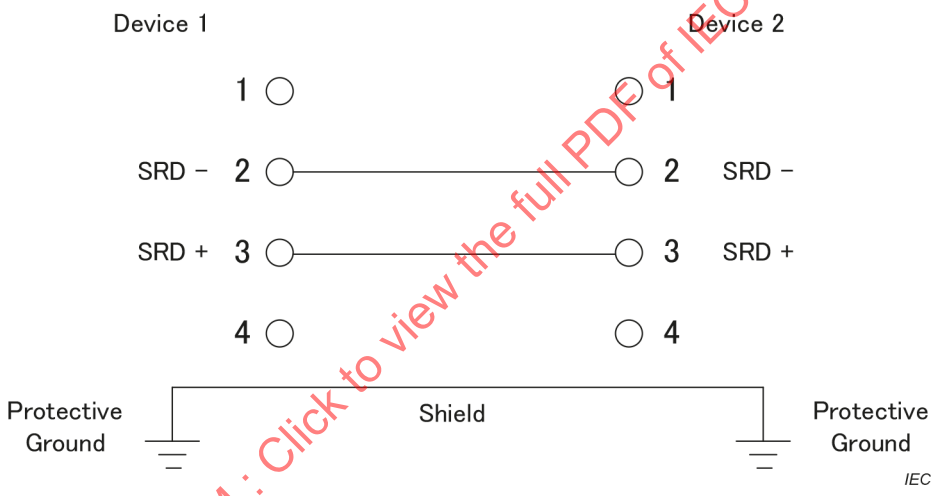


**Figure 182 – Type 24-1 Interconnecting wiring**

NOTE Inversion of the two wires is not allowed

The wiring shown in Figure 182 allows a common mode voltage between both devices (that is, the voltage difference between the protective grounds) of at most 7 V. If higher common mode voltage is expected, a compensation conductor between the grounding points shall be installed.

### 33.4.3 Grounding and shielding rules

It is recommended to connect the shield to the protective ground at both ends of the cable via low impedance (that is, low inductance) connections. This is necessary to achieve a reasonable electromagnetic compatibility.

Preferably the connections between the cable shield and the protective ground (for example, the metallic device housing) should be made via the metallic housings of the connectors.

### 33.4.4 Bus terminator

The bus cable shall be terminated at both ends with Rt. In Type 24-1, the value of the terminator shall be 130 Ω with a tolerance of ± 5 % (1/2 W min.), as shown in Figure 183. In Type 24-3, the value of the terminator shall be 124 Ω with a tolerance of ± 5 % (62 Ω × 2, 1/4 W min.) and mounted on the circuit board, as shown in Figure 183, Figure 188 and Figure 189.

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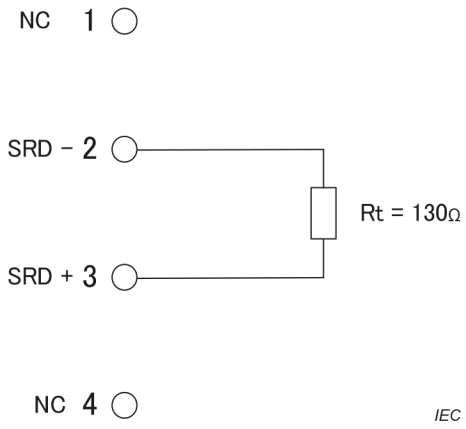


**Figure 183 – Type 24-1 Bus terminator**

### 33.4.5 Bit coding

The coded data from MDS is transmitted via a twisted pair cable. A differential signal of the transmission line is obtained from the bus connector.

In the Manchester coded data, when it is Low and the latter half is High, the first half of the bit of a differential signal becomes a binary "1" (DL_symbol = "ONE"). When it is High and the latter half is Low, the first half of the bit becomes a binary "0" (DL_symbol = "ZERO").

In the NRZI coded data, when the bit of a differential signal becomes a binary "1" (DL_symbol="ONE"), the previous signal level High or Low is held. When a differential signal becomes a binary "0" (DL_symbol="ZERO"), the previous signal level is inverted.

### 33.4.6 Transceiver control

Transceiver of Type 24 MAU shall be in accordance with the transmitter and receiver specifications shown in Table 207 and Table 208. Other specifications not listed on those tables shall be in accordance with TIA-485-A:1998.

**Table 207 – Transmitter specification**

| Specification | Limits / characteristics |
|---|---|
| High level output current High-current, IOH | −100 mA min. |
| Low level output current Low-current, IOL | 100 mA min. |

**Table 208 – Receiver specification**

| Specification | Limits / characteristics |
|---|---|
| Positive-going input threshold voltage | −10 mV max. |
| Negative-going input threshold voltage | −200 mV min. |

When a device is not transmitting the transmitter output shall be disabled and present high impedance to the line. During the idle periods, that is, when no data is transmitted by any device, the receive line signal shall represent a binary "1". The voltage level of the differential signal received during idle periods is 0 V. Therefore, the threshold voltage of the receiver shall be lower than 0 V as specified in Table 208 for the receiver to represent a binary "1". Also, the received signal shall conform to the eye pattern specified in Figure 184, in Type 24-1 and

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specified in Figure 185, in Type 24-3. The received signal shall conform to the pulse width specified in Table 209, in Type 24-3.

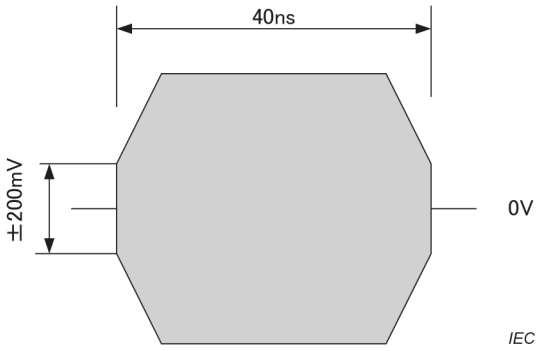


**Figure 184 – Eye pattern for Type 24-1**

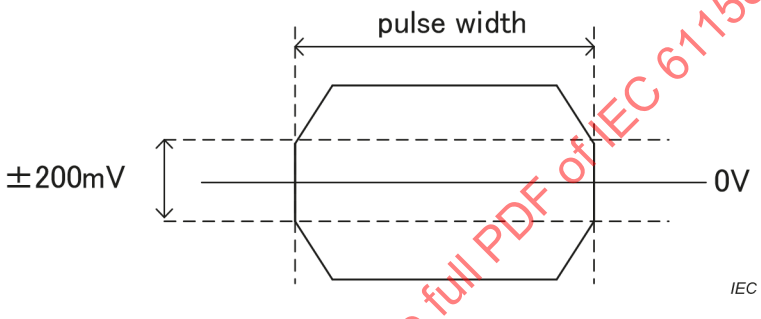


**Figure 185 – Eye pattern for Type 24-3**

**Table 209 – Pulse width for Type 24-3**

| coding | bit rate | pulse width |
|---|---|---|
| Manchester | 4 Mbit/s | 87,52 ns |
| | 8 Mbit/s | 45,86 ns |
| NRZI | 16 Mbit/s | 25,02 ns |
| | 24 Mbit/s | 30,23 ns |
| | 32 Mbit/s | 19,815 ns |

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### 33.4.7 Transformer

For galvanic isolation between medium and MAU, a pulse transformer specified in Figure 186 and Table 210 shall be used.

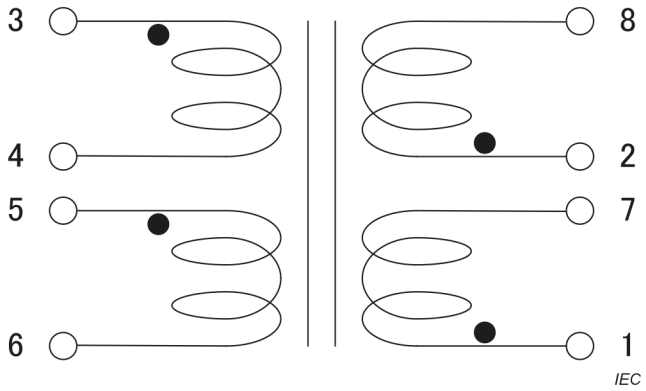


**Figure 186 – Type 24-1 Transformer symbol**

**Table 210 – Type 24-1 Specification of transformer**

| Item | Specification | Note |
|---|---|---|
| Response frequency | 2/4/10 MHz | |
| Inductance | 0,5 mH min | L (1-8) (2-7 short) 10 kHz 0,1V |
| Turn ratio | (2-8):(1-7) = 1:1<br>(2-8):(3-4) = 1:2<br>(2-8):(5-6) = 1:2 | |
| DC resistance | 600 mΩ (1-8)<br>300 mΩ (4-3) | (2-7 short)<br>(4-6 short & 3-5 short) |
| Leakage inductance | 400 nH max. | L (1-8) (2-7 short & 3-6-4-5 short) |
| Capacity | 12 pF max. | (1-2-7-8 short & 3-6-4-5 short) 1 MHz |
| Insertion loss | 0,5 dB max. | (3-4) to (1-8)<br>(2-7 short & 4-6 short & 3-5 short)<br>50 Ω: 2 MHz~10 MHz |
| Insulation resistance | 100 MΩ min. | AC 500 V |

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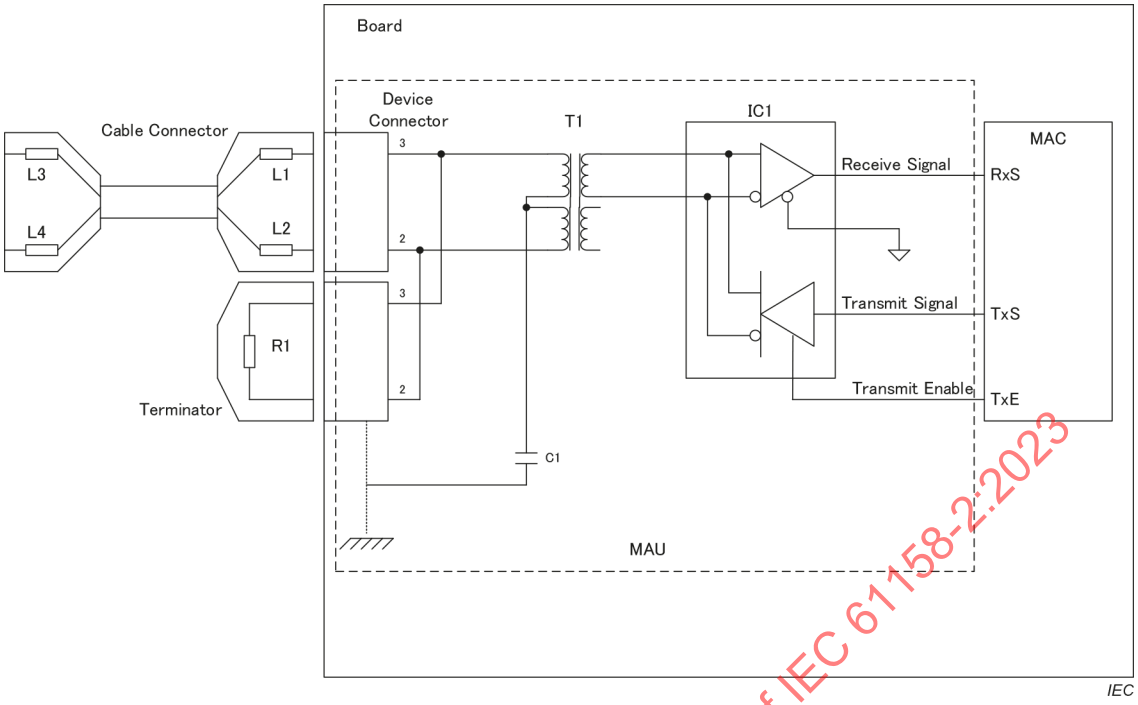
### 33.4.8 Output level requirement

Refer to TIA-485-A:1998 for the voltage level of the transmission and the reception.

### 33.4.9 Interface to the transmission medium

In Type 24-1, the recommended circuit of Type 24 MAU is shown in Figure 187.In Type 24-3, the recommended circuit of Type 24 MAU is shown in Figure 188 and Figure 189.




**Key**

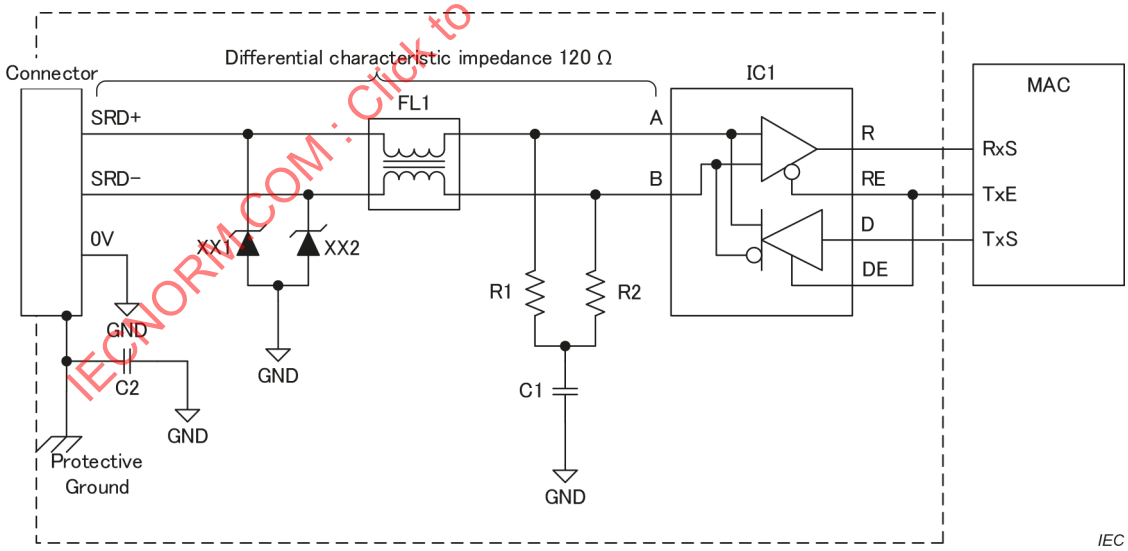
IC1 : Transceiver IC

T1 : Isolation transformer

R1 : (130 ± 6,5) Ω, 1/2 W

C1 :1000 pF, 1 kV

**Figure 187 – Type 24-1 Recommended MAU circuit**




**Key**

IC1 : Transceiver IC

FL1 : Common mode filter

R1,R2 : (62 ± 3,1) Ω,1/4 W

C1 : 0,1 µF, 50 V

C2 : To be selected according to the noise environment

XX1, XX2 : ESD protection device

**Figure 188 – Type 24-3 Recommended MAU circuit for upstream port**

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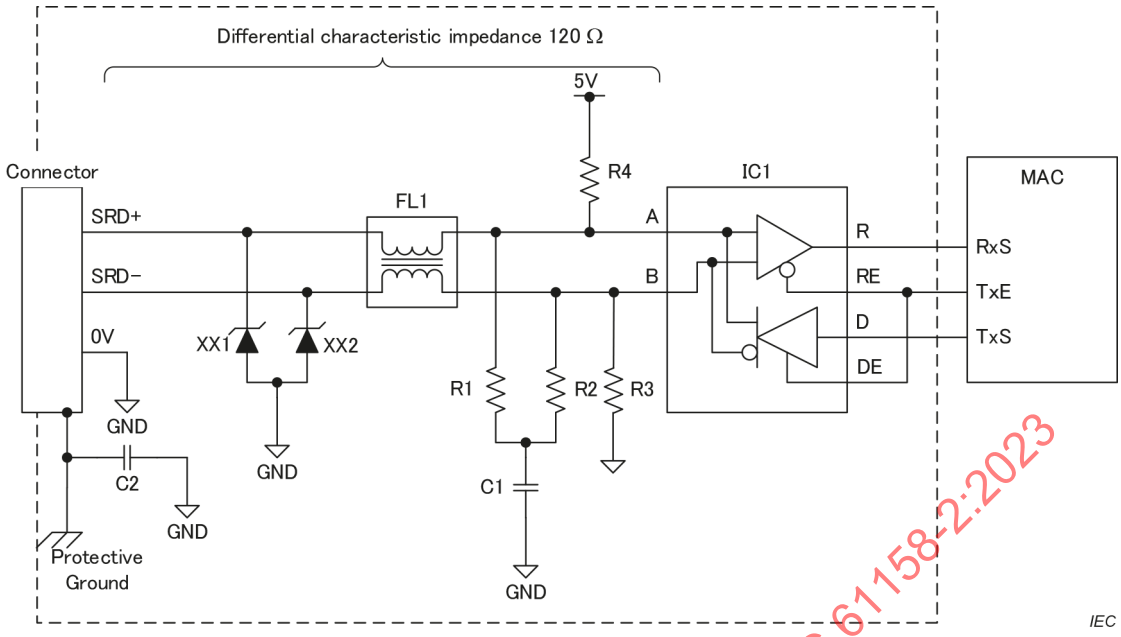


**Key**

IC1 : Transceiver IC

FL1 : Common mode filter

R1,R2 : (62 ± 3,1) Ω,1/4 W

R3,R4 : (680 ± 6,8) Ω,1/8 W

C1 : 0,1 µF, 50 V

C2 : To be selected according to the noise environment

XX1, XX2 : ESD protection device

**Figure 189 – Type 24-3 Recommended MAU circuit for downstream port**

## 34 Type 20: Medium attachment unit: FSK medium

### 34.1 Overview

The digital signaling protocol of this document uses 1 200 bit/s binary phase-continuous Frequency-Shift-Keying (FSK) to superimpose digital communications on to a 4 mA to 20 mA current loop. Devices signal by either modulating current or by supplying voltage; all signaling appears as voltage when sensed across low impedance. Phase-continuous frequency-shift-keying requires the phase angle of the mark (1 200 Hz = binary 1) and the space (2 200 Hz = binary 0) to remain continuous at the 1 200 Hz bit boundaries as shown in Figure 190.

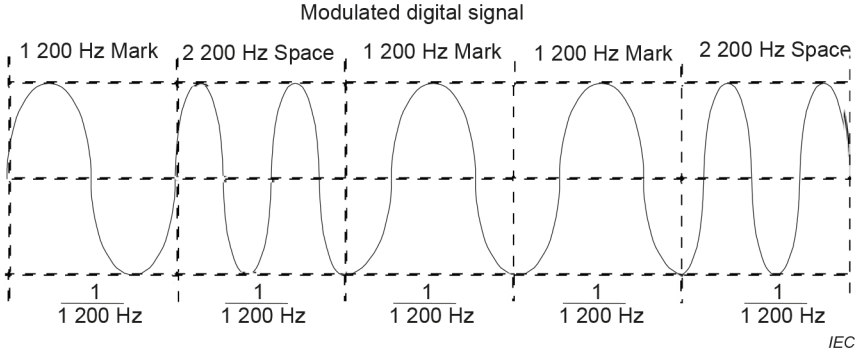


**Figure 190 – Phase-continuous Frequency-Shift-Keying**

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The device that modulates the current appears as high impedance across the medium and thus several such devices can be connected in parallel. The device that supplies the voltage signal has low series impedance. Many of the devices also use current to send or receive analog signal. The frequency and amplitude of the digital signal is such that it does not interfere with the analog signal. This document specifies the analog signal such that it does not interfere with digital signal. The device can also draw the power from the medium using analog signal.

This document also specifies devices that do not use analog or digital signal. Examples of such devices are power supply and barrier.

## 34.2 PhPDU

### 34.2.1 PhPDU structure

Figure 191 shows the structure of a PhPDU. The PhSDU is the sequence of Ph-user-data octets of PH-DATA primitive. The preamble is sequence of hexadecimal '0xFF' octets.

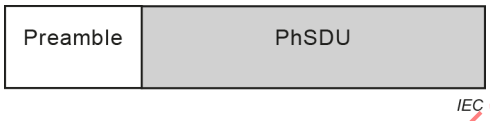


**Figure 191 – PhPDU Structure**

### 34.2.2 PhPDU transmission

#### 34.2.2.1 Character transmission

Upon receiving the PH-START request primitive, the PhE shall transmit at least five (5) and no more than twenty (20) preamble characters. The number of preamble characters is configurable parameter. After the transmission of the last preamble, the PhE shall provide PH-START confirm. The PhE shall transmit PhSDU octets as it is received from the PhS-user. Characters forming a PhPDU shall be transmitted in a single contiguous stream.

NOTE The 5 preamble characters allow sufficient time for asserting a carrier, training the modem circuit and for the listening device to begin receiving the PhPDU.

Although the maximum number of preamble octets is 20, the number of preamble octets affects system performance. In data acquisition applications, transmission of long preamble sequences can be detrimental. As a result, transmission of excessive preamble characters is strongly discouraged.

#### 34.2.2.2 Character format

Each character shall be transmitted asynchronously and consist of eleven bits. These are, in order of transmission, one start bit, eight data bits (least significant bit first), one odd parity bit, and one stop bit as shown in Figure 192. There shall be no more than one idle bit (i.e., additional stop bits) between consecutive characters. The consecutive characters in a PhPDU shall have intervening inter-character gap of less than one (1) character time.

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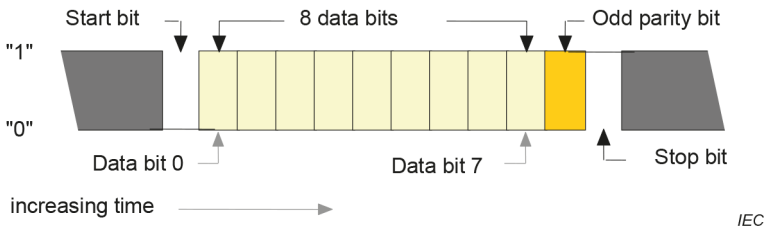


**Figure 192 – Character format**

NOTE At 1 200 bit/s, transmitting a character takes 9,167 ms. This time period is the character time for the FSK Physical Layer.

### 34.2.3 PhPDU reception

After detecting the carrier, the PhE receiver shall look for preamble characters and synchronize with the start and stop bits. After receiving two error-free preamble characters, it shall provide PH-START indication. It is equivalent to carrier detection.

During the reception of PhSDU characters, the receiver shall check for parity bit for correct value. If any error is detected the PhE shall provide PH-DATA indication with error status.

If the PhE detects the lack of medium activity then it shall provide PH-END indication primitive. The medium activity is inferred by a signal level higher than the noise rejection levels specified in 34.6 and Table 213.

If the gap between two received character is equal to or more than one (1) character time then the PhE shall provide PH-DATA indication with discontinuous data reception error status.

### 34.2.4 Preamble length

The length of preamble in a PhPDU from master to slave device is specified in DL-DATA-EXCHANGE request - see IEC 61158-3-20. The length of preamble in a PhPDU from slave to master device is set as a parameter as defined in IEC 61158-3-20.

## 34.3 Device types

### 34.3.1 General

The devices are classified based on following two criteria:

- Input or output impedance and
- Connection to the network.

All devices have parameters depending upon its type. These parameters are also defined in 34.3.2, 34.3.3 and 34.3.4.

### 34.3.2 Impedance type

#### 34.3.2.1 General

All devices are classified as one of the two types based on its input or output impedance in digital frequency band. Low impedance device has signaling element that is intended to receive analog current signal or serve as the master device for a multi-drop network. High impedance device controls the current as an analog signal or in a multi-drop network sets its analog signal at a fixed value.

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#### 34.3.2.2 Low impedance device

The low impedance device shall have an impedance of 230 Ω to 600 Ω in the digital frequency band. The variation of the impedance over the extended frequency band shall be within ± 3 dB of its value at the center of the digital frequency band.

NOTE 1 The impedance variation limit prevents excessive signal distortion.

NOTE 2 Any device that receives the analog current signal such as an analog input controller device or an actuator has low input impedance so that it is possible to use lower DC voltage to power the device that sends the analog current signal. It is impractical for devices of this type to have high impedance at digital frequency band.

NOTE 3 The device at the low end of the impedance range limits the use of parallel resistance connected to the network. The device at the high end of the impedance range limits the total cable capacitance.

#### 34.3.2.3 High impedance device

The high impedance device shall have an impedance of more than 600 Ω in the digital frequency band.

A high impedance device should be designed to have as high impedance as possible within other design constraints.

NOTE For multi-drop network application, the total impedance connected to the medium is parallel combination of input impedance of all devices connected to the medium.

### 34.3.3 Connection type

#### 34.3.3.1 General

A device shall be classified as having one of the following types of connection to the network:

a) Current input,
b) Current output,
c) Voltage input,
d) Voltage output,
e) Secondary,
f) Analog transmitter,
g) Actuator,
h) Non-DC isolated, or
i) DC isolated.

A device may exhibit characteristics of more than one of these connection types. The manufacturer should identify the connection types for which the device can be configured.

#### 34.3.3.2 Current input

A device that uses a resistor to measure the analog current signal is defined as device with current input connection. The current sense resistor can be either internal to the device or it can be attached externally. In either case, the sense resistor is considered as part of the device, and the impedance of a current input device shall be specified to include this resistor.

Current input devices can include the network power supply and provide DC power to the loop. If the device can use a range of sense resistance values, instead one fixed value, then the device parameters shall be specified as a function of the sensor resistor value.

NOTE Current input device have low impedance and are usually not isolated from the ground. The most common example of a current input device is the controller connection for an analog input loop (a loop with a common 4 mA to 20 mA transmitter as the field device).

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#### 34.3.3.3 Current output

A device that sources the current as analog signal is defined as device with current output connection. Current output device cany include the network power supply and provide DC power to the loop. Otherwise, it can be connected in series with an external power supply and only control the loop current.

NOTE Current output device has high impedance. Usually these devices are not isolated from the ground. Examples of current output devices are the controller connection for an analog output loop (a loop with a common 4 mA to 20 mA actuator or positioner as the field device) or a separately powered field device that sources current to the loop rather than sinking it from the loop.

#### 34.3.3.4 Voltage input

A device that measures the voltage input signal is defined as device with voltage input connection. A device of this type shall have high input impedance. Voltage input device does not provide DC power to the loop, and can be isolated from ground, or not.

NOTE High input impedance is required so that the resistance in the cable loop does not introduce an error in the voltage signal. Examples of voltage input device are the controller connection for an analog input loop where the analog signal is voltage (e.g., from a voltage output transmitter) or a separately powered output device that accepts voltage as its analog input signal rather than current.

#### 34.3.3.5 Voltage output

A device that sources the voltage output signal is defined as device with voltage output connection. A device of this type shall have low impedance in digital frequency band. Voltage output device does not provide DC power to the loop, and can be isolated from ground, or not.

NOTE Low output impedance is required so that the resistance in the cable loop does not introduce an error in the voltage signal. The most common example of voltage output device is a 3-wire voltage output transmitter. Another example is a controller designed to drive a separately powered field device. A network with analog voltage signaling cannot carry DC power since this causes voltage drop in loop wiring and an unacceptable error in the analog signal.

#### 34.3.3.6 Secondary

A device that has a removable connection, is not required for communication on the network and is connected only on a temporary basis is defined as secondary device. Secondary device shall have high impedance and be DC isolated from the current loop.

The network analysis for maximum wire length should include the secondary device.

NOTE The most common example of a secondary device is the handheld terminal.

#### 34.3.3.7 Analog transmitter

A device that draws DC current from the loop and varies the amount of current drawn as a means of analog signaling is defined as analog transmitter. The device may use the DC current as the power source or it may be separately powered.

NOTE Analog transmitter has high impedance and it is usually DC isolated from the ground. Examples of analog transmitter type are 2-wire transmitters or separately powered transmitters with loop interface that draw DC from the loop.

#### 34.3.3.8 Actuator

A device that draws DC current from the loop at a value determined by the current sourcing device is defined as actuator. The device may use the DC current as the power source or it may be separately powered.

NOTE Actuator has low impedance and it is usually DC isolated from the ground. The most common examples of actuators are 2-wire devices that receive an analog signal via 4 mA to 20 mA loop current supplied by a controller.

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#### 34.3.3.9 Non DC isolated

A device that draws constant value of DC current from the loop and does not use analog signal is defined as non DC isolated device. The device may use the DC current as the power source or it may be separately powered. It uses digital signal for communication.

NOTE Non DC isolated device has high impedance and it is usually DC isolated from the ground. The most common example of this type of device is a 2-wire transmitter when in a fixed current mode.

#### 34.3.3.10 DC isolated

A device that does not draw DC current from the loop and does not use analog signal is defined as non DC isolated device. The device is separately powered. It uses digital signal for communication.

NOTE DC isolated device has high impedance. It is possible that DC isolated bus devices exist on any loop, including loops with analog signaling, since it does affect the analog signal. A network is possibly constructed with all devices of this type, that is, loops with no DC current flowing at all.

### 34.3.4 Device parameters

One or more parameters defined in this Table 211 apply to a device based on its impedance and connection type.

**Table 211 – Device parameters**

| Device type | Parameter |
|---|---|
| DC isolated from the ground | Minimum $R_{tt}$ and maximum $C_{tt}$ under worst-case conditions of an unbalanced network |
| Non DC isolated from the ground | Minimum $R_{tt}$ and maximum $C_{tt}$ as normally connected and a description of the ground reference |
| Device that draws DC current from the loop | The amount of current drawn and the minimum voltage at the device terminal that is required for the device to operate |
| Device that sources DC current to the loop | The minimum and maximum values of the sourced current and the voltage, and the maximum load voltage at which the device can operate |
| Device that produces analog signal | The minimum and maximum values of the sourced current and the minimum voltage at the device terminal that is required for the device to operate |
| Low impedance device | Minimum and maximum impedance magnitudes in the digital frequency band |

The values of the applicable parameters shall be specified by the device manufacturer.

## 34.4 Network configuration rules

A device shall conform to the requirements of this document when used in a network which comply with these rules.

Rule 1: The network has at least one low impedance device. The combined parallel impedance of all connected devices shall be in the range of 170 Ω to 600 Ω.

NOTE 1 The network possibly has more than one low impedance device as long as the total parallel impedance is in the range specified above.

Rule 2: The network has only one analog signaling device.

NOTE 2 More than one analog signaling device in one network causes the two analog signals to interfere and thus make it ineffective.

Rule 3: One secondary device is connected to the network.

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Rule 4: A point-to-point network with one primary master.

Rule 5: The cable for a point-to-point network has capacitance of 150 pF per meter, resistance of 0,05 Ω per meter, the length of 1 200 m and total device capacitance - $C_{dev}$ of all devices 5 000 pF.

NOTE 3 The cable length is the requirement for the conformance test but it does not preclude the use of longer lengths in an installed network.

Rule 6: The device specified for multi-drop network connected to a network with 16 devices

NOTE 4 This limit was derived by the noise calculations. This rule does not preclude the use of more than the specified number of devices in an installed network. The maximum number of devices connected to one network depends upon the cable length, noise environment and availability of the required DC power at the device terminal.

Rule 7: The cable for a multi-drop network has capacitance of 400 pF per meter, resistance of 0,0368 Ω per meter, the length of 500 m and total device capacitance - $C_{dev}$ of all devices 25 000 pF.

NOTE 5 The cable length is the requirement for the conformance test but is does not preclude the use of longer lengths in an installed network.

The network configuration rules are for the conformance test of a device. The network can be installed with various topologies. Clause T.1 shows some of these topologies.

The guidelines for cable lengths are given in Clause T.2.

### 34.5 Digital transmitter specification

#### 34.5.1 Test configuration

Figure 193 shows the configuration that shall be used for testing. Figure 193 (a), 'Analog transmitter' is an example of device under test. In Figure 193 (b) either 'Current output' or 'Actuator' can be the device under test. For device under test of the other types defined in 34.3.3, the test configuration shall be similar. All devices shall be tested using this test configuration and digital transmitter parameters shall be measured across the test load.

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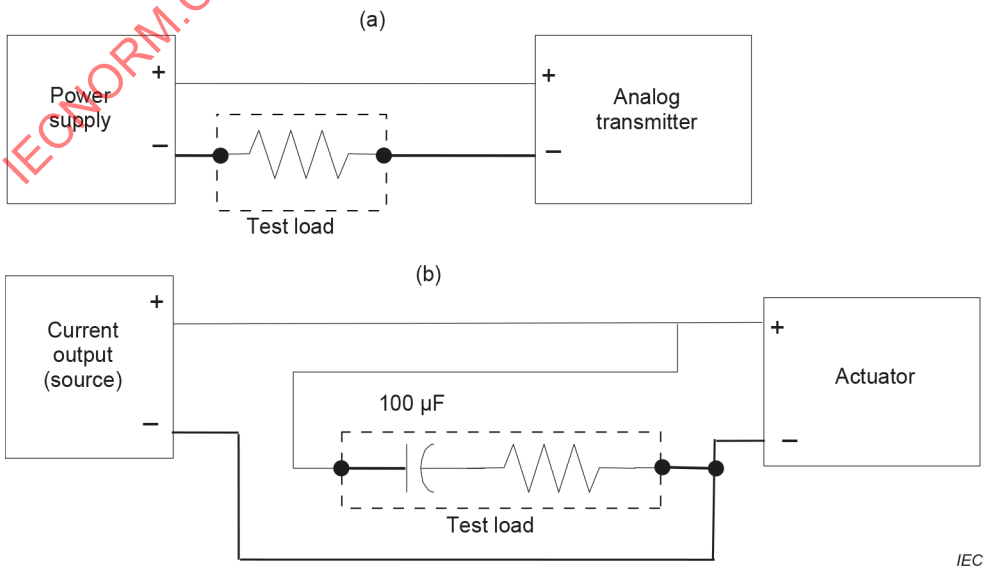


**Figure 193 – Transmit test configuration**

In some cases, it is necessary to prevent DC current flow through the test load. When this is necessary, a 100 microfarad DC blocking capacitor should be placed in series with test load as shown in Figure 193 (b).

In the case of analog signaling device such as analog transmitter or current output device, the test load can also serve as the current sense impedance.

The value of the resistance part of the test load shall be:

- 1 000 Ω for low impedance device, and
- 500 Ω for high impedance device.

### 34.5.2 Bit rate and modulation

The bit rate shall be 1 200 bit/s with a tolerance of ± 1 %. The device shall either modulate the current drawn or apply the voltage on the medium. All signals appear as voltage when sensed across a low impedance load. The modulation technique shall be phase-continuous frequency-shift-keying i.e. the phase angle of the Mark and the Space shall remain continuous at the bit boundaries. The frequency for the Mark (logic 1) shall be 1 200 Hz with a tolerance of ± 1 %; the frequency for the Space (logic 0) shall be 2 200 Hz with a tolerance of ± 1 %.

### 34.5.3 Amplitude

Figure 194 shows an example of the AC component of one cycle of the Mark and Space waveforms, illustrating some key items from the transmit circuit specification. Only signal voltages are shown; this diagram takes no account of power supply voltages. The transmit amplitude limits are summarized in Table 212.

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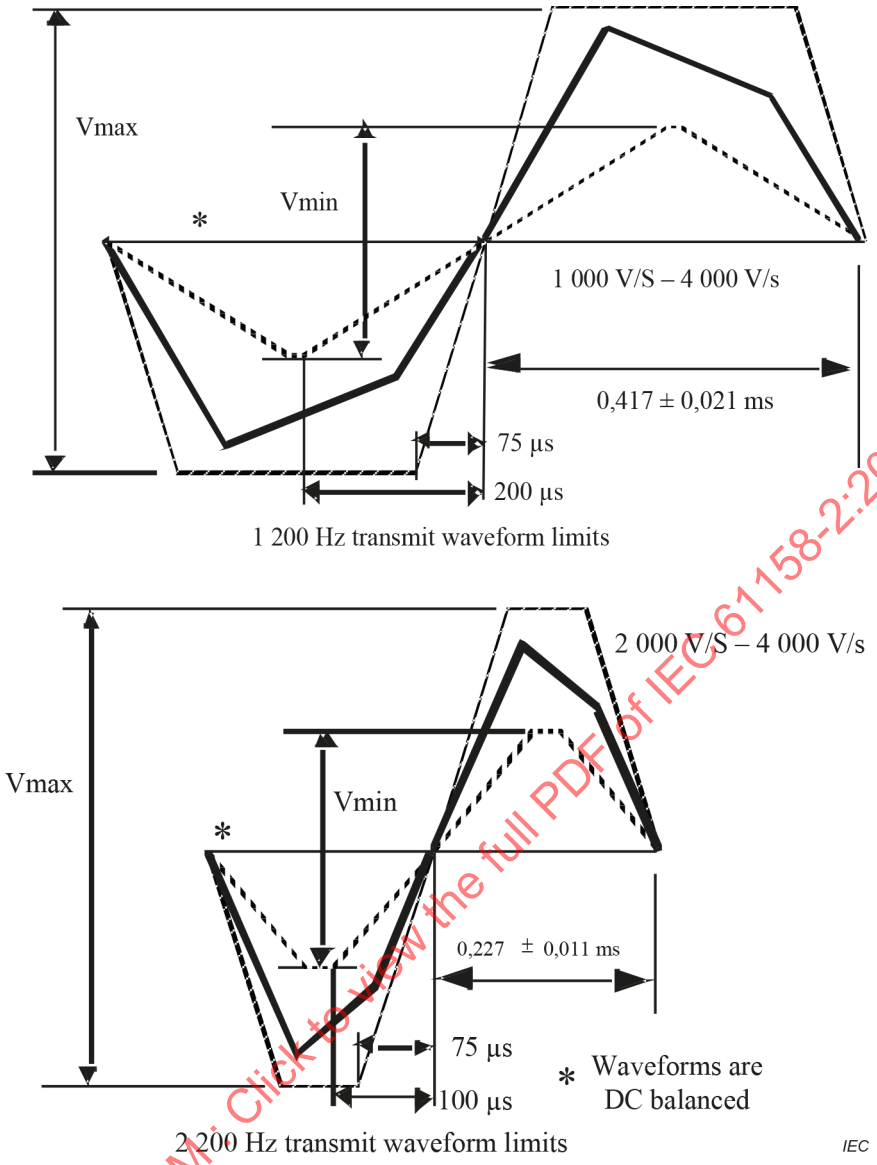


**Figure 194 – Transmit waveform**

**Table 212 – Transmit amplitude limits**

| Device impedance | Vmin - minimum peak-to-peak level | Vmax - maximum peak-to-peak level | Test load |
|---|---|---|---|
| Low | 400 mV | 800 mV | 1 000 Ω with a tolerance of ± 1 % |
| High | 400 mV | 600 mV (see text) | 500 Ω with a tolerance of ± 1 % |

The output voltage of a low impedance device shall be between 400 mV and 800 mV peak-to-peak, with a load resistance of 1 000 Ω with a tolerance of ± 1 %.

The output voltage of a high impedance device shall be

a) Either, between 400 mV and 600 mV peak-to-peak, with a load resistance of 500 Ω with a tolerance of ± 1 %,

b) or between 400 mV and 800 mV peak-to-peak, with a load resistance of 500 Ω with a tolerance of ± 1 % and less than or equal to 800 mV peak-to-peak with a load resistance of 1 000 Ω with a tolerance of ± 1 %.

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### 34.5.4 Timing

As shown in Figure 194 the transmit waveform of a device shall conform to the following timing.

a) The rise and fall times measured from one peak to the next peak shall be more than or equal to 150 µs.

b) The rise and fall times measured from one peak to the next peak for Mark shall be less than or equal to 400 µs.

c) The rise and fall times measured from one peak to the next peak for Space shall be less than or equal to 200 µs.

d) The slew rate for Mark shall be between 1 000 V/s and 4 000 V/s.

e) The slew rate for Space shall be between 2 000 V/s and 4 000 V/s.

As shown in Figure 195, Figure 196 and Figure 197 the carrier shall conform to the following timing.

f) Carrier start time

The transmit circuit shall turn on, i.e. the signal shall rise from quiescent level to the minimum required transmit level specified in 34.5.3, in less than five (5) nominal bit times.

g) Carrier stop time

After having transmitted the last bit, the transmit circuit shall turn off, i.e. the signal shall fall below the minimum required receive level specified in 34.6, in less than three (3) nominal bit times.

NOTE 1 The minimum required receive level is 120 mV peak to peak.

h) Carrier decay time

After having transmitted the last bit, the transmit circuit shall turn off and the signal shall fall below the maximum acceptable noise level specified in 34.6, in less than six (6) nominal bit times.

The maximum acceptable noise level is 80 mV peak to peak.

NOTE 2 The carrier start, stop and decay time specifications are such that it keeps the interference to analog signal at an acceptable level. These timings are such that when the digital signal waveform, using a 250 Ω test load, is passed through a 2-pole 25 Hz low-pass Butterworth filter, the output of the filter does not exceed 10 mV at any time. The amplitude response of this filter is same as analog signal spectrum specified in 34.7.1.

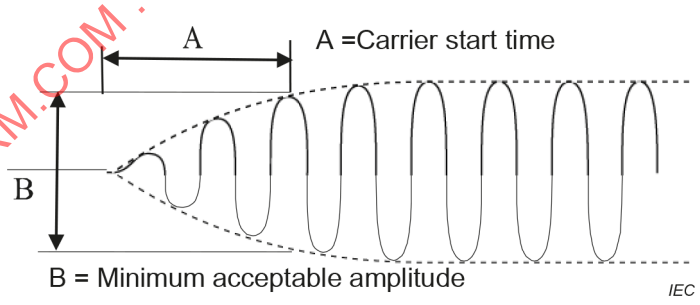


**Figure 195 – Carrier start time**

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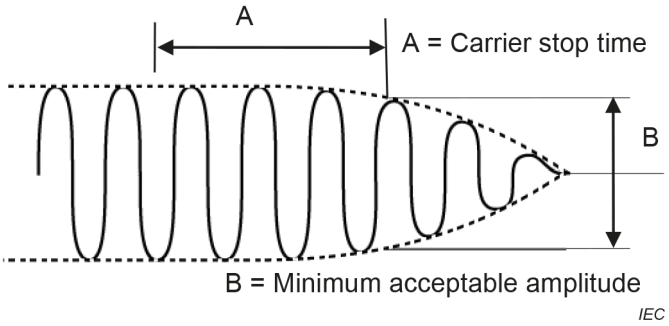


**Figure 196 – Carrier stop time**

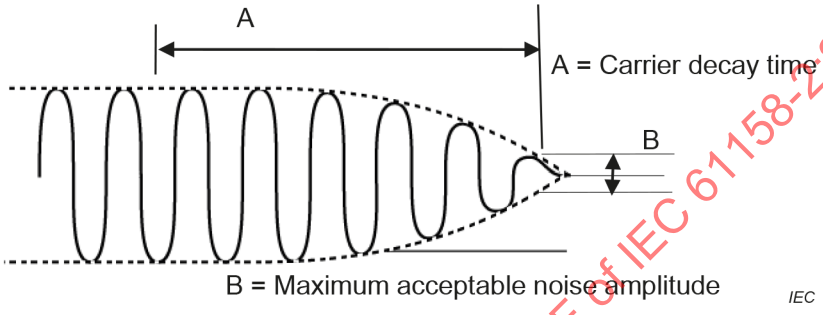


**Figure 197 – Carrier decay time**

### 34.5.5 Digital signal spectrum

The digital signaling spectrum is defined as the frequencies from 500 Hz to 10 kHz as defined in 3.12.13 and shown in Figure 198. It decreases at a rate of 40 dB per decade below 500 Hz and 20 dB per decade above 10 kHz.

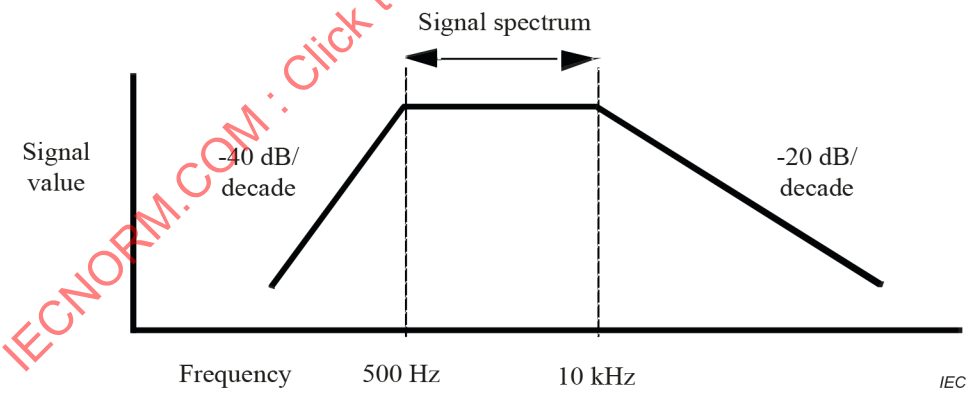


**Figure 198 – Digital signal spectrum**

NOTE There is no conformance test for the digital signal spectrum. If the device conforms to the timing specified in 34.5.4, then the spectrum is expected to be as shown.

### 34.6 Digital receiver specification

The digital receiver specifications are summarized in Table 213. Figure 199 shows the requirements for the interference tolerance.

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**Table 213 – Digital receiver specifications**

| Receiver circuit parameter | Test condition | Limits |
|---|---|---|
| Sensitivity - minimum peak-to-peak signal required to be accepted | | 120 mV |
| Noise rejection - maximum peak-to-peak signal required to be rejected | | 80 mV |
| Maximum peak-to-peak signal required to be accepted | High impedance device under test | 1 500 mV |
| Maximum peak-to-peak signal required to be accepted | Low impedance device under test | 800 mV |
| Maximum error rate | Signal level 200 mV peak-to-peak, added Gaussian noise of constant density of 163 microvolt/root Hz over the extended frequency band, pseudo-random bit sequence | 1 in 10 000 bits |
| In-band common mode interference with no degradation in receiver performance - see Note | Extended Frequency Band i. e. 500 Hz to 10 kHz | 200 mV peak-to-peak |
| In-band normal mode interference with no degradation in receiver performance | Extended Frequency Band i. e. 500 Hz to 10 kHz | 55 mV peak-to-peak |
| Below-band common mode interference with no degradation in receiver performance - see Note | 47 Hz to 500 Hz | 2 V peak-to-peak |
| Out-of-band normal mode interference with no degradation in receiver performance | 0 Hz to 500 Hz<br>10 kHz to 1 MHz | See Figure 199 |
| NOTE The common mode requirements apply only to those devices that have all inputs floating with respect to the ground. | | |

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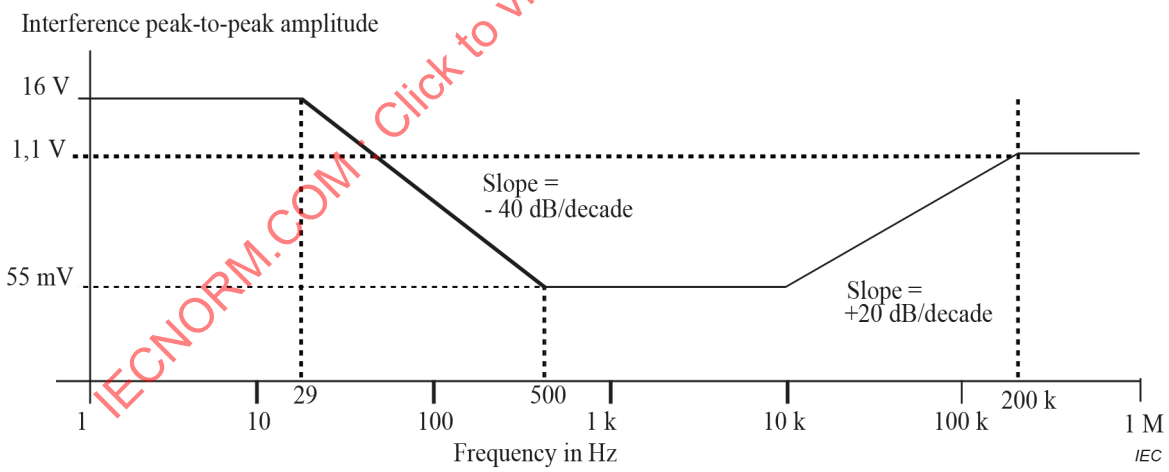


**Figure 199 – Digital receiver interference**

The receive circuit shall be capable of accepting an input signal of amplitude no less than 120 mV peak-to-peak, including overvoltage and oscillation. The receive circuit shall not respond to an input signal with a peak-to-peak amplitude which does not exceed 80 mV. The receiver shall operate without error, with following peak-to-peak input signal level:

- 1 500 mV at the input of the high impedance device,
- 800 mV at the input of the low impedance device.

The receiver shall operate with no degradation in its performance (no more than 1 error in 10 000 bits) in the presence of common mode voltage or interference as follows:

a) a common mode sinusoidal signal of any frequency from 500 Hz to 10 kHz with an amplitude of 200 mV peak-to-peak;

b) a normal mode sinusoidal signal of any frequency from 500 Hz to 10 kHz with an amplitude of 55 mV peak-to-peak;

c) a common mode sinusoidal signal of any frequency from 47 Hz to 500 Hz with an amplitude of 2 V peak-to-peak;

d) a normal mode sinusoidal signal interference of any frequency below 29 Hz with an amplitude of 16 V peak-to-peak;

e) and specified for few frequencies below:

- at 63 Hz, 3,52 V peak-to-peak,
- at 125 Hz, 880 mV peak-to-peak,
- at 250 Hz, 220 mV peak-to-peak.

NOTE The interference due to analog signal for low impedance device is impedance × 16 mA. The maximum value of this impedance is 600 Ω. Thus, maximum interference due to analog signal over zero to 25 Hz is 9,6 V.

The receiver with input signal of 200 mV peak-to-peak and pseudo-random bit sequence shall produce no more than 1 detected frame errors in 10 000 bits during operation in the presence of Gaussian noise of constant density of 163 microvolt/root Hz over the extended frequency band.

### 34.7 Analog signaling

#### 34.7.1 Analog signal spectrum

The analog signal spectrum is defined as the frequencies from DC to 25 Hz decreasing at a rate of 40 dB per decade above 25 Hz.

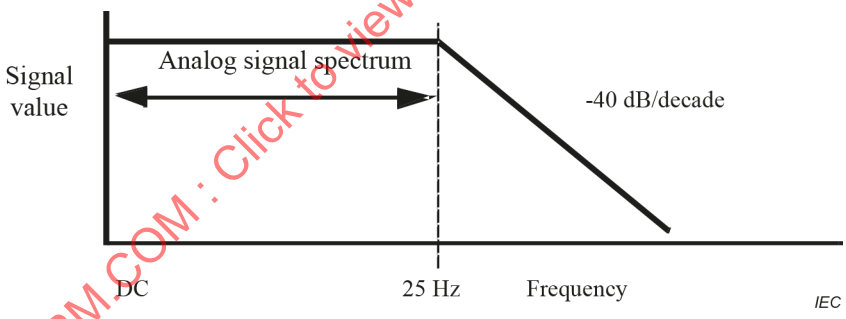


**Figure 200 – Analog signal spectrum**

The device that produces analog signal shall comply with the frequency spectrum shown in Figure 200.

NOTE This specification does not define analog signal type and signal values, but it defines the frequency spectrum. This is done so that analog signal does not interfere with digital signal defined in this specification. The analog signal is current or voltage output.

#### 34.7.2 Interference to digital signal

The analog signal changes shall be such that when analog signal is applied to 500 Ω with a tolerance of ± 1 % load for a high impedance device, or 1 000 Ω with a tolerance of ± 1 % load for a low impedance device, and filtered through the digital test filter the instantaneous peak voltage at the filter output shall be less than or equal to 15 mV.

The digital test filter is a Butterworth bandpass filter with a pass band of 500 Hz to 10 kHz, 2nd order roll-off below 500 Hz, and 1st order roll-off above 10 kHz.

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NOTE 1 This specification is such that the analog output signal generated by an analog signaling device (i.e., analog transmitter or current output device) does not interfere with the digital signal.

NOTE 2 The digital test filter has the same amplitude response as the digital signal spectrum specified in 34.5.5.

The analog input devices, such as current inputs and actuators should filter the analog signal with a low-pass filter within the analog signaling spectrum defined above, to avoid interference from the digital signal.

### 34.8 Device impedance

#### 34.8.1 High impedance device

The high impedance device should have impedance as high as possible. The recommended values measured over the digital frequency band are shown in Table 214. The bus powered and self-powered device should have the recommended high impedance.

**Table 214 – High impedance device characteristics**

| Parameter | Test condition | Value |
|---|---|---|
| Equivalent device capacitance - $C_{dev}$ | Not transmitting | 5 000 pF max |
| Equivalent device resistance - $R_{dev}$ | Not transmitting | 100 kΩ min. |

The polarized devices shall exhibit the same or larger high impedance when connected across the voltage of reverse polarity as when it is connected with the correct polarity voltage. The self-powered device shall exhibit the same or larger high impedance when not powered as when it is powered.

#### 34.8.2 Low impedance device

The low impedance device shall have impedance as shown in Table 215.

**Table 215 – Low impedance device characteristics**

| Parameter | Test condition | Limits |
|---|---|---|
| Terminal to terminal impedance - $Z_{tt}$ | Not transmitting | 230 Ω to 600 Ω |
| Terminal to terminal impedance - $Z_{tt}$ | Transmitting | 230 Ω to 600 Ω |

The terminal-to-terminal impedance, not including the current sense resistor in the device, measured over the digital frequency band shall be:

- in the range of 230 Ω to 600 Ω when not transmitting,
- the impedance over the extended frequency band, within ± 3 db of the value measured over the digital frequency band,
- in the range of 230 Ω to 600 Ω when transmitting and less than or equal to the value measured when not transmitting.

The impedance shall be measured without using the test load as specified in 34.5.3.

#### 34.8.3 Secondary device

The secondary device shall have impedance as shown in Table 216.

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**Table 216 – Secondary device characteristics**

| Parameter | Test condition | Limits |
|---|---|---|
| Terminal to terminal impedance - $Z_{tt}$ | Not transmitting | 5 kΩ min. |
| Terminal to terminal resistance - $R_{tt}$ | Transmitting | See text below |
| Terminal to ground capacitance - $C_{tg}$ | All conditions | 250 pF max. |
| Terminal to ground resistance - $R_{tg}$ | | 100 kΩ min. |

The terminal-to-terminal impedance of the secondary device measured over the digital frequency band shall be:

- when not transmitting, a minimum of 5 kΩ,
- when transmitting, less than or equal to the value measured when not transmitting.

The terminal to ground capacitance of the secondary device measured over the digital frequency band shall be less than or equal to 250 pF.

The terminal to ground resistance of the secondary device measured over the digital frequency band shall be more than or equal to 100 kΩ.

The polarized devices shall exhibit the same or larger high impedance when connected across the voltage of reverse polarity as when it is connected with the correct polarity voltage.

### 34.9 Interference to analog and digital signals

#### 34.9.1 Connection or disconnection of secondary device

When a secondary device is connected to the network or disconnected from the network, the transients on the medium shall be such that

- the peak value is less than or equal to 160 uA (1 % of the span) analog signal current averaged over 10 ms,
- interference to digital signal shall comply with the requirements of 34.7.2.

#### 34.9.2 Cyclic connection

When a low impedance is connected to the network or disconnected from the network, the transients on the medium shall be such that

- the peak value is less than or equal to 160 uA (1 % of the span) analog signal current averaged over 10 ms,
- interference to digital signal shall comply with the requirements of 34.7.2.

#### 34.9.3 Output during silence

During silence the device output voltage, averaged over 1 s or more, shall contain less than 2,2 mV RMS of combined broadband and correlated noise in the extended frequency band as shown below in Figure 201. For devices capable of analog signaling, the requirement shall apply while it is adjusted to produce a constant analog output current.

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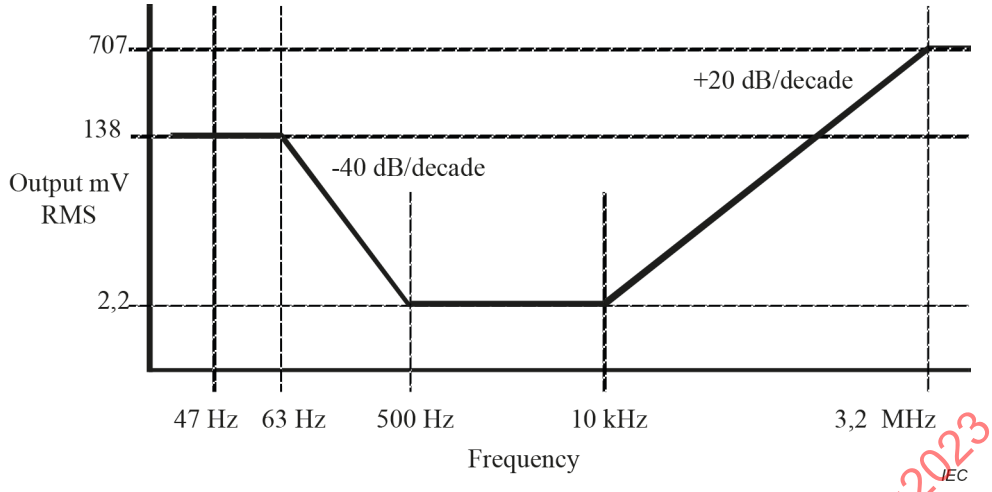


**Figure 201 – Output during silence**

NOTE The peak-to-peak sinusoidal noise is equal to 2,8 × RMS value. The peak-to-peak white noise is approximately equal to 6 × RMS value.

### 34.10 Non-communicating devices

#### 34.10.1 Network power supply

The network power supply provides DC power to the network. If the supply is intended to be used with external fuses or external current limit resistances, the supply shall be tested with these external components. The network power supply requirements are stated in Table 217 and Figure 202.

**Table 217 – Network power supply characteristics**

| Parameter | Test condition | Limits |
|---|---|---|
| Ripple | 47 Hz to 63 Hz at all rated loads | 138 mV RMS max. |
| Ripple | 94 Hz to 126 Hz at all rated loads | 35 mV RMS max. |
| Noise | Extended frequency band at all rated loads | 2,2 mV RMS max. |
| Noise | Outside of extended frequency band at all rated loads | See Figure 202 |
| Impedance magnitude | Extended frequency band at all rated loads | 10 Ω max. |

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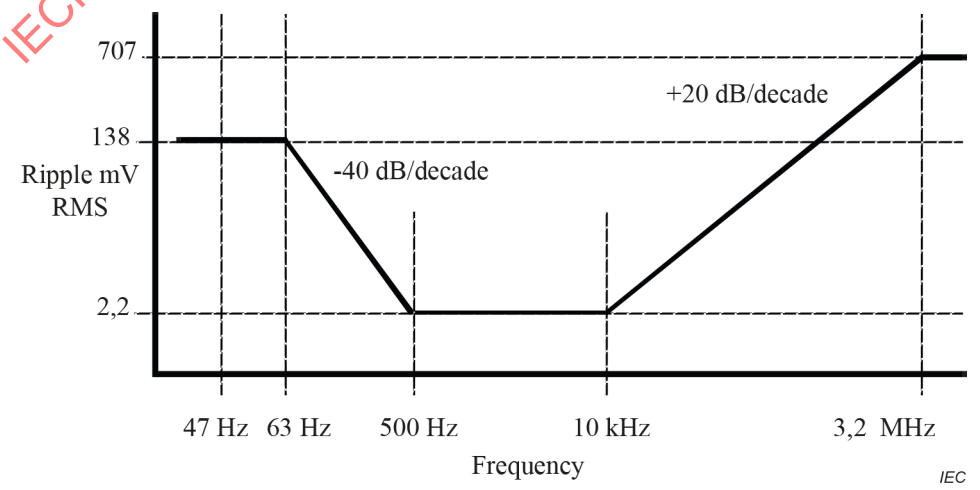


**Figure 202 – Network power supply ripple**

NOTE The peak-to-peak sinusoidal noise is equal to 2,8 × RMS value. The peak-to-peak white noise is approximately equal to 6 × RMS value.

For intrinsically safe applications, the network power supply voltage and barrier should be selected and operated such that an AC voltage of up to 1,4 V peak-to-peak can be superimposed onto the DC at the hazardous (network) side of the barrier.

The connection of network power supply is shown in Figure T.28. The grounding and shielding recommendations are shown in Clause T.4.

### 34.10.2 Barrier

Barrier is characterized by its impedance, the attenuation and delay distortion of the digital signal as it passes through the barrier.

Intrinsic safety barrier output impedance shall be defined in terms of its frequency dependent characteristics when connected in the test circuits of Figure 203, Figure 204 and Figure 205. The real part of the measured impedance shall be between 230 Ω and 600 Ω. The imaginary part of the measured impedance shall be between −350 Ω and 350 Ω. The test frequencies shall be:

- 200 Hz, 500 Hz, 950 Hz, 1,6 kHz, 2,5 kHz, 5,0 kHz and 10,0 kHz for the barriers specified to be used with the low impedance device.
- 500 Hz, 950 Hz, 1,6 kHz, 2,5 kHz, 5,0 kHz, 10,0 kHz, 20 kHz and 50 kHz for the barriers specified to be used with the high impedance device.

The attenuation and delay distortion of digital signal shall also be measured when connected in test circuits of Figure 203, Figure 204 and Figure 205. The requirements are summarized in Table 218.

**Table 218 – Barrier characteristics**

| Parameter | Test condition | Limits |
|---|---|---|
| Output voltage from hazardous side to safe side | Figure 203, test frequencies | 185 mVpp min.<br>800 mVpp max. |
| Output voltage from hazardous side to safe side | Figure 204, test frequencies | 135 mVpp min.<br>400 mVpp max. |
| Output voltage from safe side to hazardous side | Figure 205, test frequencies | 270 mVpp min.<br>400 mVpp max. |
| Delay distortion | Digital frequency band | 50 µs max. |

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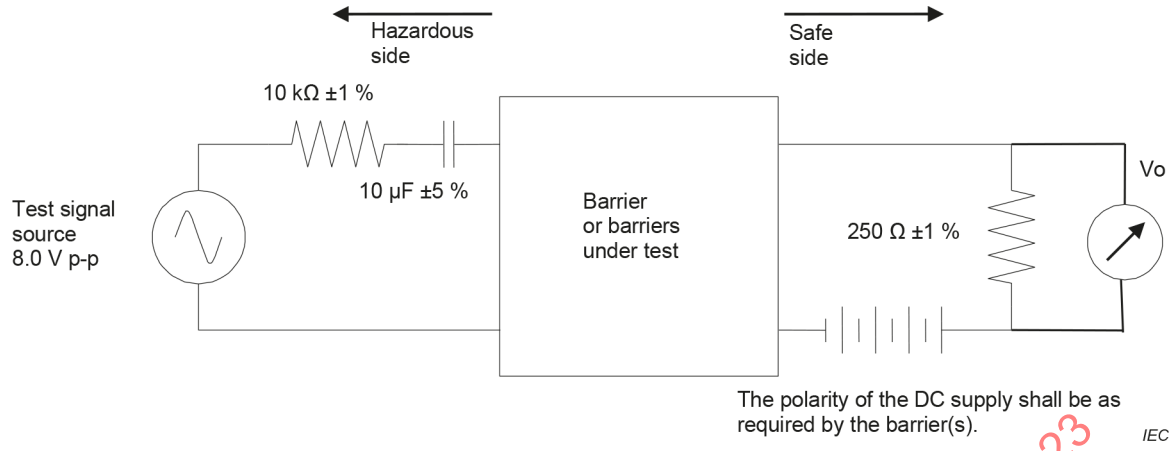


**Figure 203 – Barrier test circuit A**

For the test shown in Figure 203, the test signal source shall be set to 8,0 V peak to peak on the hazardous side and the output shall be measured across the 250 Ω ±1 % resistor on the safe side. The output voltage shall be between 185 mV and 800 mV peak-to-peak at the test frequencies.

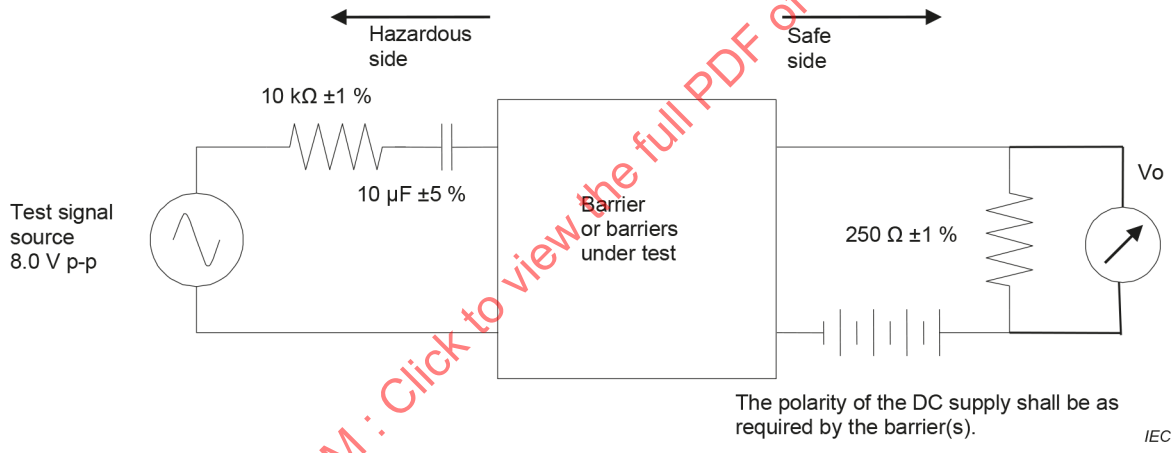


**Figure 204 – Barrier test circuit B**

For the test shown in Figure 204, the test signal source shall be set to 0,4 V peak-to-peak on the hazardous side and the output shall be measured across the 250 Ω ±1 % resistor on the safe side. The output voltage shall be between 135 mV and 400 mV peak-to-peak at the test frequencies.

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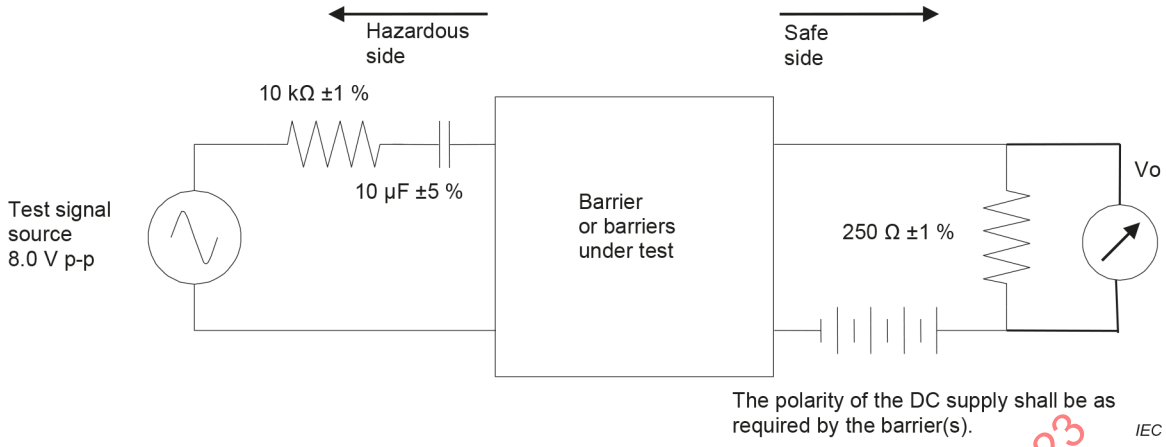


**Figure 205 – Barrier test circuit C**

For the test shown in Figure 205, the test signal source shall be set to 0,4 V peak-to-peak on the safe side and the output shall be measured across the 0,13 µF ±5 % capacitor on the hazardous side. The output voltage shall be between 270 mV and 400 mV peak-to-peak at the test frequencies.

The connection of network power supply and barriers is shown in Figure T.28.

### 34.10.3 Miscellaneous hardware

Miscellaneous hardware is connected in series with a field device or in parallel with field devices according to its function. Miscellaneous hardware shall not be connected in series with a network power supply such that it becomes a common element to two or more networks which share the same power supply. Miscellaneous hardware shall not be connected between the network and the ground. The requirements are summarized in Table 219. Some of the characteristics as shown in Table 220 are the recommended values, but not required for conformance to this document.

NOTE 1 The recommended parameter limits are specified, so that the networks can be implemented using longer cable lengths.

**Table 219 – Miscellaneous hardware required characteristics**

| Parameter | Test condition | Limits |
|---|---|---|
| Resistance to ground | Extended frequency band | 100 kΩ min. |
| Impedance rate of change of series connected hardware | Extended frequency band | ±5 Ω per ms max. |
| Impedance rate of change of parallel connected hardware | Extended frequency band | ±5 kΩ per ms max. |
| Broadband or correlated noise or interference | Extended frequency band, 500 Ω load | 2,2 mV RMS max. averaged over 1 s or more |

NOTE 2 It is possible that a network accommodates more than one component of miscellaneous hardware provided that the electrical characteristics of the combined devices are within the limits given in Table 220.

The miscellaneous hardware shall be tested for impedance in the extended frequency band. Its resistance to the ground shall be at least 100 kΩ. If the hardware is intended to be connected in series with a field device, then its impedance should be less than or equal to 100 Ω and its impedance rate of change shall be less than or equal to ±5 Ω per ms. If the hardware is intended to be connected in parallel with field devices, then its impedance should be more than or equal to 10 kΩ and its impedance rate of change shall be less than or equal to ±5 kΩ per ms. The capacitance to the ground should be less than or equal to 1 000 pF. The broadband or

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correlated noise or interference shall be less than or equal to 2,2 mV RMS with 500 Ω load, when averaged over 1 s or more.

**Table 220 – Miscellaneous hardware recommended characteristics**

| Parameter | Test condition | Limits |
|---|---|---|
| Capacitance to ground | Extended frequency band | 1 000 pF max. |
| Impedance of series connected hardware | Extended frequency band | 100 Ω max. |
| Impedance of parallel connected hardware | Extended frequency band | 10 kΩ min. |

## 35 Type 28: Twisted-pair wire and coaxial media

### 35.1 Overview

PhL MAU provides access to the communication network, and the devices connected to the network communicate over the medium. The network communication medium is usually composed of a pair of twisted-pair wires or a coaxial cable that supports bus and ring topologies. Devices are connected to the network through the medium. A network contains a backbone cable that requires terminal resistor at both ends of the backbone to eliminate the signal reflection.

### 35.2 Network Topology

Type 28 supports bus and ring topologies. Figure 206 shows the network topology. One Type 28 network supports 254 nodes.

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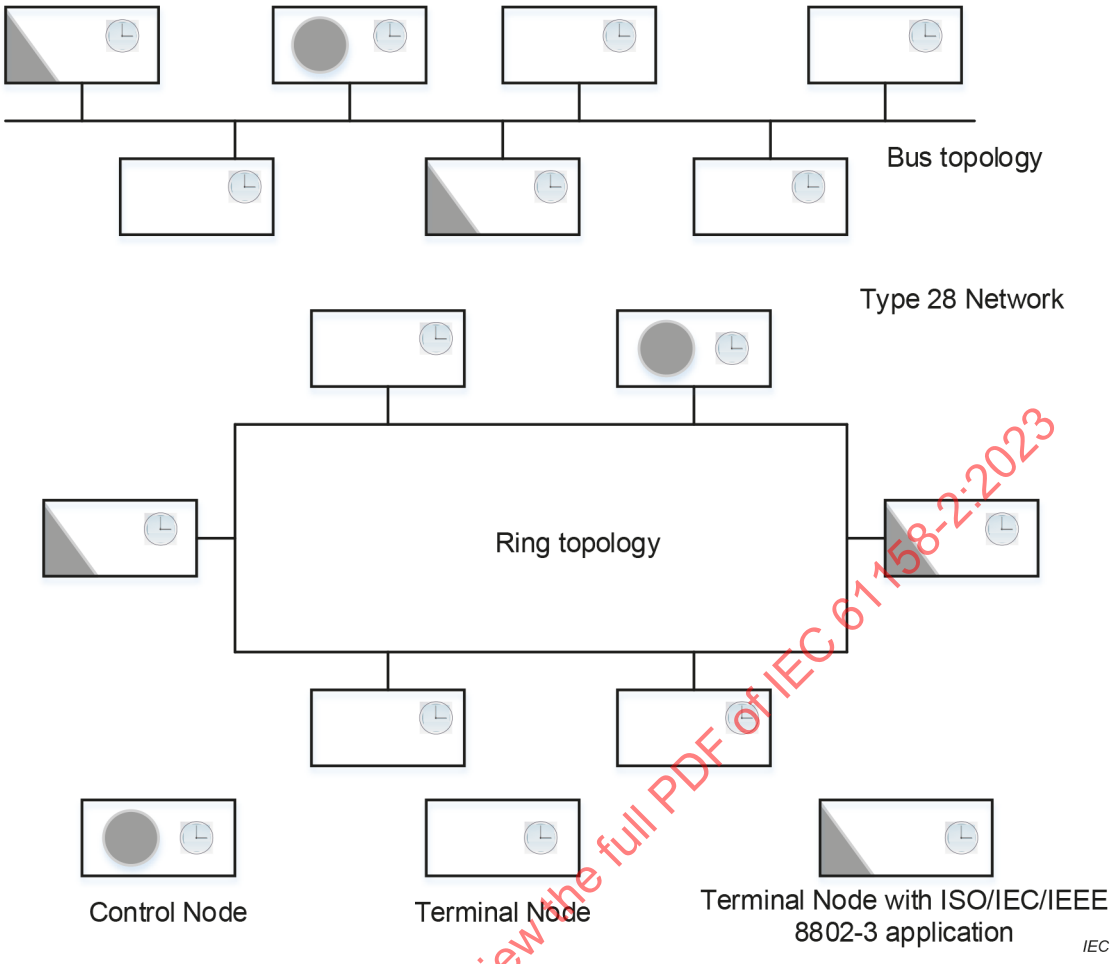


**Figure 206 – Network topology of Type 28**

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### 35.3 Electrical specifications

Receiver signal voltage: ≤ 20 Vpp.

Transmitter signal voltage: ≤ 20 Vpp.

Clock jitter range: ≤ 10 ns.

Time synchronization accuracy: ≤ 100 ns.

Electrical isolation characteristics: transformer coupling.

### 35.4 Transmission Medium Interface

The input and output interfaces contain the same 2 signal lines to connect to the network. This pair of signal lines is in differential mode. Table 221 shows the interface signal definition.

**Table 221 – Transmission medium interface**

| Short name | Name |
|---|---|
| IO | Tx/Rx + |
| /IO | Tx/Rx − |

The minimum requirements for the physical transmission medium interface are defined as follows:

Number of pins: 2

Power supply characteristics: 12 VDC to 36 VDC

Connector: 50 Ω to 100 Ω

Couplers: capacitance coupling, transformer coupling

Isolator: photoelectric isolation or safety barrier is required on individual occasions

Working temperature: −40 °C to 150 °C

Carrier bandwidth: 1,536 MHz to 32,256 MHz

Transmit power: 10 dBmW to 20 dBmW

Receive power: −82 dBmW to 0 dBmW

Sensitivity: −82 dBmW (min)

### 35.5 Medium

#### 35.5.1 Cable

##### 35.5.1.1 General

A fully shielded single pair of twisted-pair cables is preferred. As long as all devices share shielding or grounding at one end of the cable (typically at the end of the control room) and all shielding are connected to this ground, the cable is combined in a given network. Unshielded cables can be used only if the ambient noise is given and crosstalk are sufficiently low to ensure BER within threshold value.

The signal coding mode is OFDM (constellation mapping from 16QAM to 256QAM), and the polarity of the signal is a differential balanced twisted pair with no polarity.

The preferred minimum wire size is 0,511 mm diameter (24 AWG).

##### 35.5.1.2 Twisted pair

A twisted-pair medium that complies with the PhL medium specification for connecting or testing fieldbus devices should meet the following minimum requirements:

Impedance: 100 Ω to 120 Ω

Capacitance: < 50 pF/m

Velocity factor: > 60 %

Frequency band: > 50 MHz

Attenuation: 30 dB/100 m @ 100 MHz

Temperature: −40 °C to 150 °C

Withstand voltage: 500 VMS

Insulation voltage: 36 VDC

Maximum current: ≥ 500 mA

##### 35.5.1.3 Coaxial cable

Coaxial cable medium that comply with the PhL medium specification for connecting and testing fieldbus devices should meet the following minimum requirements:

Impedance: 50 Ω

Capacitance: < 100 pF/m

Velocity factor: > 70 %

Frequency band: > 50 MHz

Attenuation: 30 dB/100 m @ 100 MHz

Temperature: −40 °C to 150 °C

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Withstand voltage: 500 VMS

Insulation voltage: 36 VDC

Maximum current: ≥ 500 mA

### 35.5.2 Connector

A network is formed by connecting multiple devices using cables. Each device connects to cable medium with the help of connector to implement the communication with other devices. The number of nodes within a network can up to 254. Figure 207 shows the connector of the shielded twisted pair.

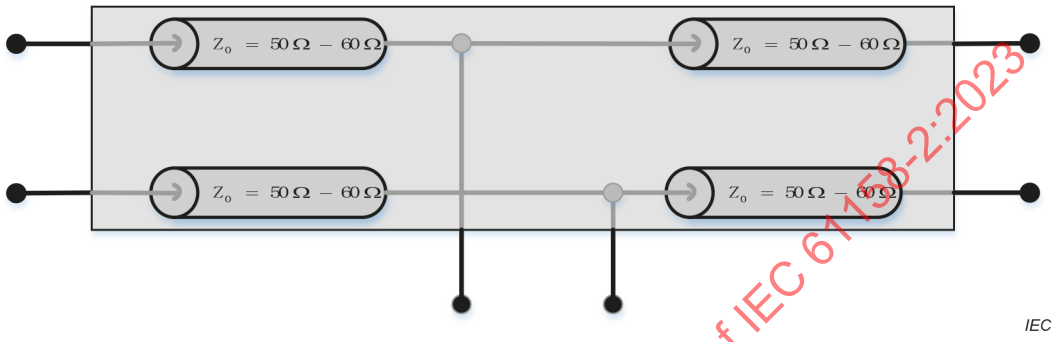


**Figure 207 – Connector of the shielded twisted pair**

### 35.5.3 Terminal resistor

The terminal resistor should be located at both ends of the backbone cable and connect one signal wire to another. The terminal resistor should not be connected to the cable shield. The impedance characteristics of the terminal resistor should be consistent with the impedance characteristic parameters of the connected cable. Figure 208 shows the terminal resistor connected to the twisted pair receiver.

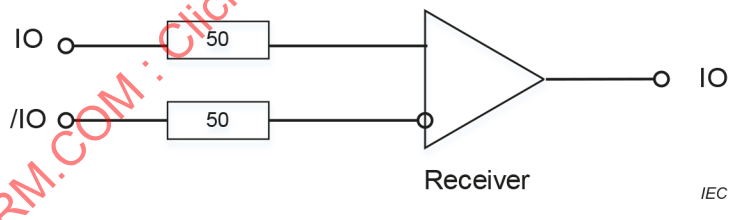


**Figure 208 – Terminal resistor**

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# Annex A
(normative)

# Type 1: Connector specification

## A.1 Internal connector for wire medium

A fieldbus connector that is inside the enclosure of the fieldbus device and therefore requires no protection against the electromagnetic and physical environment shall be specified as an internal connector. An internal connector shall meet the following functional requirements:

a) distinctly marked to avoid conductors being interchanged;

b) positive locking with a minimum of 50 N extraction force locked;

c) field installation with hand tools shall be possible;

d) the fixed (device) side shall be 4,8 mm × 0,8 mm male tabs with hole as shown in Figure A.1, Table A.1, and specified in IEC 61210;

e) each conductor of the cable shall be terminated with a locking female connector with an insulating sleeve or housing;

f) the female connector with insulating sleeve or housing shall fit through a 9,5 mm diameter hole.

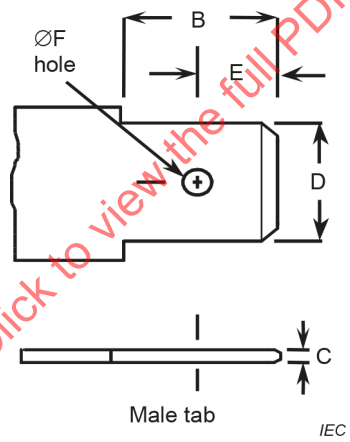


**Figure A.1 – Internal fieldbus connector**

**Table A.1 – Internal connector dimensions**

| 4,8 mm (0,187 in) Male tab | | | | |
|---|---|---|---|---|
| | Millimetres | | Inches | |
| | max. | min. | max. | min. |
| B | 6,5 | 6,2 | 0,256 | 0,244 |
| C | 0,84 | 0,77 | 0,033 | 0,030 |
| D | 4,9 | 4,7 | 0,193 | 0,185 |
| E | 3,4 | 3,0 | 0,134 | 0,117 |
| ∅ F | 1,5 | 1,3 | 0,060 | 0,050 |

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## A.2 External connectors for wire medium

### A.2.1 General

A fieldbus connector that is outside the enclosure of the fieldbus device and therefore requires protection against the electromagnetic and physical environment shall be specified as an external connector.

Two external connectors are specified in accordance with the environment of the installation.

### A.2.2 External connector for harsh industrial environments

An external connector for harsh industrial environments shall meet the following functional requirements:

a) polarized to avoid conductors being interchanged, both mated and unmated;
b) available with sealing to IEC 60529: IP65 when mated or fitted with protective caps;
c) the free (cable) side shall be available with a cable clamp which secures the cable but does not subject the cable conductors to damaging stress;
d) the conductors shall be completely surrounded by a conductive shell which maintains the electrical continuity of the shield;
e) the conductive shell of the free (cable) side shall be covered by insulating material;
f) the conductive shell of the fixed (device) side shall be insulated from its mounting surface;
g) the fixed (device) side shall provide a connection to the shield, other than the shell;
h) the contacts shall accommodate wire sizes of 0,20 $mm^2$ to 0,64 $mm^2$;
i) provided with positive locking to prevent disconnection by cable strain;
j) provided with four pins (two signal pins and two power pins);
k) available with crimped conductors;
l) provided with male contacts on the fixed (device) side;
m) a cable connector with male pins shall be available for in-line connection;
n) dielectric strength from contacts to shell and from shell to ground shall be at least as high as specified under isolation for the appropriate MAU;
o) contacts shall be assigned to functions as shown in Table A.2 and Figure A.2;
p) connector dimensions (mating face) shall be as shown in Figure A.3, Figure A.4 and Figure A.5.

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**Table A.2 – Contact assignments for the external connector for harsh industrial environments**

| Contact No. | Function |
|---|---|
| A | DATA + with the option of power + |
| B | DATA - with the option of power - |
| C | Reserved for option of power + |
| D | Reserved for option of power - |

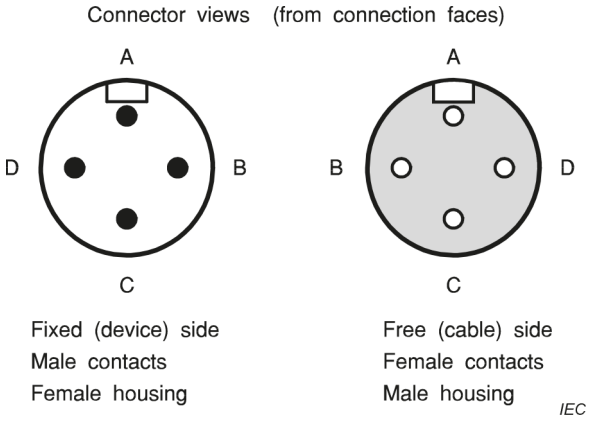


**Figure A.2 – Contact designations for the external connector for harsh industrial environments**

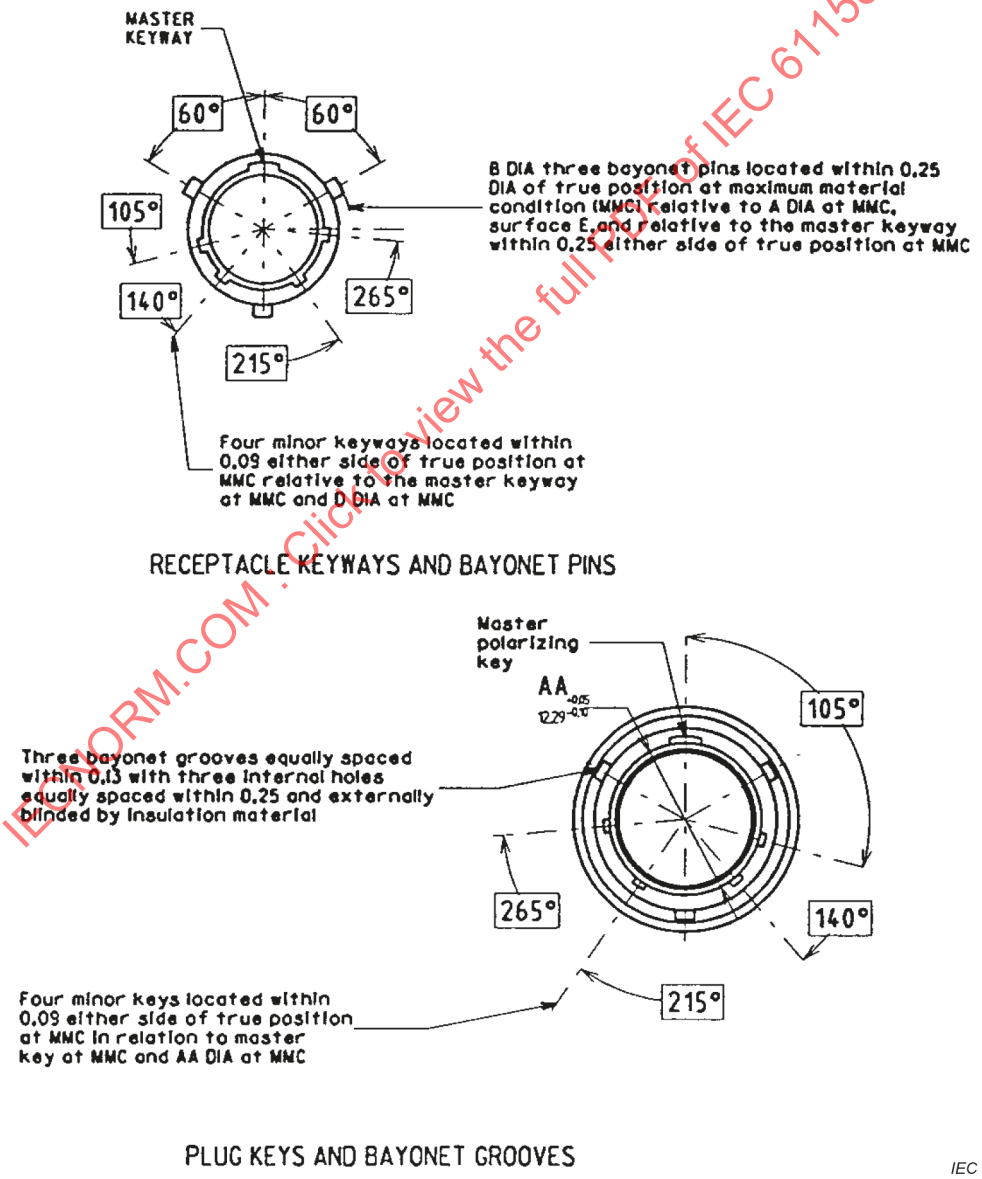


**Figure A.3 – External fieldbus connector keyways, keys, and bayonet pins and grooves**

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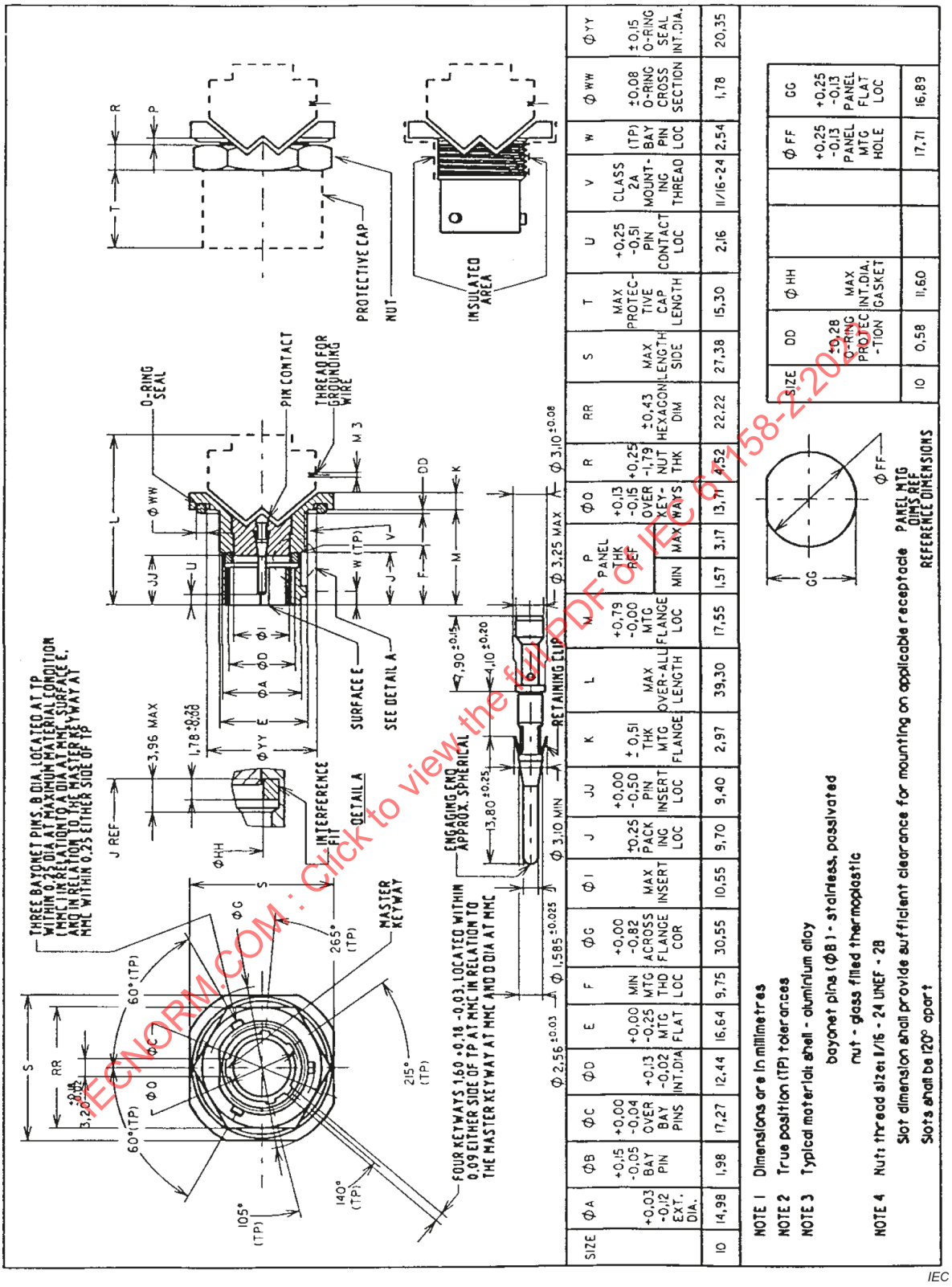


| SIZE | Φ A | Φ B | Φ C | Φ D | E | F | Φ G | Φ I | J | JJ | K | L | N | P | Φ O | R | RR | S | T | U | V | W | Φ WW | Φ YY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | +0,03 -0,12 EXT. DIA. | +0,15 -0,05 BAY PIN | +0,00 -0,04 OVER BAY PINS | +0,13 -0,02 INT.DIA | +0,00 -0,25 MTG FLAT | MIN MTG THD LOC | +0,00 -0,82 ACROSS FLANGE COR | MAX INSERT | ±0,25 PACK ING LOC | +0,00 -0,50 PIN INSERT LOC | ± 0,51 THK MTG FLANGE | MAX OVER-ALL LENGTH | +0,79 -0,00 MTG FLANGE LOC | PANEL THK REF | +0,13 -0,15 OVER KEY-WAYS | +0,25 -1,79 NUT THK | ±0,43 HEXAGON DIM | MAX LENGTH SIDE | MAX PROTEC-TIVE CAP LENGTH | +0,25 -0,51 PIN CONTACT LOC | CLASS 2A MOUNT-ING THREAD | (TP) BAY PIN LOC | ±0,08 O-RING CROSS SECTION | ±0,15 O-RING SEAL INT.DIA. |
| 10 | 14,98 | 1,98 | 17,27 | 12,44 | 16,64 | 9,75 | 30,55 | 10,55 | 9,70 | 9,40 | 2,97 | 39,30 | 17,55 | 1,57 | 3,17 | 13,17 | 22,22 | 27,38 | 15,30 | 2,16 | 11/16-24 | 2,54 | 1,78 | 20,35 |

| SIZE | DD +0,28 -0,0 O-RING PROTEC -TION | Φ HH MAX INT.DIA. GASKET | Φ FF +0,25 -0,13 PANEL MTG HOLE | GG +0,25 -0,13 PANEL FLAT LOC |
|---|---|---|---|---|
| 10 | 0,58 | 11,60 | 17,71 | 16,89 |

NOTE 1 Dimensions are in millimetres

NOTE 2 True position (TP) tolerances

NOTE 3 Typical material: shell - aluminium alloy
bayonet pins (Φ B) - stainless, passivated
nut - glass filled thermoplastic

NOTE 4 Nut: thread size: 11/16 - 24 UNEF - 2B
Slot dimension shall provide sufficient clearance for mounting on applicable receptacle
Slots shall be 120° apart

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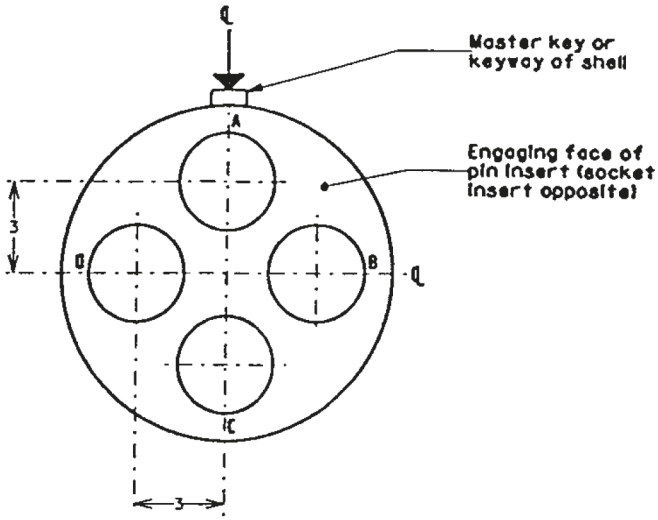
**Figure A.4 – External fieldbus connector intermateability dimensions**




IEC

| Shell size | Number of contacts | Size contacts |
|---|---|---|
| 10 | 4 | 16 |

NOTE Dimensions are in millimetres.

Insert arrangement is shown in the normal position in the shell with the A cavity in front of the master key or keyway of the shell. Only this "normal position" shall be used.

Four keys or keyways (MMC) and insert shall be located within 0,09 mm either side of (TP) relative to master key or keyway (MMC) and shall be DD or ID (MMC).

**Figure A.5 – External fieldbus connector contact arrangement**

### A.2.3 External connector for typical industrial environments

A connector for typical industrial environments shall meet the following functional requirements:

a) polarized to avoid conductors being interchanged, both mated and unmated;

b) completely surrounded by a conductive shell;

c) provided with male contacts on the fixed (device) side, and with female threaded stand-offs for screw type locking (4-40NC-2B thread);

d) provided with female contacts on the free (cable) side, and with locking screws (4-40 NC-2A thread);

e) provided with nine pins (two signal pins, two power pins, and five reserved pins);

f) contacts shall be assigned to functions as shown in Figure A.6 and Table A.3;

g) connector dimensions (mating face) shall be as shown in Figure A.7 and Figure A.8, Table A.4 and Table A.5, and specified in IEC 60807-3.

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**Table A.3 – Contact assignments for the external connector for typical industrial environments**

| PIN number | Function |
|---|---|
| 1 | Reserved |
| 2 | Reserved |
| 3 | Reserved |
| 4 | Reserved |
| 5 | Reserved |
| 6 | DATA + with the option of power + |
| 7 | DATA - with the option of power - |
| 8 | Reserved for option of power + |
| 9 | Reserved for option of power - |

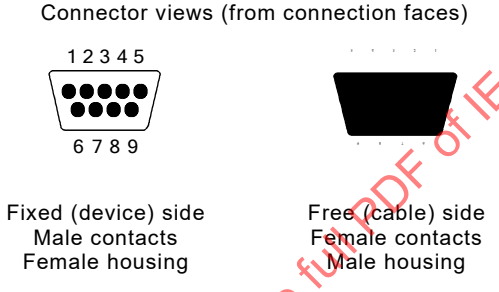


**Figure A.6 – Contact designations for the external connector for typical industrial environments**

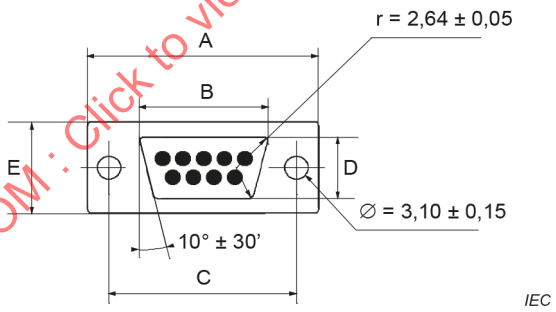


**Figure A.7 – External fixed (device) side connector for typical industrial environments: dimensions**

**Table A.4 – Fixed (device) side connector dimensions**

| Fixed (device) side connector (male contacts, female housing) | | | | |
|---|---|---|---|---|
| | Millimetres | | Inches | |
| | max. | min. | max. | min. |
| A | 31,19 | 30,43 | 1,23 | 1,20 |
| B | 17,04 | 16,79 | 0,67 | 0,66 |
| C | 25,12 | 24,87 | 0,99 | 0,98 |
| D | 8,48 | 8,23 | 0,33 | 0,32 |
| E | 12,93 | 12,17 | 0,51 | 0,48 |

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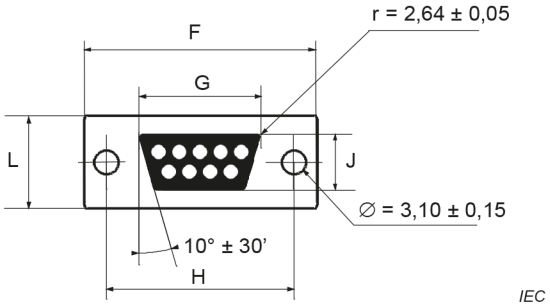


**Figure A.8 – External free (cable) side connector for typical industrial environments: dimensions**

**Table A.5 – Free (cable) side connector dimensions**

| Free (cable) side connector (female contacts, male housing) | | | | |
|---|---|---|---|---|
| | Millimetres | | Inches | |
| | max. | min. | max. | min. |
| F | 31,19 | 30,43 | 1,23 | 1,20 |
| G | 16,46 | 16,21 | 0,65 | 0,64 |
| H | 25,12 | 24,87 | 0,99 | 0,98 |
| J | 8,03 | 7,77 | 0,32 | 0,31 |
| L | 12,93 | 12,17 | 0,51 | 0,48 |

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## A.3 External connectors for optical medium

### A.3.1 General

A fieldbus connector that is outside the enclosure of the fieldbus device and therefore requires protection against the electromagnetic and physical environment shall be specified as an external connector.

Two types of external connectors are specified in accordance with the environment of the installation.

### A.3.2 External connector for typical industrial environments

#### A.3.2.1 External connector for typical industrial environments (1)

For the CPIC interface at the level of a fieldbus device, or an optical active star or an optical passive star, the connector used shall be compatible with the connector shown in Figure A.9 and Table A.6 (see IEC 61754-13).

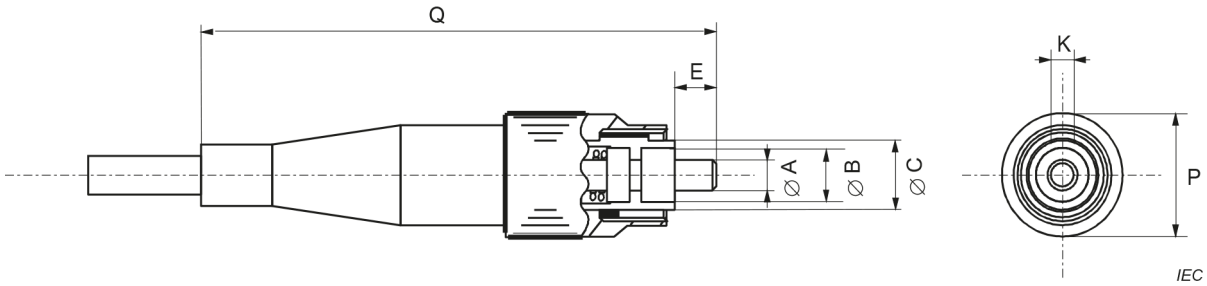


**Figure A.9 – Optical connector for typical industrial environments (FC connector)**

**Table A.6 – Connector dimensions**

| Reference | Millimetres | |
|---|---|---|
| | min. | max. |
| ∅ A | 2,498 | 2,500 |
| ∅ B | 4,40 | 4,42 |
| ∅ C | 5,95 | 6,00 |
| E | 3,75 | 4,05 |
| K | 1,85 | 2,14 |
| P | - | 10,5 |
| Q | - | 45 |

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### A.3.2.2 External connector for typical industrial environments (2)

For the CPIC interface at the level of a fieldbus device, or an optical active star or an optical passive star, the connector used shall be compatible with the connector shown in Figure A.10.

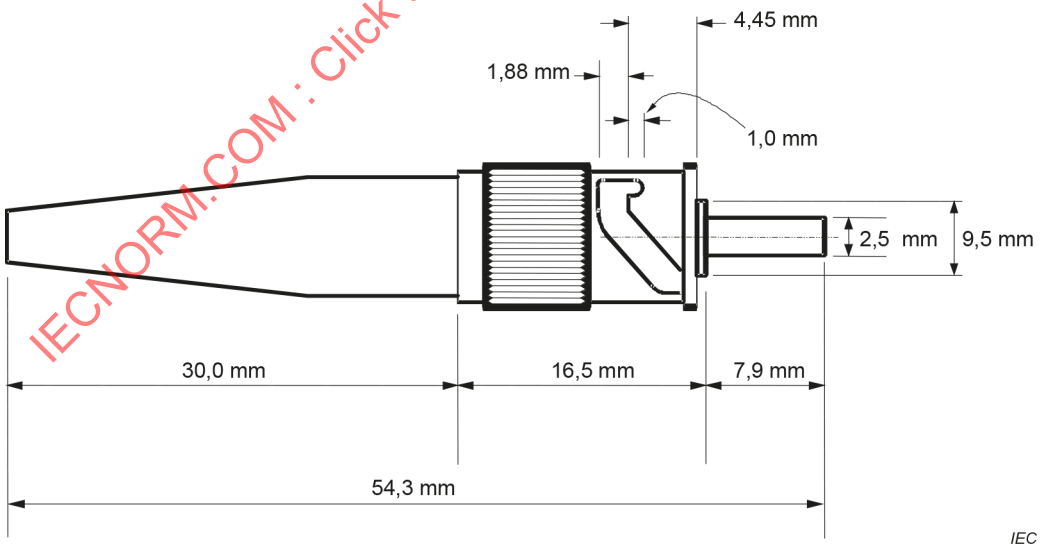


**Figure A.10 – Optical connector for typical industrial environments (ST connector)**

# Annex B
(informative)

# Types 1 and 3: Cable specifications and trunk and spur lengths for the 31,25 kbit/s voltage-mode MAU

## B.1 Cable description and specifications

The preferred fieldbus cable is specified in 12.8.2 for conformance testing, and it is referred to as type A fieldbus cable.

NOTE 1 This cable will probably be used in new installations.

Other types of cables can be used for fieldbus wiring, other than for conformance testing. The alternate preferred fieldbus cable is a multiple, twisted pair cable with an overall shield, hereinafter referred to as type B fieldbus cable.

NOTE 2 This cable will probably be used in both new and retrofit installations where multiple fieldbuses are run in the same area of the user's plant.

A less preferred fieldbus cable is a single or multiple, twisted pair cable without any shield, hereinafter referred to as type C fieldbus cable. The least preferred fieldbus cable is a multiple conductor cable without twisted pairs but with an overall shield, hereinafter referred to as type D fieldbus cable.

NOTE 3 Type C and type D cables will mainly be used in retrofit applications. They will have some limitations in fieldbus distance and S/N ratios that the type A and type B cables do not have. Therefore the use of type C and type D cables in certain applications is precluded.

Typical cable specifications at 25 °C are listed in Table B.1.

**Table B.1 – Typical cable specifications**

| Parameter | Conditions | Type B | Type C | Type D |
|---|---|---|---|---|
| Impedance, Ω | $f_r$ (31,25 kHz) | 100 ± 30 | Not specified | Not specified |
| Max. DC resistance, Ω/km | Per conductor | 56 | 132 | 20 |
| Max. attenuation, dB/km | 1,25 $f_r$ (39 kHz) | 5,0 | 8,0 | 8,0 |
| Nominal conductor cross-sectional area, $mm^2$ (wire size) | | 0,32 | 0,13 | 1,25 |
| Max. capacitive unbalance, nF/km | ≥30 m length | 6 | Not specified | Not specified |

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## B.2 Typical trunk and spur lengths

Using the network configuration rules specified in 12.3.3, the maximum lengths for type B, type C and type D cables, including all spurs, typically will be:

– type B - 1 200 m;
– type C - 400 m;
– type D - 200 m.

NOTE These typical guidelines do not supersede the network configuration rules of 12.3.3.

Allowable spur lengths for either bus or tree topology are dependent on the number of communication elements on the fieldbus. Table B.2 relates the recommended number of communication elements to spur length. Maximum spur lengths are the same for type A,

type B, type C, and type D cables. The table assumes one communication element per spur. When a spur with passive trunk coupler has more than one communication element, the length of that spur should be reduced by 30 m per communication element. As the recommended maximum total spur length is 120 m, the maximum number of communication elements per spur should be four.

**Table B.2 – Recommended maximum spur lengths versus number of communication elements**

| Total number of communication elements | Recommended maximum spur length<br>m |
|---|---|
| 25 to 32 | 0 |
| 19 to 24 | 30 |
| 15 to 18 | 60 |
| 13 to 14 | 90 |
| 1 to 12 | 120 |

Spurs of length less than 1 m should be regarded as splices.

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# Annex C
(informative)

# Types 1 and 7: Optical passive stars

## C.1 Definition

A passive device in which the signal from input optical fibers is distributed among a larger number of output optical fibers (input and output optical fibers may be the same).

a) Optical reflective passive star

A device whose purpose is to reflect optical power input at any output port (see Figure C.1). This device can only be used with a single fiber mode MAU.

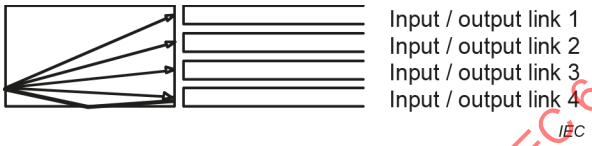


**Figure C.1 – Example of an optical passive reflective star**

b) Optical transmitive passive star

A device whose purpose is to divide optical power input at any output port (see Figure C.2). This device allows a broadcasting of information only over one direction. It can only be used with a dual fiber mode MAU.

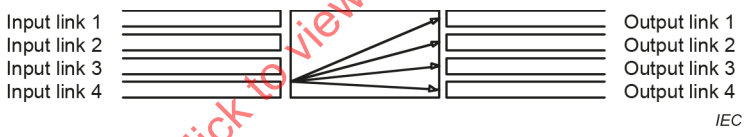


**Figure C.2 – Example of an optical passive transmitive star**

## C.2 Example of attenuations

For a wavelength included between 700 nm and 900 nm, Table C.1 gives an example of minimal and maximal attenuations of optical passive star (these specifications are equally available for 62,5/125 fiber or 100/140 fiber).

**Table C.1 – Optical passive star specification summary: example**

| 700 nm ≤ $\lambda_p$ ≤ 900 nm | Star 4/4 | Star 8/8 | Star 16/16 | Star 32/32 | Unit |
|---|---|---|---|---|---|
| Min. attenuation | −6,0 | −9,0 | −12,0 | −16,0 | dB |
| Max. attenuation | −9,0 | −12,0 | −16,0 | −20,0 | dB |

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# Annex D
(informative)

# Types 1 and 7: Star topology

## D.1 Examples of topology

Clause D.1 illustrates some of the network topologies that can be constructed in accordance with this document. This does not imply that these are the only possible topologies.

The physical size of a network, both in geographic length and the number of desired fieldbus devices, will have a significant impact on the choice of network topology. When a limited number of fieldbus devices are required, almost any topology can be used. Figure D.1 illustrates a possible topology.

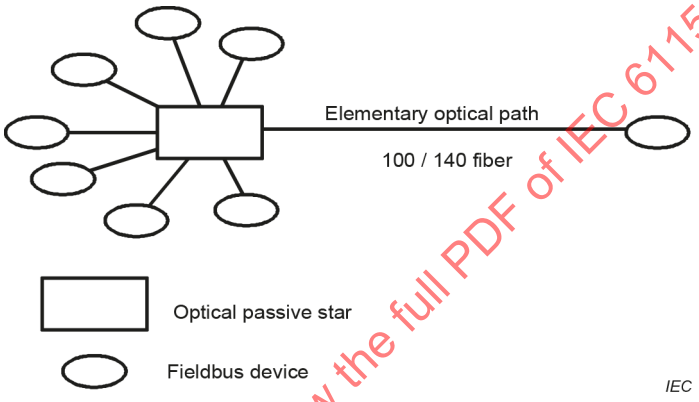


**Figure D.1 – Example of star topology with 31,25 kbit/s, single fiber mode, optical MAU**

For situations that require a large number of fieldbus devices located in widely separated geographic locations, a multi-star topology may be required. Topologies of this type can grow to very large numbers of communicating devices (see Figure D.2).

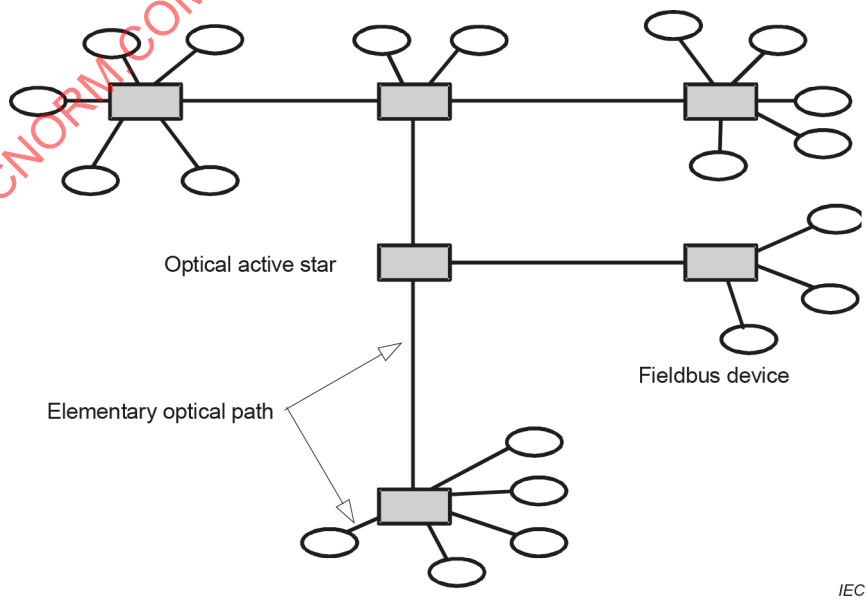


**Figure D.2 – Multi-star topology with an optical MAU**

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## D.2 Optical power budget

### D.2.1 General

An optical power budget allows anticipation of the distribution of different losses and attenuations of the optical signal along an optical link.

From the transmitter effective launch power levels and the receiver operating range, it is possible to establish the minimum and maximum length of the link.

Two cases are considered.

– Minimum power case: corresponds to the minimum transmitter effective launch power, maximum losses, maximum penalties and maximum margin system, and the lower limit of the receiver operating range. This case gives the maximum guaranteed length.
– Maximum power case: corresponds to the maximum transmitter effective launch power, minimum losses, minimum penalties and minimum margin system, and the upper limit of the receiver operating range. This case gives the minimum guaranteed length.

Two examples are given. The first corresponds to the topology shown in Figure D.1 and the second, to the topology given in Figure D.2.

### D.2.2 Passive star topology (31,25 kbit/s, single fiber mode, optical MAU)

For this example the transmission between high sensitivity modems is considered. Table D.1 summarizes the passive star topology specifications.

Parameters that will be considered are the following:

– typical fiber 100/140 attenuation: 4,0 dB/km
– optical passive star 8/8 attenuation: 9,0 dBm to 12,0 dB
– effective launch power (100/140 µm fiber): −14,5 dBm to −12,5 dBm
– high sensitivity receiver operating range: −40,0 dBm to −20,0 dBm

**Table D.1 – Passive star topology**

| Parameters | max. | min. | Units |
|---|---|---|---|
| Receiver operating range (high sensitivity) | −40,0 | −20,0 | dBm |
| Effective launch power | −14,5 | −12,5 | dBm |
| Dynamics for all losses and attenuations | 25,5 | 7,5 | dB |
| Margin system | 3,0 | 0,0 | dB |
| Losses due to two connectors | 2,0 | 0,0 | dB |
| Reflective optical passive star (8/8) | 12,0 | 9,0 | dB |
| Max. and min. attenuations due to fiber | 8,5 | - | dB |
| Length of fiber between modems (fiber attenuation: 4,0 dB/km) | 2 125 | 0 | m |

### D.2.3 Active star topology (optical MAU)

For this example, the transmission between low sensitivity modems is considered. Table D.2 summarizes the passive star topology specifications.

Parameters that will be considered are the following:

– typical fiber 62,5/125 attenuation: 3,0 dB/km

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– transmitter (effective launch power): (−11,5 ± 1,5) dBm
– low sensitivity receiver (receiver operating range): (−30,0 to −10,0) dBm.

**Table D.2 – Active star topology**

| Parameters | max. | min. | Unit |
|---|---|---|---|
| Receiver operating range (high sensitivity) | −30,0 | −10,0 | dBm |
| Transmitter effective launch power | −13,0 | −10,0 | dBm |
| Dynamics for all losses and attenuations | 17,0 | 0,0 | dB |
| Margin system | 3,0 | 0,0 | dB |
| Losses due to two connectors | 2,0 | 0,0 | dB |
| Max. and min. attenuations due to fiber | 12,0 | 0,0 | dB |
| Length of fiber between modems (fiber attenuation 3,0 dB/km) | 4 000 | 0 | m |

## D.3 Mixed with wire media

The mixing of wire and optical media is achieved with an electro-optical converter. This element presents one or several wire medium accesses and one or several optical accesses. Each access, wire or optical, shall respect the transmit and receive circuit specifications.

This element regenerates the signal to their nominal optical power levels or electrical levels and to nominal timing characteristics (jitter, rise and fall times, slew rate, etc.).

Two examples are shown in Figure D.3 and Figure D.4.

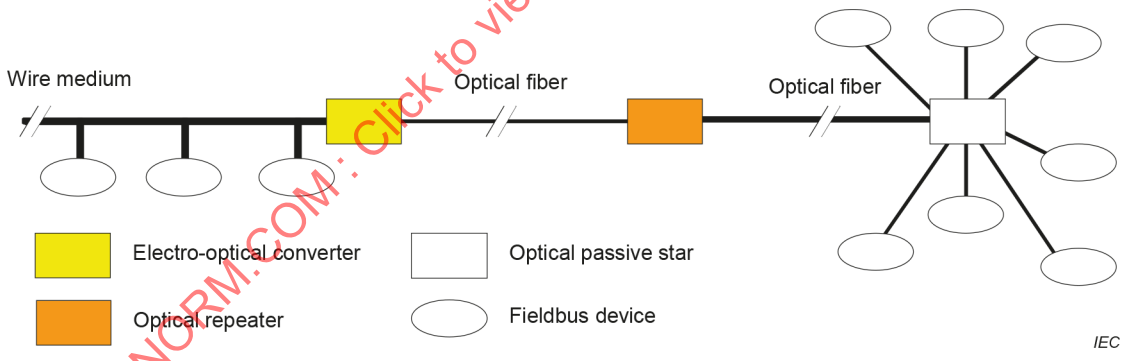


**Figure D.3 – Example of mixture between wire and optical media for 31,25 kbit/s**

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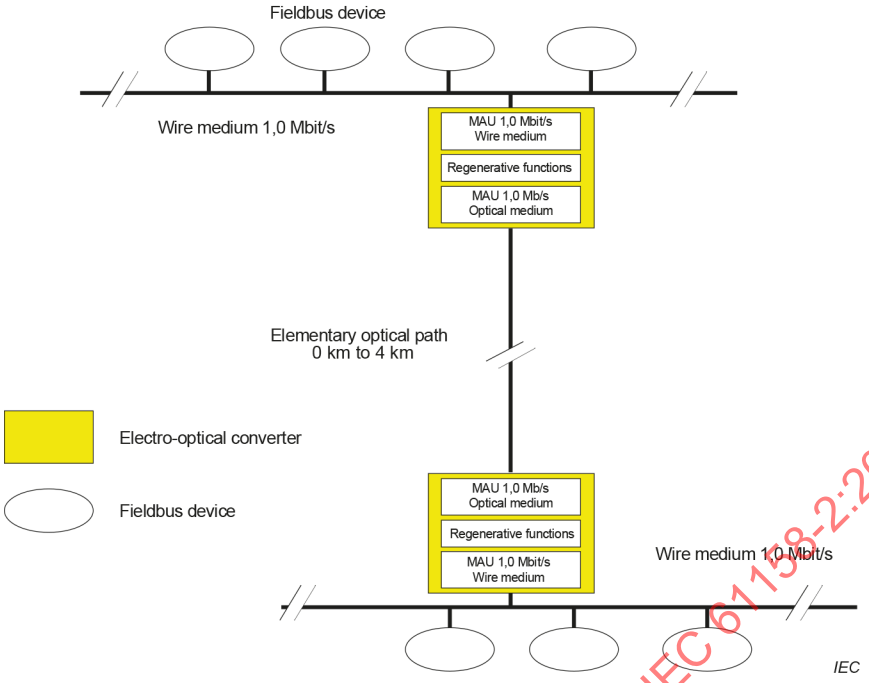


**Figure D.4 – Example of mixture between wire and optical media**

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# Annex E
(informative)

# Type 1: Alternate fibers

## E.1 Alternate fibers for dual-fiber mode

It is possible to use other fibers than the fiber A1d specified as standard test fiber. Depending on the characteristics of these fibers, effective launch power levels differ. On the other hand, receiver operating ranges for low and high sensitivities are identical.

Table E.1 allows a comparison between these different fibers.

**Table E.1 – Alternate fibers for dual-fiber mode**

| Parameters | Subclause | Specified fiber test standard | Specified alternate fiber | Specified alternate fiber |
|---|---|---|---|---|
| Fiber | 15.7.2 | A1b (62,5/125) | A1a (50/125) | A1d (100/140) |
| Effective launch power | 15.4.2 | (−11,5 ± 1,5) dBm | (−14,5 ± 1,5) dBm | (−7,5 ± 1,0) dBm |
| Receiver operating range low sensitivity | 15.5.2 | −30,0 dBm to −10,0 dBm | −30,0 dBm to −10,0 dBm | −30,0 dBm to −10,0 dBm |
| Receiver operating range high sensitivity | 15.5.2 | −40,0 dBm to −20,0 dBm | −40,0 dBm to −20,0 dBm | −40,0 dBm to −20,0 dBm |

## E.2 Alternate fibers for single-fiber mode

It is possible to use other fibers than the fiber A1d specified as standard test fiber. Depending on the characteristics of these fibers, effective launch power levels differ. On the other hand, receiver operating ranges for low and high sensitivities are identical.

Table E.2 allows a comparison between these different fibers.

**Table E.2 – Alternate fibers for single-fiber mode**

| Parameters | Subclause | Specified fiber test standard | Specified alternate fiber | Specified alternate fiber |
|---|---|---|---|---|
| Fiber | 16.7.2 | A1d (100/140) | A1a (50/125) | A1b (62,5/125) |
| Effective launch power | 16.4.2 | (−13,5 ± 1,0) dBm | (−21,0 ± 1,0) dBm | (−17,5 ± 1,0) dBm |
| Receiver operating range low sensitivity | 16.5.2 | −30,0 dBm to −12,5 dBm | −30,0 dBm to −12,5 dBm | −30,0 dBm to −12,5 dBm |
| Receiver operating range high sensitivity | 16.5.2 | −40,0 dBm to −20,0 dBm | −40,0 dBm to −20,0 dBm | −40,0 dBm to −20,0 dBm |

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# Annex F
(normative)

# Type 2: Connector specification

## F.1 Connector for coaxial wire medium

Attachment to the coaxial medium shall be via BNC (see IEC 61169-8:2007, Annex A, 75 Ω variant) or TNC (see IEC 60169-17, 75 Ω variant) plug and jack connectors.

The TNC variant shall be sealed to IP67 minimum. Where sealing is required, the node shall also meet IP67 requirements.

NOTE It is possible to achieve sealing up to IP65 with the BNC.

The characteristic impedance shall be between 45 Ω and 80 Ω.

The center conductor contact shall be plated in conformance with one of the following specifications:

a) 0,75 µm gold minimum over 1,25 µm nickel minimum over base metal;
b) 0,05 µm to 0,2 µm gold flash over 1,25 µm palladium nickel minimum over 1,25 µm nickel minimum over base metal.

## F.2 Connector for optical medium

### F.2.1 General requirements

Connectors for optical medium shall meet the requirements specified in Table F.1.

**Table F.1 – Connector requirements**

| Specification | Short range | Medium and long range |
|---|---|---|
| Connector Insertion Loss (nominal value) | 1,5 dB | 1,0 dB |

### F.2.2 Connector for short range optical medium

This variant shall use a two-part connector, composed of a pin connector (as specified in Figure F.1) and a crimp ring that crimps the cable to the pin connector (as specified in Figure F.2).

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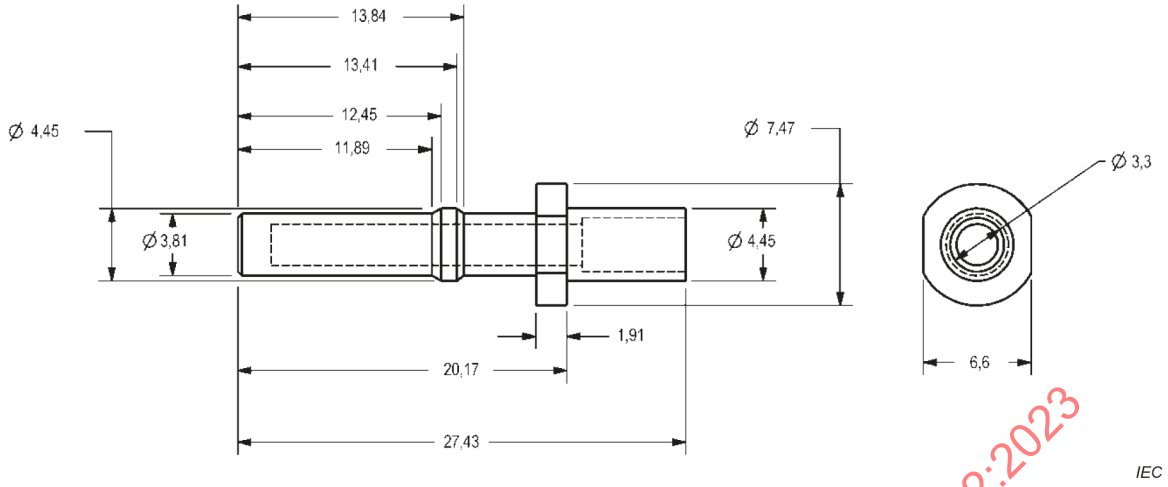
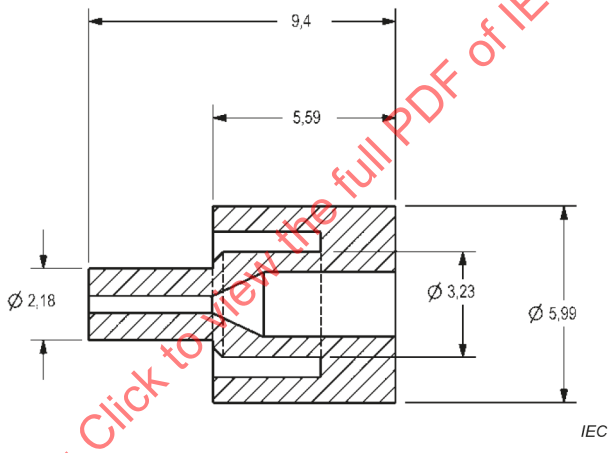



NOTE Dimensions are in mm.

**Figure F.1 – Pin connector for short range optical medium**




NOTE Dimensions are in mm.

**Figure F.2 – Crimp ring for short range optical medium**

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### F.2.3 Connector for medium and long range optical medium

These variants shall use an ST type connector, as specified in IEC 61754-2.

## F.3 Connector for NAP medium

The connector used at both ends of a NAP connection shall be a shielded 8-pin RJ-45 type connector (see IEC 60603-7-4).

The NAP connector pins shall be as shown in Table F.2. This pin definition shall apply to both ends of the cable. The connector shall be installed on the cable to meet the requirements shown in Figure 113.

**Table F.2 – NAP connector pin definition**

| Pin number | Signal name |
|---|---|
| 1 | GND REF |
| 2 | N/C (no connection) |
| 3 | Tx_H |
| 4 | Tx_L |
| 5 | Rx_L |
| 6 | Rx_H |
| 7 | N/C (no connection) |
| 8 | GND REF |

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# Annex G
(normative)

# Type 2: Repeater machine sublayers (RM, RRM) and redundant PhLs

## G.1 General

A PhL repeater device (bus or ring) shall be used to increase trunk lengths and number of nodes by connecting full length and/or fully loaded sections of medium. Repeaters may also be used to connect between different PhL variants, for example between fiber and coaxial wire. In addition, a ring repeater device shall support media redundancy through the use of a ring topology.

Repeater devices shall conform to all applicable clauses concerning the MAU sublayer and the MDS-MAU interface. A PhL bus repeater device shall consist of two (or more) complete PhL interfaces (MDS/MAU, from the same or different variants) connected together by a Repeater Machine (RM) sublayer. A PhL ring repeater device shall consist of two or more complete PhL interfaces connected together by a Ring Repeater Machine (RRM) sublayer.

A PhL repeater (bus or ring) need not have a MAC ID. A PhL repeater device is not the source of network traffic and shall not support layers above the RM or RRM sublayers. Rather, it shall only be responsible for retransmitting network traffic from one segment to one or more other segments, and for the correct implementation of the RM or RRM sublayer.

Optionally, a node may include the RM or RRM sublayer functionality as part of that node's MAC sublayer to allow a network node to function as both a network node and a repeater between PhL variants. This type of node shall be considered a network node and shall have a MAC ID.

A node that supports multiple PhL variants and an RM sublayer shall function as both a node (that is the source of network traffic) with redundant PhL entities (see Clause G.3) and a PhL bus repeater device. A node that supports multiple PhL variants and a RRM sublayer shall function as both a node and a PhL ring repeater device.

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## G.2 Repeater machine (RM) sublayer

### G.2.1 Requirements

Figure G.1 shows the reference model for a PhL bus repeater device.

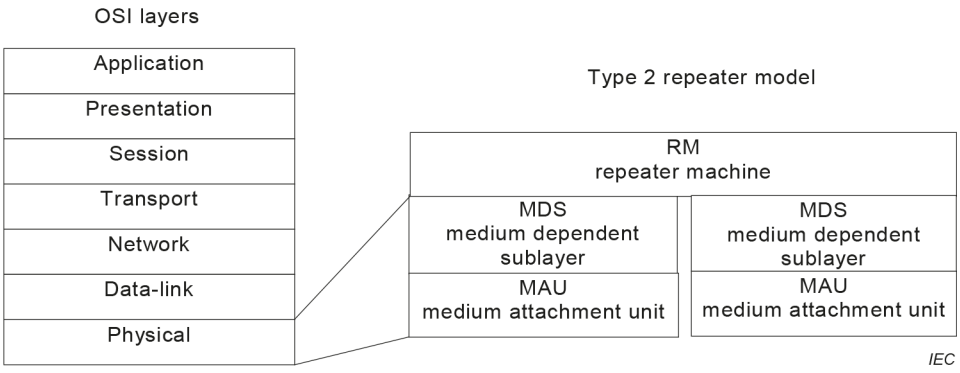


**Figure G.1 – PhL repeater device reference model**

Each of the two (or more) PhL entities connected by the RM sublayer shall follow the specifications shown for a given PhL variant.

A RM sublayer shall be used as a connection between segments to form a link as shown in Figure 106. Any MAC ID used on one PhL variant that is connected to another PhL variant using the RM sublayer shall be unique as the two sides share a common link.

The RM sublayer shall be completely transparent to network traffic. All valid MAC symbols between the start and end delimiters (inclusive) that are received by one PhL entity in the RM shall be passed unaltered to all of the others for transmission. The preamble shall be regenerated by the RM sublayer to correct any discrepancies introduced by the MDS or MAU. Preamble regeneration shall recreate the original preamble of 16 consecutive {1} M_symbols and can introduce up to an additional 4 consecutive {1} M_symbols. Following the retransmission of the end delimiter, the RM sublayer can introduce up to 4 additional consecutive M_symbols of any value.

The RM shall be a half-duplex sublayer. Only one PhL entity connected to the RM shall receive data at any one time while all the other PhL entities are retransmitting the received data.

The RM sublayer shall not be the cause of collisions on any medium. At any point in time, only one PhL entity shall be selected for reception while all others shall be selected for transmission. The PhL entity that is selected for reception shall be based on the state of the PLS_CARRIER_INDICATION from the PhL entity that indicates PLS_CARRIER_INDICATION (true) first. All other PhL entities connected to the RM sublayer shall be set for transmission while the PhL entity is receiving PLS_CARRIER_INDICATION (true) and PLS_FRAME_INDICATION (true). While that PhL entity is selected for reception, any PLS_CARRIER_INDICATION (true) from other PhL entities shall be ignored. A new PhL entity shall be selected for reception after the completion of the previous frame (PLS_FRAME_INDICATION = false).

The RM sublayer shall be designed to minimize the length of time delay that is added to the PLS_DATA_INDICATION retransmission. The RM sublayer time delay shall be defined as the time delay from the end of the received start delimiter to the end of the retransmitted start delimiter as measured at the MDS-MAU interface. Any delay added by the RM sublayer shall be included in the calculation of slot time used by the MAC sublayer. The total amount of delay that is added by the RM sublayer shall be made available for use by network configuration tools and users.

NOTE Any delay in the RM sublayer reduces the total amount of medium that can be supported and reduces the efficiency of the network by increasing the slot time required by the DLL protocol (see IEC 61158-4-2).

The RM sublayer shall be designed to reconstruct the data as transmitted from the originating node. This requirement shall allow an unlimited number of repeaters to be cascaded (in series) with no distortion being added to the original data by the repeaters. The only limit to the total number of RM sublayers that can be cascaded shall be the ability of the slot time to be adjusted to compensate for the total amount of delay on the medium. The maximum slot time is defined in the DLL protocol (see IEC 61158-4-2).

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### G.2.2 **RM sublayer state machine** (informative)

NOTE Subclause G.2.2 describes an example implementation. There are no normative requirements.

The RM sublayer consists of two interconnected state machines. The first machine dictates which channel is receiving while all other channels are transmitting. The second state machine controls when the transmitting channel transmits data.

The first state machine consists of one state per channel to be arbitrated. When the second machine is in its idle state and a PLS_CARRIER_INDICATION arrives on any channel, this state machine moves to the state corresponding to the indication. If the second machine is in any state other than idle, this machine is locked and does not move, independent of PLS_CARRIER_INDICATION. The simultaneous first arrivals of two or more

PLS_CARRIER_INDICATIONS is not a normal operating condition of the PhL and this machine's state transitions are unspecified.

The second state machine consists of 4 states: RM_IDLE, RM_CARRIER, RM_FRAME, RM_WAIT. If the node MAC sublayer is transmitting data, the RM should be forced to RM_WAIT:

– RM_Idle indicates that no activity is present on any channel. Other states move to RM_Idle when pls_carrier_indication is false for every channel. The presence of pls_carrier_indication on any channel causes the machine to move to the state RM_Carrier. While in RM_Idle, the pls_frame_request on all channels is false. The simultaneous first arrivals of two or more pls_carrier_indication is not a normal operating condition of the network and this machine should transition to RM_Wait;

– RM_Carrier indicates receive activity, but the MDS sublayer has not yet achieved lock (pls_lock_indication = false). This state should activate pls_frame_request on all channel's except the one indicated by the first machine as being the receive channel. The pls_data_request is preamble. If preamble regeneration is not used, this state serves as a placeholder to lock the first machine from transitioning. The presence of pls_lock_indication on the channel selected by the first machine causes the machine to move to the state RM_Frame;

– RM_Frame indicates the active repeating of data. This state activates pls_frame_request on all channels except the one indicated by the first machine as being the receive channel. It moves M_symbols from the receiving PhL entity to the transmitting channels, pls_data_indication => pls_data_request. At the point where the start delimiter of the repeated data is transmitted, it is required that at least 16 M_symbols of preamble have already been transmitted. The loss of pls_lock_indication on the channel selected by the first machine causes the machine to move to state RM_Wait;

– RM_Wait indicates the closing period of the repeated data. It holds off both state machines from moving to any other state to prevent repeating of echoes and end of packet noise. The machine remains in RM_Wait until pls_carrier_indication is false for all channels and the end of the blanking timer has occurred (see DLL protocol, IEC 61158-4-2). At that point, the machine moves to RM_Idle. While in RM_Wait, the pls_frame_request on all channels is false.

The PLS_FRAME_INDICATION of the receiving channel is not directly used by the repeater machines. Indirectly, the condition causing the end of frame should also force the receiver clock recovery to immediately unlock (PLS_LOCK_INDICATION = false) to eliminate repetition of noise after the end delimiter is repeated.

Failure to maintain PLS_LOCK_INDICATION or failure to detect a valid start delimiter probably indicates a corrupted data frame or a burst of noise on the medium. The RM should be designed to minimize the possibility of repeating a corrupted frame or noise.

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## G.3 Redundant PhL

Figure G.2 shows a reference model for a node that contains multiple MDS and MAU entities to achieve PhL redundancy.

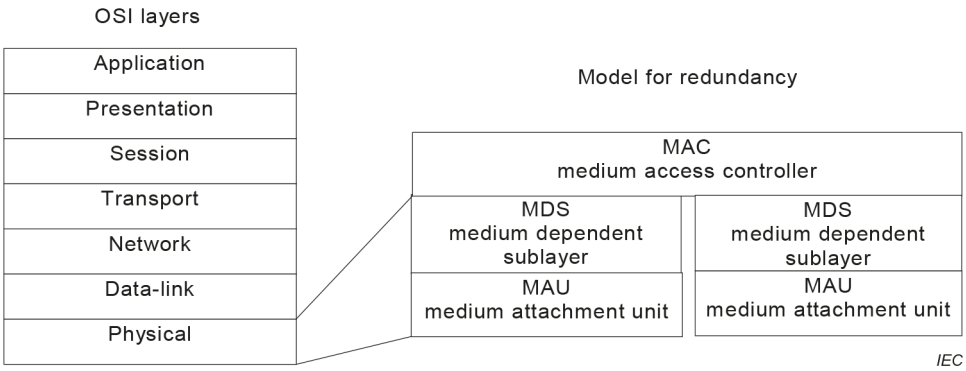


**Figure G.2 – Reference model for redundancy**

NOTE 1 The basic model is very similar to that used for the PhL Repeater devices specified in Clause G.2.

The redundant PhL entities ('channels') in a single node shall transmit the same information on all channels at all times. The PLS_FRAME_REQUEST and PLS_DATA_REQUEST shall be common to all redundant channels.

PLS_DATA_INDICATION, PLS_CARRIER_INDICATION, PLS_FRAME_INDICATION, PLS_LOCK_INDICATION and PLS_STATUS_INDICATION shall be independent for each channel. At any point in time, some nodes may listen to one channel while other nodes listen to the other channel. Since both channels are considered independent and identical, neither channel shall be considered to be primary or preferred even though they are generally referred to as channel A and channel B.

NOTE 2 The MAC sublayer on each node determines which channel to select for use by the upper layers of its node. This determination is made independently on each node.

As the same data is transmitted on both channels, the same data shall be received on both channels. If PLS_FRAME_INDICATION of a channel has not yet been true for a MAC frame when PLS_STATUS_INDICATION of the other channel signals Normal, an error shall be declared on the channel that did not detect the MAC frame. Because the smallest MAC frame has 64 Ph-symbols from the end of the start delimiter to the end of the end delimiter, the two channels shall be designed and installed such that the difference in MAC frame arrival times at the DLL is ≤ 64 Ph-symbol times.

NOTE 3 If one channel detects a Normal frame and the other channel does not, the DLL raises either DLL_EV_ERRA or DLL_EV_ERRB (see IEC 61158-4-2).

In the example of a node with redundant PhL entities and a NAP shown in Figure G.3, the MAC sublayer shall support the RM sublayer functionality to allow the data on the selected channel to be retransmitted onto the NAP port. At the same time, the data received on the NAP shall be transmitted onto both of the redundant channels. Any data sourced from this node shall be transmitted on both channels and the NAP at the same time.

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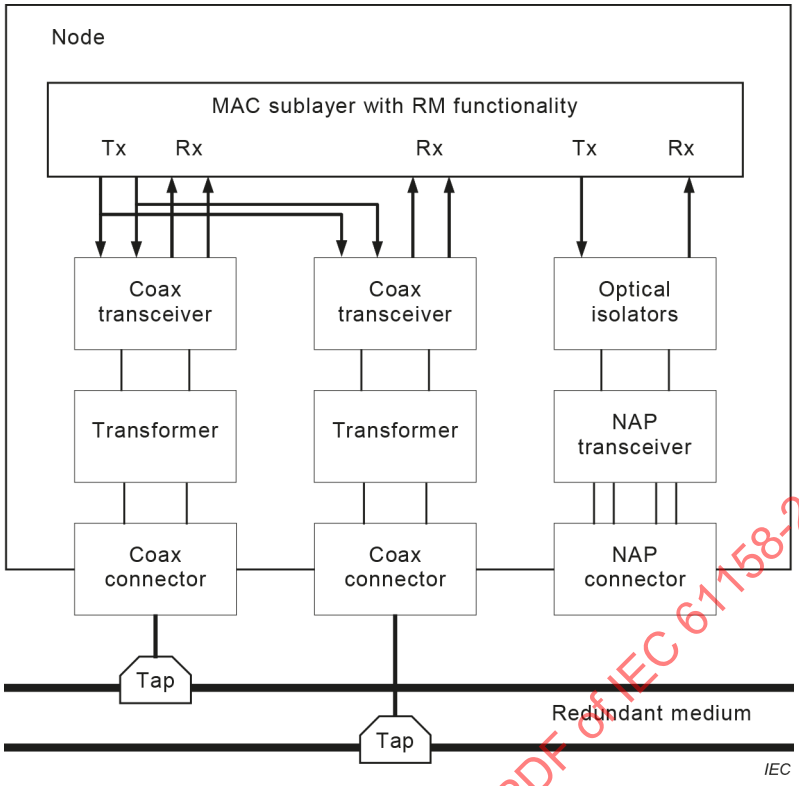


**Figure G.3 – Block diagram showing redundant coaxial medium and NAP**

## G.4 Ring repeater machine (RRM) sublayer

### G.4.1 Requirements

The minimum RRM shall be a three-port packet-based switch (see Figure G.4). Port 1, the primary port, shall see a given data packet only once, and may be used as an interface to point to point network segments or to a node. The two secondary ports, port 2 and 3, shall be equal and shall participate in the ring. The RRM shall decide which port to repeat data packets from and shall prevent data packets from endlessly circling the ring.

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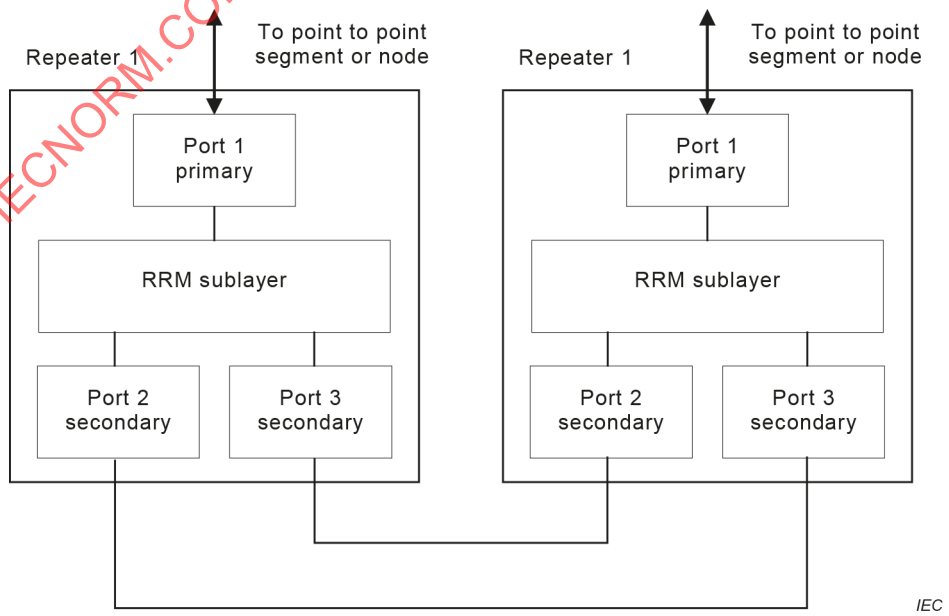


NOTE If one connection fails, the other can still be active.

**Figure G.4 – Block diagram showing ring repeaters**

### G.4.2 RRM sublayer operation

#### G.4.2.1 RRM requirements

To support RRM operation, the ports in each ring repeater shall meet the following requirements:

a) The secondary ports in each repeater shall have the ability to send and receive data at the same time. Each secondary port shall be independent of the other port, and each secondary port shall also have the ability to operate in a duplex fashion with a separate receiver and transmitter for each port.

b) The RRM shall have the ability to detect the network slot time, either by deciphering the moderator packet or by monitoring network activity, or by some other means.

c) Each secondary port shall have its own fiber port stack counter, called `fps_portx`, where x is the port number.

RRM operation shall start in an idle state when there is no network activity and `fps_port2` and `fps_port3` are both zero.

#### G.4.2.2 Port segmentation

The segmentation process shall be used by the RRM to reset counters for the synchronization purpose. At power up ports 2 and 3 shall begin in segmentation mode. The ports shall return to segmentation mode any time that communication is lost between adjacent fiber connected repeater ports. A port in segmentation mode shall block all messages from the other ports within the same module/node. Further a port in segmentation mode shall not rebroadcast segmentation frames from other ports within the same module.

NOTE For example, a node will enter segmentation mode during power up, when a fiber cable is disconnected from one of the fiber ports, or when traffic stops for one second or more.

In addition, the RRM shall force segmentation mode at any time the RRM detects that the counters are out of sync with traffic. Counter synchronization/resynchronization can be performed by determining the correct NUT boundaries.

A node shall enter segmentation mode based on the following conditions:

– upon power up,

– an echo of message is not received from an adjacent connected node,

– fiber link between two ports is quiet for more than one second, indicating no traffic (idle).

This method uses two special segmentation frames to acquire counter synchronization. The segmentations frames consist of M_symbols, as defined in 5.3.2. The segmentation frames are used for RRM handshaking during the segmentation process.

During segmentation, the affected port will broadcast as a query a preamble of 32 consecutive {1} M_symbols, as shown in Figure G.5. A port that is connected to a port broadcasting 32 consecutive {1} M_symbols that is in segmentation shall respond upon hearing this preamble with a (16 M_symbols preamble, start delimiter, 16 M_symbols preamble) sequence as shown in Figure G.6. A module transmitting preamble who is soliciting a response shall listen for a (preamble, start delimiter, preamble) sequence. Upon hearing a response it shall then reset the appropriate fps_portx counters, switch from port segmentation mode to port active mode. The port shall only be switched from segmentation mode to port active mode during a NUT boundary (quiet time). The segmentation process shall be used by the RRM to reset counters for the synchronization purpose. A port in segmentation mode and broadcasting queries shall continue until a response has been received back from a connected node. Upon receiving a response and during the NUT quiet time, the port may be put in service for transmission of data packets.

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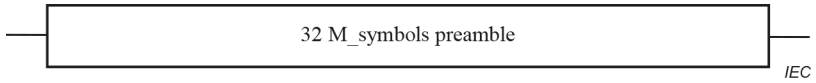


**Figure G.5 – Segmentation query**

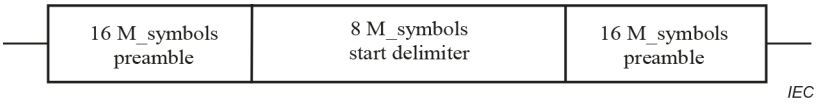


**Figure G.6 – Segmentation response**

### G.4.2.3 Main operation

The port that sees network activity first shall define where the data shall be repeated to. If port 2 sees network activity first, data shall be repeated from port 2 to port 1 and port 3 (see details in G.4.2.4). Similarly, if port 1 sees network activity first, data shall be repeated from port 1 to port 2 and port 3 (see details in G.4.2.5). Port 2 and 3 are equal, so the behavior of the RRM when port 2 sees activity first shall be identical to its behavior when port 3 sees activity first.

For correct power up operation and to recover from a media failure, the RRM requires a timeout with no network activity equal to the slot time.

NOTE 1 It could be required that SMAX be set to one greater than the actual number of nodes on the network to get this timeout. This method will guarantee at least one quiet time per NUT. There is no problem with multiple quiet times per NUT.

NOTE 2 The RRM does not store parts of the frame to determine whether or not echoes are actually the same data packet that was sent transmitted. The order of data packets is guaranteed by the Type 2 DLL that specifies that nodes are transmitted sequentially. It is not possible for the order of the echoed frames to become garbled, unless a media or module malfunction occurs. At the instant of media malfunction a frame can be lost. However, the network will continue to function normally since the other message path still exists.

NOTE 3 The maximum value of `fps_portx` can be calculated as follows. The shortest possible data packet length is 56 bits, or 11,2 µs. The minimum time between frames is the node turnaround time of 11,2 µs. At a maximum distance between the repeaters of 22,5 km, no more than 10 data packets can be travelling between neighbouring modules.

The corresponding main switch state machine for RRM operation is shown in G.4.2.6.

### G.4.2.4 RRM operation when port 2 (or port 3) is active first

In the case where port 2 is active first, the RRM operation shall be as follows.

Port 2 receives the data packet. Since `fps_port2` is zero, the RRM shall repeat the data to port 1, port 2 and port 3 and shall increment `fps_port3`.

NOTE 1 The data is repeated out of the receive port, port 2, because the neighbouring RRM expects this to occur. This action generates an echo packet.

The RRM shall then wait for either:

a) Network activity on port 1.

   See G.4.2.5 for resulting behavior.

b) New network activity on port 2.

   The RRM shall simply behave as it did previously.

NOTE 2 This requires that `fps_port3` be allowed to be greater than one and less than 11, since the worst-case timeout will have occurred by the time `fps_port3` reaches 11 (see case 4 below).

c) Reception of a data packet on port 3.

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This data packet should be the echo of the packet that was originally transmitted out of port 3 and is returned by the neighbouring module. Upon reception of this packet, `fps_port3` shall be decremented and the RRM shall return to the original idle state. Reception of this data packet shall not cause the RRM to repeat the packet to ports 1 and 2.

NOTE 3 This is because the `fps_port3` counter is non-zero, which indicates to the RRM that the received packet is an echo and is not a new data packet. Using this mechanism, the RRM prevents packets from endlessly circling the ring.

d) A timeout with no network activity equal to the slot time occurs.

In this case, the neighbouring module has not returned the data packet transmitted out of port 3. This can have occurred due to a module malfunction or a media failure. If this occurs, `fps_port2` and `fps_port3` shall be reset to zero.

Port 2 and 3 are equal, so the behavior of the RRM when port 3 sees activity first shall be identical to its behavior when port 2 sees activity first (roles for port 2 and 3 shall be inverted in sequence above).

The corresponding state machine for port 2 (and 3) is shown in G.4.2.6.

#### G.4.2.5 RRM operation when port 1 is active first

In the case where port 1 is active first, the RRM operation shall be as follows.

Port 1 receives the data packet. The RMM shall repeat this packet by transmitting it out of port 2 and 3. When the port 2 and 3 transmit this data packet, they shall both increment their respective `fps_portx` counters.

The RRM shall then wait for either:

a) Network activity on port 1.

The RRM shall simply behave as it did previously, namely transmitting the packet out of port 2 and port 3 and incrementing `fps_port2` and `fps_port3`.

b) Network activity on port 2 or port 3.

Similar to case 3 in G.4.2.4: in this situation the next data packet that port 2 or port 3 receives should be an echo from a neighbouring module. Upon reception of this data packet, the port shall decrement its fps_portx counter. It shall not repeat this echoed packet.

c) A timeout with no network activity equal to the slot time occurs.

Again, this means that echoes were not received (for whatever reason). In this case, `fps_port2` and `fps_port3` shall be reset to zero.

The corresponding state machine for port 1 is shown in G.4.2.6.

#### G.4.2.6 State machines

Figure G.7 shows the main switch state machine for RRM operation.

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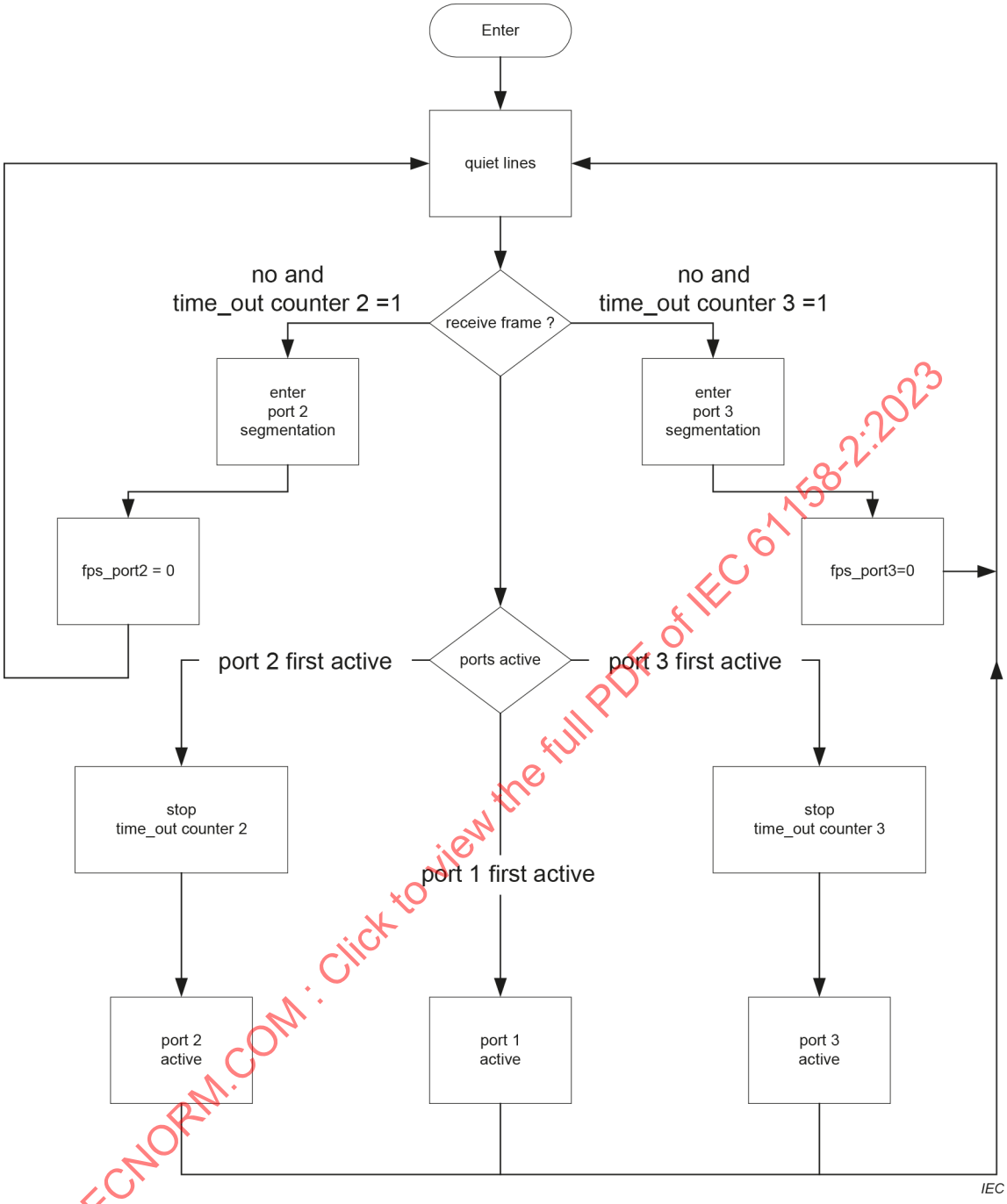


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**Figure G.7 – Main switch state machine**

Figure G.8 shows the RRM behavior when port 1 is active first.

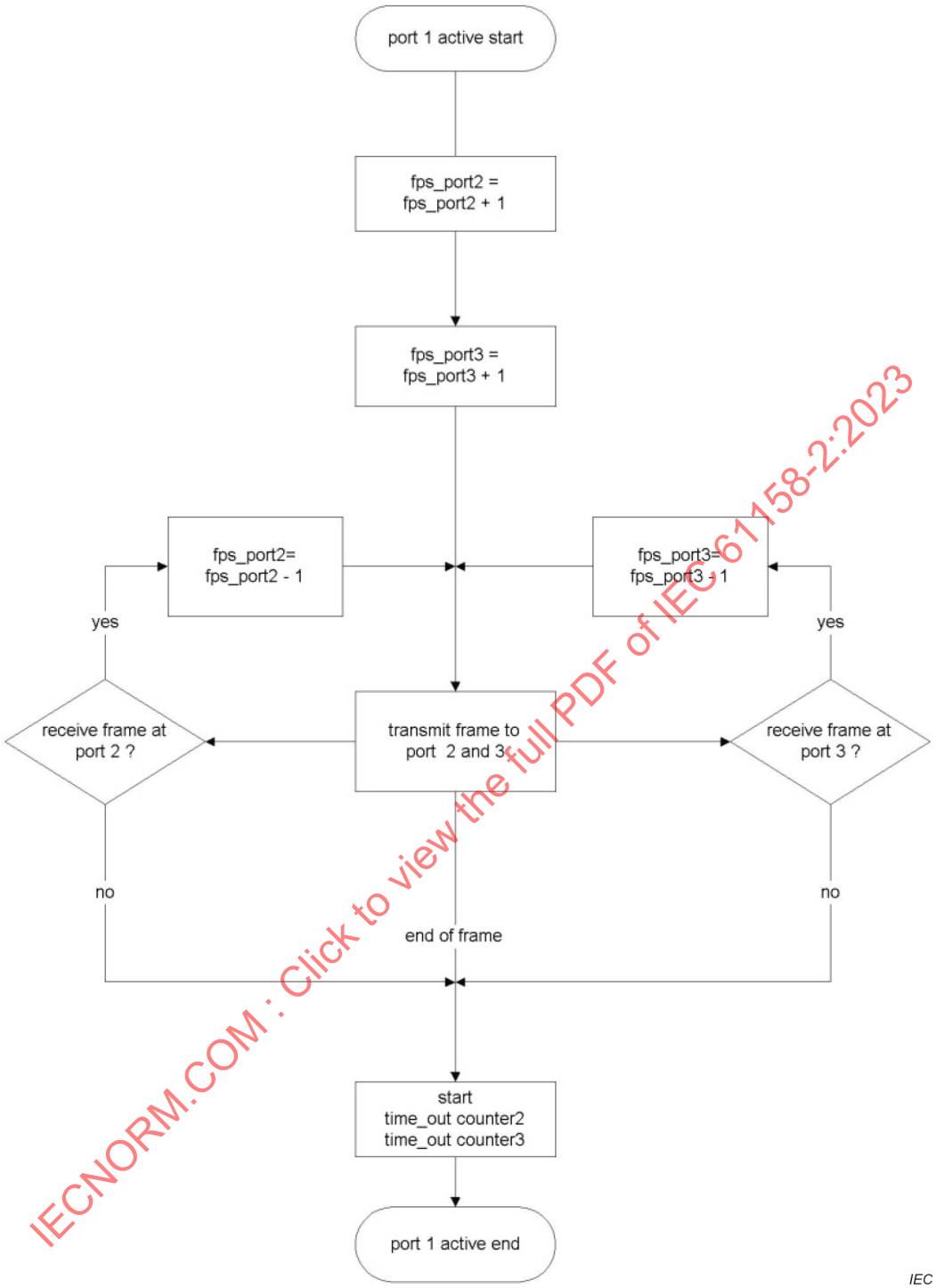


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**Figure G.8 – Port 1 sees network activity first**

Figure G.9 shows the RRM behavior when port 2 is active first. RRM behavior when port 3 is active first shall be identical, with "2" and "3" being exchanged in Figure G.9.

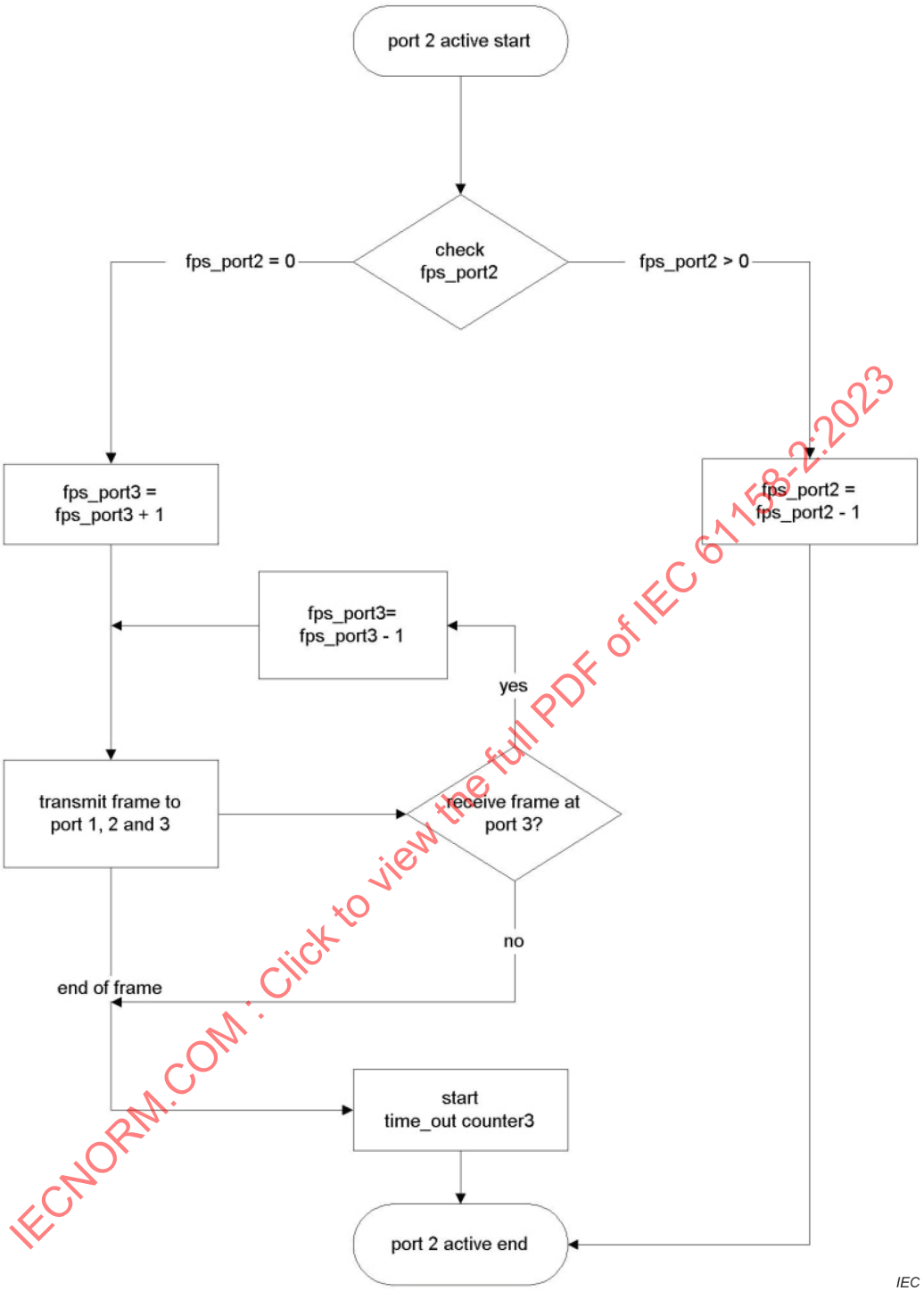


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**Figure G.9 – Port 2 sees network activity first**

# Annex H
(informative)

# Type 2: Reference design examples

## H.1 MAU: 5 Mbit/s, voltage mode, coaxial wire

### H.1.1 Transceiver reference design example

The transmitter, shown in Figure H.3 and Figure H.4 is made up of a CMOS pre-transmitter pair, transistor transmitter pair, and the transformer. The series Schottky diodes and over voltage diodes are discussed later in Clause H.1.

The pre-transmitter is a 74AC08. This device allows the combination of the data and enables signals and provides the base drive for the drive transistors.

The transistor driver uses a pair of MMBT2369 transistors. These are high-speed switches selected for important performance factors including the following

- collector current capability of at least 150 mA;
- fast switching characteristics typically better than 10 ns;
- small size SOT-23;
- low $V_{ce}$ sat at $I_c$ about 0,5 V;
- low output capacitance 4,0 pF nom.

The series base resistors define the required base drive and the shunt base resistors reduce turn off time. The base capacitors provide slew rate limiting that improves radiated emissions slightly.

The transformer (1:1:1) couples the transmit signal to the medium. Each side of the driver pair controls one side of the center tapped transformer, such that the driver operates in a push pull configuration. The voltage presented to each side of the driver is 4,2 V typical (at $V_{cc}$ = 5 V) and 4,7 V maximum (at $V_{cc}$ = 5,5 V). This corresponds to a peak driver output current (into 37,5 Ω) of about 110 mA typical and about 125 mA maximum. The total peak supply current including the base drive is about 140 mA.

The receiver circuitry is conceptually simple. The complexity arises in controlling the detection thresholds. Figure H.1 is a schematic reduced to include just the important components of the RXDATA detector.

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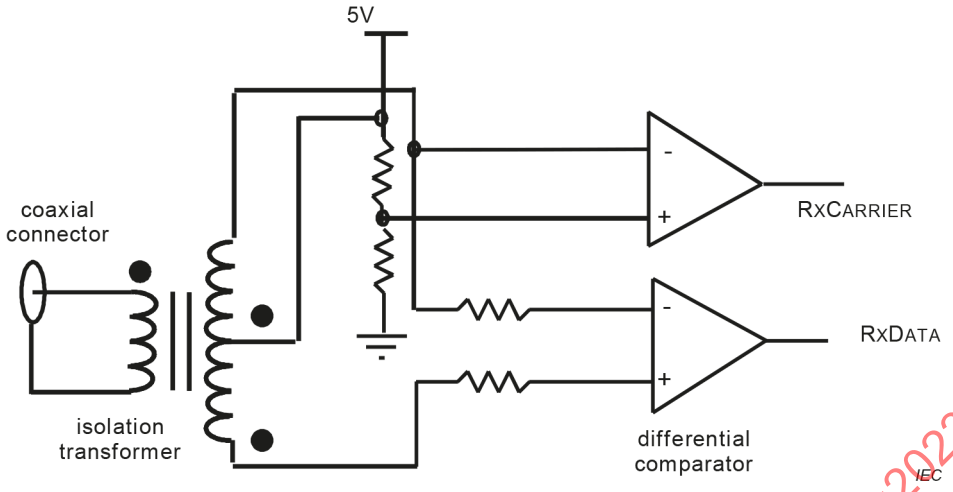


**Figure H.1 – Coaxial wire MAU RXDATA detector**

The detector example uses a 26LS32A (quad receiver) selected for high input impedance. Many devices of this class offer a minimum input impedance spec of 6 kΩ, whereas one supplier has a specification of 12 kΩ minimum. A special screening is required for this part, in the reference design, to allow an improved sensitivity over a smaller common-mode range. The important specifications for this device are the following:

a) high input impedance (this is required to meet the node input impedance requirements): 15 kΩ typical, 12 kΩ minimum;

b) low worst case threshold voltages: ± 100 mV over a common-mode range of 0 V to 5,5 V;

c) 0 °C to 85 °C temperature range;

d) single 5 V supply;

e) ±10 % supply tolerance;

f) fast enough to handle the Manchester encoded 5 Mbit/s bit rate.

For the Rx detector shown in Figure H.1 and in the schematic diagrams shown in Figure H.3 and Figure H.4, Table H.1 shows the input voltage levels for transition of RXDATA and RXCARRIER.

**Table H.1 – 5 Mbit/s, voltage-mode, coaxial wire receiver output definitions**

| Input voltage at medium | RXDATA | RXCARRIER |
|---|---|---|
| $V_{in}$<-140 mV | false (0) | false(0) |
| -140 mV < $V_{in}$< 23 mV | undefined | false(0) |
| 23 mV < $V_{in}$< 140 mV | undefined | undefined |
| 140 mV < $V_{in}$< 255 mV | true(1) | undefined |
| 255 mV < $V_{in}$ | true(1) | true(1) |

The series resistors on the input to the 26LS32A are different in value to counteract the threshold offset caused by the 26LS32A's fail-safe resistors.

Carrier detection uses another of the receivers in the 26LS32A. It performs a single ended comparison of the input signal to a DC threshold as shown in the simplified schematic of Figure H.2.

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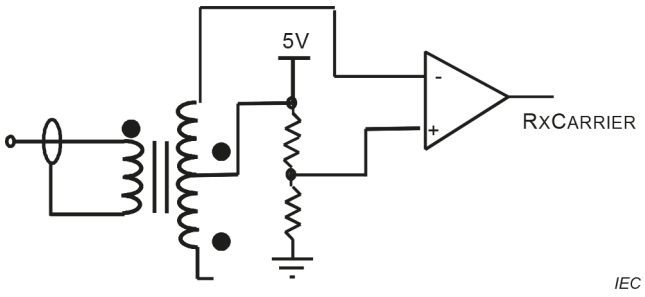


**Figure H.2 – Coaxial wire MAU RXCARRIER detection**

The RXCARRIER signal looks just like the RXDATA signal at high signals. At low signal levels it looks similar, except that the RXCARRIER 'one' pulse widths are narrower than those of the data are. When no signal is present the RXCARRIER output is always low, unlike the data, which is undefined and could be changing state with noise.

Figure H.3 shows an example of a redundant transceiver and Figure H.4 shows an example of a single channel transceiver.

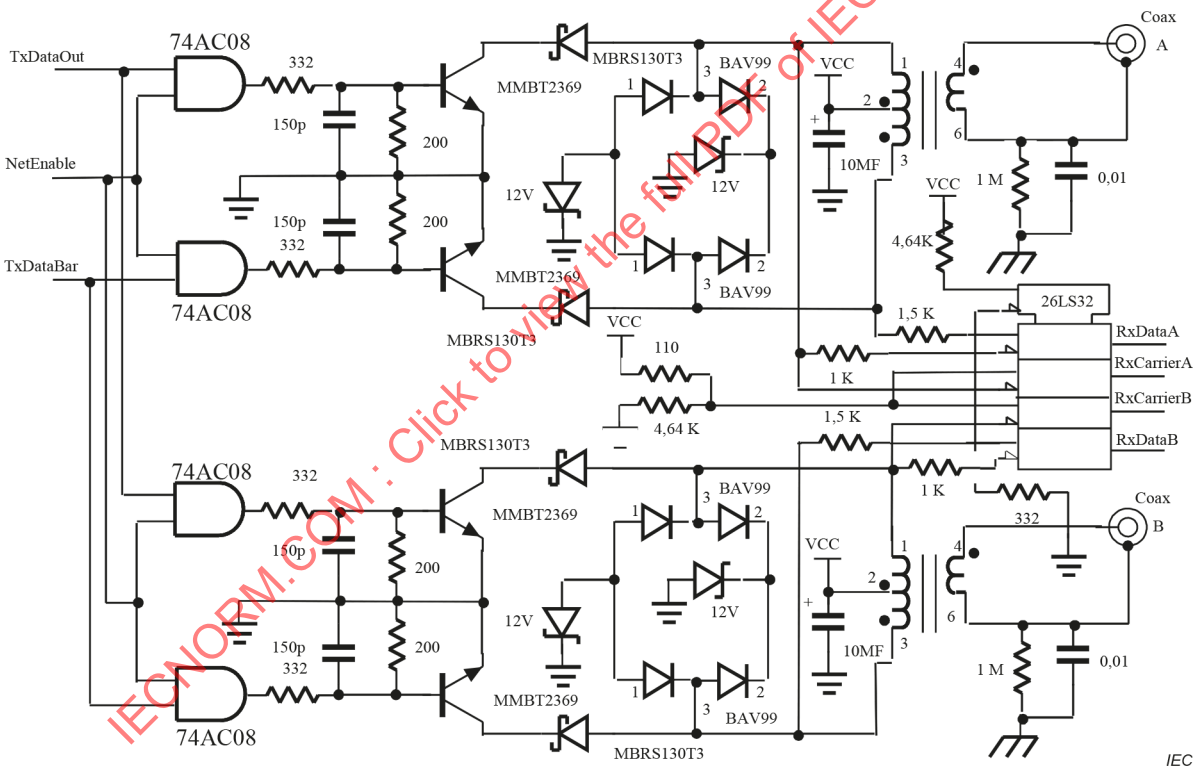


**Figure H.3 – Redundant coaxial wire MAU transceiver**

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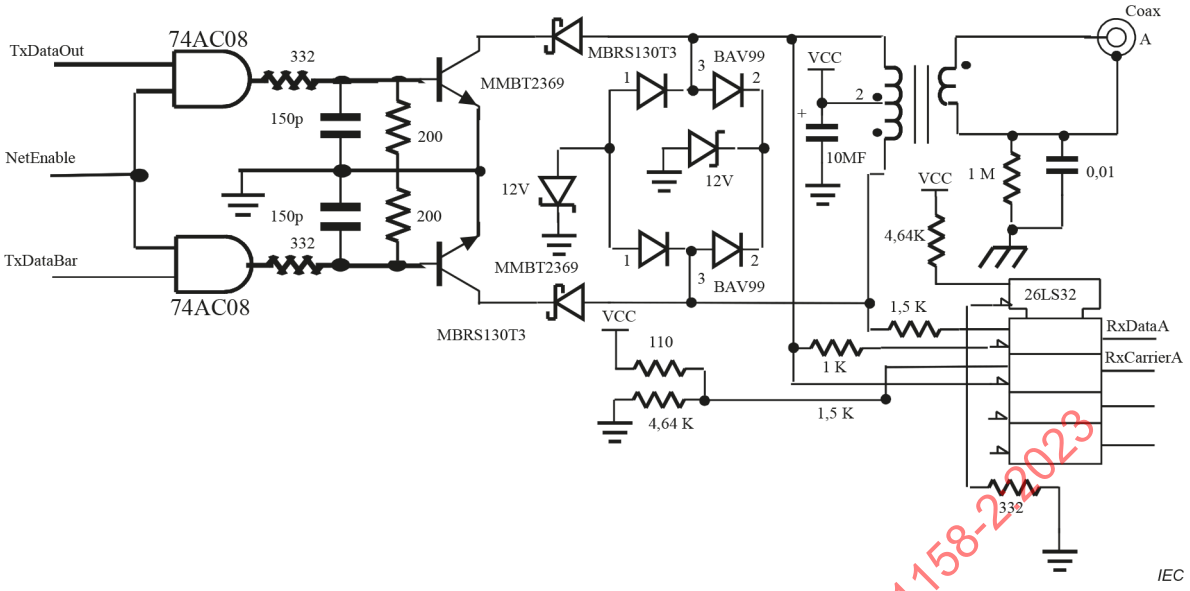


**Figure H.4 – Single channel coaxial wire MAU transceiver**

### H.1.2 Transformer reference design example

Core is IEC 61596 type EP-7, ungapped, with minimum $A_L$ = 1 100 nH per turn$^2$. Construction sequence for the windings is as follows:

a) winding 1 between pins 3 and 2: diameter 0,127 mm, 18 turns;

b) 1 mil. tape;

c) winding 2 between pins 2 and 1: diameter 0,127 mm, 18 turns;

d) 1 mil. tape;

e) winding 3 between pins 4 and 6: diameter 0,127 mm, 18 turns;

f) outer wrap.

### H.1.3 Tap reference design example

An example design of the Tap is shown in Figure H.5. The autotransformer (T1) is wound on a Ferronics 11-720B toroidal core. Winding is 18 turns bifilar, single strand, with minimum overlap of 0,254 mm diameter heavy poly-nylon magnet wire.

Measured electrical characteristics are as shown in Table H.2.

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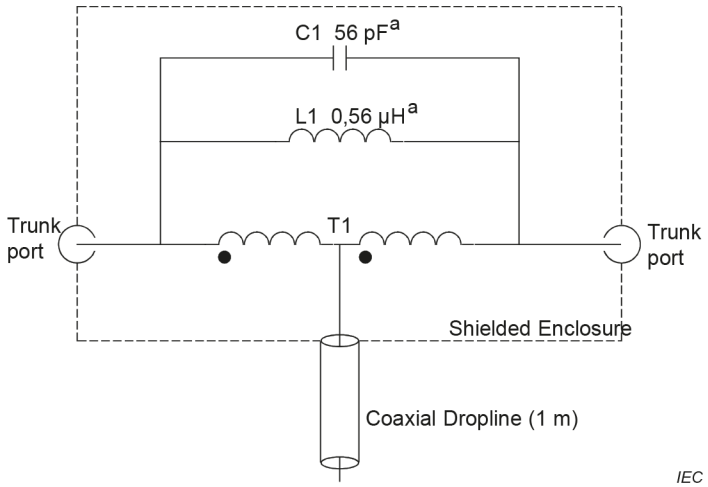
**Table H.2 – Coaxial wire medium toroid specification**

| Parameter | Value |
|---|---|
| Leakage inductance | 75 µH at 300 kHz |
| Magnetising inductance | 890 µH at 300 kHz |
| Winding capacitance | 20 pF at 25 MHz |
| Winding loss resistance | 0,1 Ω at 300 kHz |
| Core loss resistance | 16 kΩ at 1,3 MHz |




[a] Values shown are nominal. The actual values should be adjusted to meet the scattering parameter requirements detailed in Figure 108.

**Figure H.5 – Coaxial wire medium tap**

## H.2 Network access port (NAP)

The design of the node NAP circuitry shown in the schematic in Figure H.6 is relatively simple. A single transmitter and receiver are used. The receiver has an internal offset voltage added to produce a zero data state for the fault conditions (medium removed, short circuited, etc.) listed in the requirements shown in Table 134. The polarity of the receive signal is high for data zero. Differential TIA-422-B transmitters and receivers are used to improve noise rejection.

Back biased diodes are provided on the NAP transmitter lines to prevent damage due to electrostatic discharge.

For the fiber medium option, the NAP circuitry is the same. The coaxial wire medium transceivers are simply replaced by optical fiber transceivers.

The schematic for a non-isolated permanent node uses a transceiver similar to the one shown Figure H.6.

As in the node, a single transmitter/receiver is used for data. The same offset circuit is used to guarantee the correct disconnect and power off levels. In addition, the same transmitter protection diodes are used.

For a transient node that derives its power from a grounded source, opto-isolators are used. The design shown in Figure H.7 shows how opto-isolators and a DC-DC converter can be used to supply the required ground isolation.

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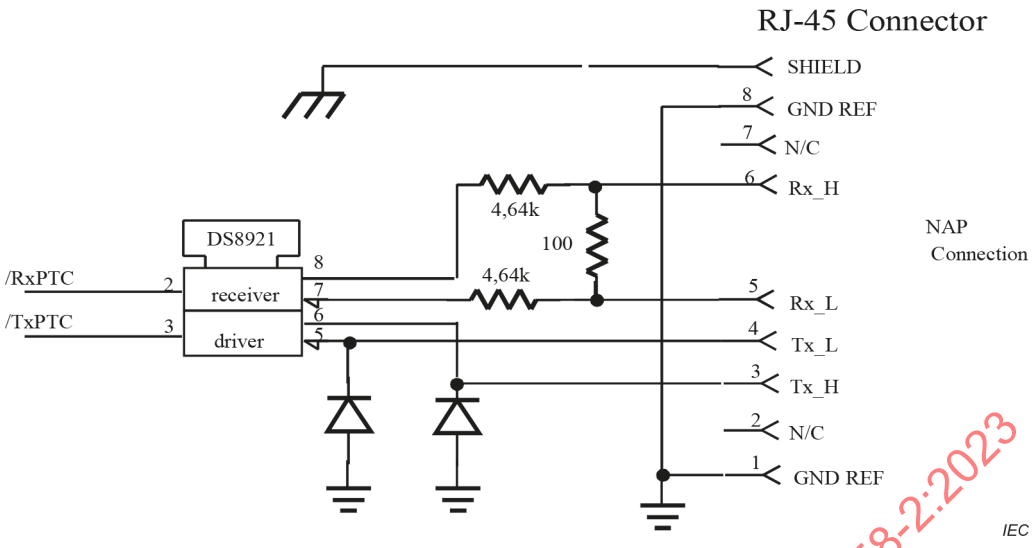


**Figure H.6 – Non-isolated NAP transceiver**

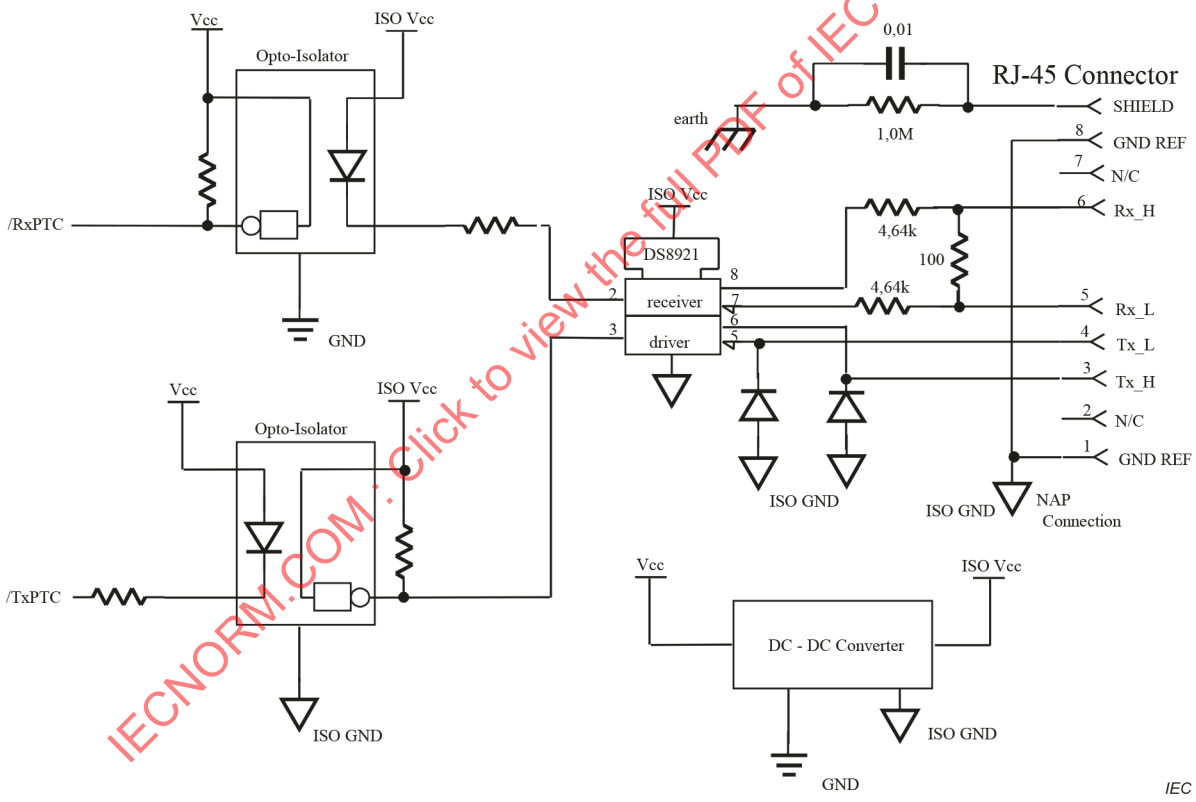


**Figure H.7 – Isolated NAP transceiver**

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# Annex I
(normative)

# Type 3: Connector specification

## I.1 Connector for synchronous transmission

### I.1.1 General

The topology can be in the form of a tree, line or a combination of the two. The tees connect the stations (e.g. field devices) to the bus cable; they shall have an IP 65 rating. The tee connect can be constructed in single T or multiple T, see Figure I.1. The tee function can also be integrated into the station.

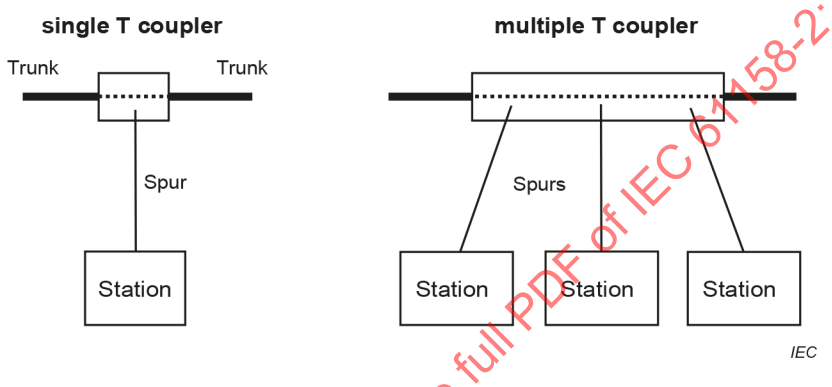


**Figure I.1 – Schematic of the station coupler**

### I.1.2 Pin assignment of M12 circular connector

The contacts of the M12 circular connector shall be assigned to functions as shown in Table I.1 and Figure I.2.

**Table I.1 – Contact assignments for the external connector for harsh industrial environments**

| Contact No. | Function |
|---|---|
| 1 | Data + with the option of power + |
| 2 | not connected |
| 3 | Data - with the option of power - |
| 4 | not connected |
| Thread | Shield |

The shield shall be concentric around the thread. The shield potential shall be transmitted via the thread. Existing Type 3 devices with connected pin 4 are still conforming to this document. For new devices the pin 4 shall not be used. Existing pre-harnessed Type 3 cables with connected pin 4 are still conform to this document. For new cables the pin 4 shall not be connected.

The M12 circular connector and the female connector shall be IP 65 or higher.

The male and female contacts shall be designed such that they maintain their transmission properties even in a corrosive atmosphere, e.g. chemical environment.

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The centered hole of the female plug shall not be fitted because of the increased air and creepage distances in potentially explosive atmospheres, see Figure I.2.

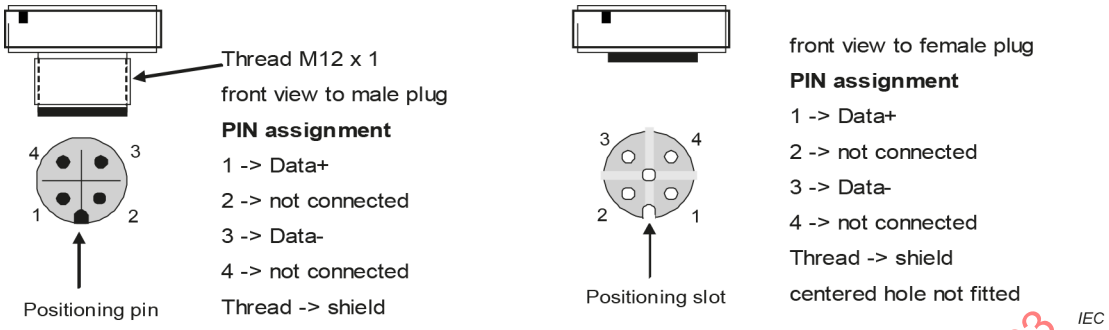


**Figure I.2 – Pin assignment of the male and female connectors IEC 60947-5-2 (A coding)**

### I.1.3 Connection between a tee and a station

The tees and the stations are connected using a shielded circular connector M12. The tee can be connected directly to the station or a branch using a shielded M12 connector.

Always make sure that the bus cable shield is applied over a large surface according to the grounding guidelines (for grounding and shielding, see 21.8.6 and 21.8.7).

Field termination techniques such as screw or blade terminals and permanent termination may also be used.

## I.2 Connector for asynchronous transmission

### I.2.1 Connector for non-intrinsic safe asynchronous transmission

Each station is connected to the medium via a 9-pin sub-D connector. The female side of the connector is located in the station, while the male side is mounted to the bus cable.

The mechanical and electrical characteristics are specified in IEC 60807-3.

Preferably a metal connector housing should be used. When put together both parts of the connector should be fixed by conducting screws. The connection between the cable sections and the stations should be realized as T-connectors, containing three 9-pin sub-D connectors (two male connectors and one female connector). Such T-connectors allow disconnection or replacement of stations without cutting the cable and without interrupting operation (on line disconnection).

The pin assignments for the connectors are shown in Table I.2 and Figure I.3

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**Table I.2 – Contact designations 9-pin sub-D connector**

| Pin number | RS-485 ref. | Signal name | Meaning |
|---|---|---|---|
| 1 | | SHIELD (see Notes 1, 2) | Shield, protective ground |
| 2 | | M24V (see Note 1) | Minus 24 V output voltage |
| 3 | **B/B'** | RxD/TxD-P | Receive/transmit-data-P |
| 4 | | CNTR-P (see Note 1) | Control-P |
| 5 | **C/C'** | DGND | Data ground |
| 6 | | VP | Voltage-plus |
| 7 | | P24V (see Note 1) | Plus 24 V output voltage |
| 8 | **A/A'** | RxD/TxD-N | Receive/transmit-data-N |
| 9 | | CNTR-N (see Note 1) | Control-N |

NOTE 1 Signals are optional.

NOTE 2 Recommended to be not connected.

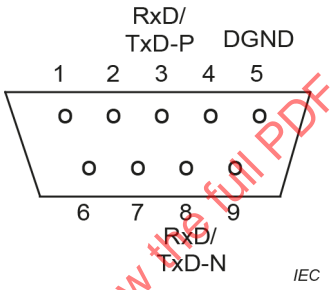


**Figure I.3 – Connector pinout, front view of male and back view of female respectively**

The Data Ground, connected to pin 5, and the Voltage-Plus, connected to pin 6, supply the Bus Terminator.

The control signals CNTR-P and CNTR-N, connected to pin 4 and pin 9, support direction control when repeaters without self-control capability are used. TIA-485-A:1998 signaling is recommended. For simple devices the signal CNTR-P may be a TTL signal (1 TTL load) and the signal CNTR-N may be grounded (DGND). The definition of signaling is not a subject of this document.

The DC 24 V output voltage, according to IEC 61131-2:2017, Table 16, allows the connection of operator panels or service devices without integrated power supply. If a device offers 24 V output voltage it shall allow for a current load up to 100 mA.

### I.2.2 Connector for intrinsic safe asynchronous transmission

#### I.2.2.1 IP20 connecting technique

For mechanical and electrical characteristics, see I.2.1.

The pin assignments for the connectors are shown in Table I.3.

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**Table I.3 – Contact designations**

| Pin number | RS-485 ref. | Signal name | Meaning |
|---|---|---|---|
| 1 | | SHIELD (see Note 1) | Shield |
| 2 | | NC | (Not connected) |
| 3 | **B** | RxD/TxD-P | Receive/transmit-data-P |
| 4 | | NC | (Not connected) |
| 5 | | ISM (see Note 2) | Bus termination minus |
| 6 | | ISP (see Note 2) | Bus termination plus |
| 7 | | NC | (Not connected) |
| 8 | **A** | RxD/TxD-N | Receive/transmit-data-N |
| 9 | | NC | (Not connected) |

NOTE 1 Signal is optional and usually not connected.

NOTE 2 Signal is current-limited by resistors.

The ISM, connected to pin 5, and the ISP, connected to pin 6, supply the Bus Terminator.

Series inductances in the data lines, as used in non-intrinsic safe connectors, shall not be used. The wiring from bus input to bus output in the connector shall be designed for a maximum current of 4,8 A. The trap to the communication device (A, B, ISM and ISP wire) shall be designed for the maximum input current of 2 × Io (~300 mA). The appropriate values for the design of the connector (track widths, separation distances etc.) shall be according to IEC 60079-11.

The separation distances between A, B, ISM and ISP wire from the connector's trap to the current limiting resistors in the communication device shall be infallible in accordance IEC 60079-11.

### I.2.2.2 IP65 connecting technique

The 4-pin M-12 connector according to IEC 60947-5-2 is used for fieldbus systems where extreme industrial environments exist. Only shielded connectors are permitted. The connectors feature a mechanical key (B-coding). The pin assignments for the connectors are shown in Table I.4.

**Table I.4 – Contact designations 4-pin M-12**

| Pin number | RS-485 ref. | Signal name | Meaning |
|---|---|---|---|
| 1 | | ISP (see Note) | Bus termination plus |
| 2 | **A** | RxD/TxD-N | Receive/Transmit-Data-N |
| 3 | | ISM (see Note) | Bus termination minus |
| 4 | **B** | RxD/TxD-P | Receive/Transmit-Data-P |
| Threaded joint | | SHIELD | Shield |

NOTE Signal is current-limited by resistors.

The ISM, connected to pin 3, and the ISP, connected to pin 1, supply the Bus Terminator.

Series inductances in the data lines, as used in non-intrinsic safe connectors, shall not be used. The connector contacts shall be designed for the maximum current of 4,8 A.

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The connector at the field device shall be a female type M12 connector, as shown in Figure I.4.

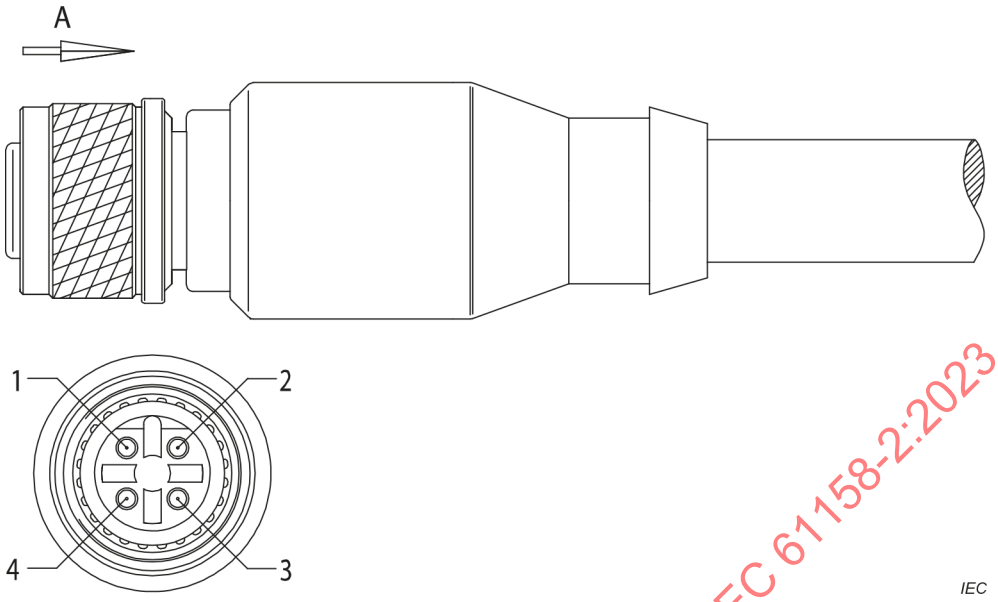


**Figure I.4 – Connector pinout, front view of female M12 connector**

The connector at the cable side shall be a male type M12 connector, as shown in Figure I.5.

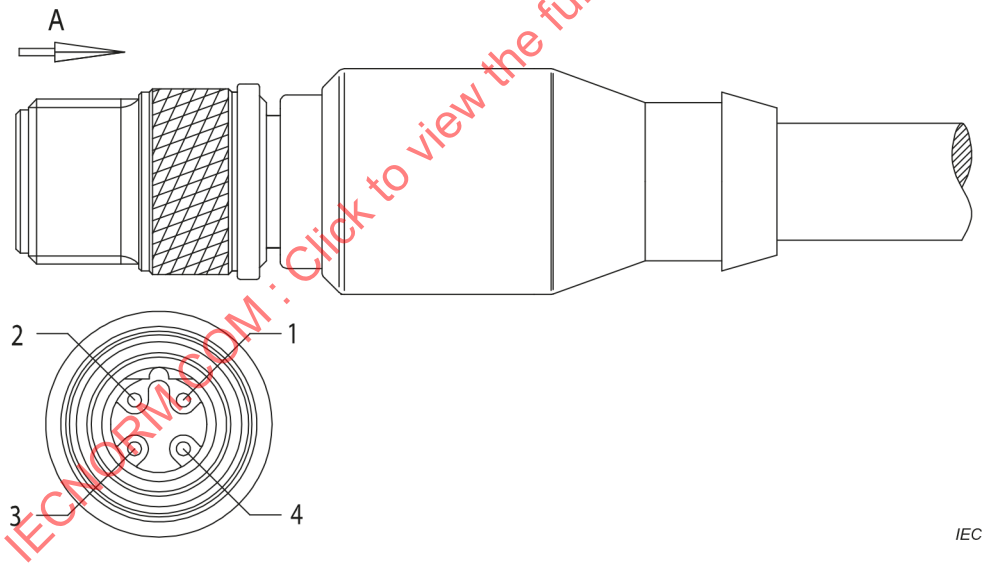


**Figure I.5 – Connector pinout, front view of male M12 connector**

The fieldbus topology has a linear structure. The junctions (tees), as shown in Figure I.6, connect the individual devices to the trunk cable. The stub length should be as short as possible. Series inductances in the data lines shall not be used.

The Tee shall be uniform and concentric all the way to the cap nut (Threaded joint), (metal connectors and similar).

The supply voltage provided by the devices for driving the termination resistance shall be passed on via the Tee.

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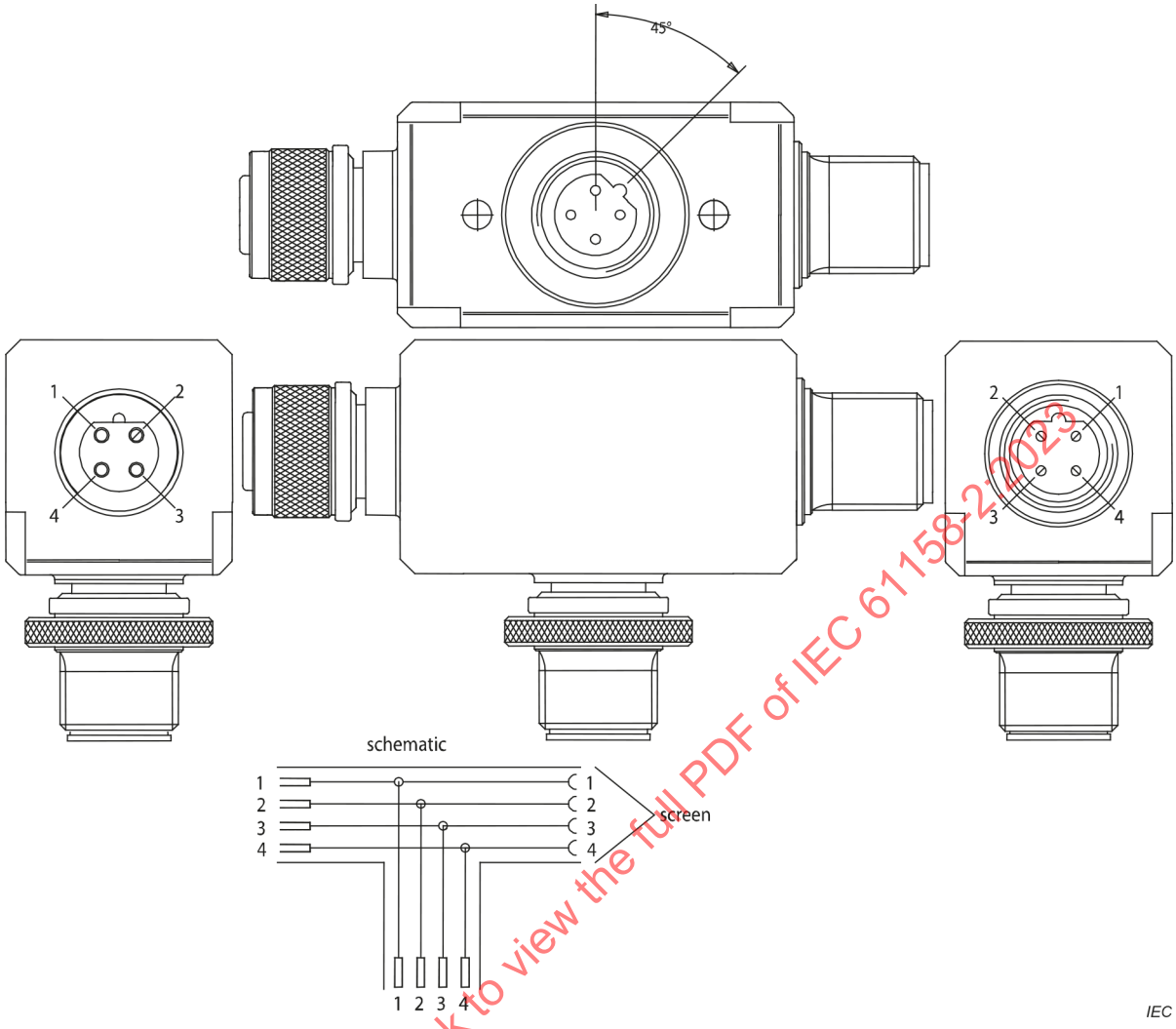


**Figure I.6 – M12 Tee**

Figure I.7 shows the pinout and schematic of the M12 bus termination.

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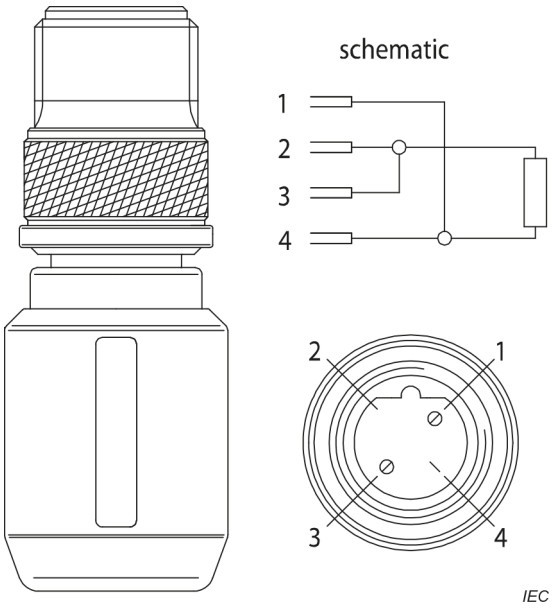


**Figure I.7 – M12 Bus termination**

#### I.2.2.3 Terminal connecting technique

The terminal connection shall provide the signals A, B, ISM and ISP. The terminal designation shall be according to the signal name. Alternatively, when internal bus termination is available, only the signals A and B may be provided. The communication device shall provide a suitable connection for cable shield.

The wiring from bus input to bus output in the terminal shall be designed for a maximum current of 4,8 A.

### I.3 Connectors for fiber optic cable

#### I.3.1 Connectors for glass fiber optic cable (850 nm and 1 300 nm wavelength)

Glass fiber optic cables are connected or interconnected using type BFOC/2.5 connectors according to IEC 61754-2.

NOTE Butt joint contact of the fibers, so-called physical contact (PC), minimizes the attenuation and reflection for fiber-fiber connections.

#### I.3.2 Connectors for plastic and glass fiber optic cable (660 nm wavelength)

Plastic fiber optic cables are preferentially connected or interconnected using type BFOC/2.5 connectors.

Other connector elements are admissible if they are compatible to reference fiber 980/1 000 µm plastic fiber or 200/230 µm glass fiber.

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# Annex J
(normative)

## Type 3: Redundancy of PhL and medium

The use of a redundant PhL improves the reliability of the fieldbus. When implemented, the redundant PhL contains two separately installed medium (bus cable "a" and bus cable "b") and two complete Medium Attachment Units (MAUs) per station. The redundancy architecture in principle is shown in Figure J.1.

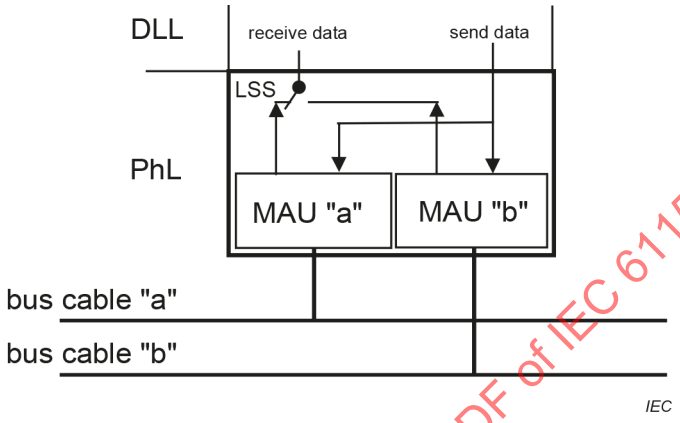


**Figure J.1 – Redundancy of PhL MAU and Medium**

The basic principle, shown in Figure J.1, assumes that data is sent out simultaneously by both MAUs (transceivers) onto both mediums (bus cable "a" and bus cable "b"). In contrast to this, each station receives from only one medium (either bus cable "a" or bus cable "b"). The receive channel is selected by a Line Selector Switch (LSS), which is located between both MAUs and the DLL. The Line Selector Switch is controlled by the Ph-management. For this the Medium Access Control (MAC) of each station's DLL monitors the medium activity, and gives corresponding information to DL-management (see IEC 61158-3-3 the DLMS Event and Get Value service) independently of any other station. The main switching conditions for masters and slaves are as follows:

– two or more successive invalid frames are received; invalid means frames with invalid format, invalid parity bit or invalid frame check sequence are detected;
– time out timer $T_{TO}$ expires (see IEC 61158-4-3, 5.5);
– no Syn. Time $T_{SYN}$ (i.e. line idle for at least $T_{SYN}$) was detected during one Synchronization Interval Time $T_{SYNI}$ (see IEC 61158-4-3, 5.5).

Dependent on the execution, further switch conditions may be selected.

The selected receive channel "a" (primary) or "b" (alternate) is notified to the Ph-management, see 6.3. The Ph-management then provides this information to the PHMS-user via the management interface.

NOTE There is no preferred receive channel after the system initialization is finished.

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# Annex K
(normative)

# Type 3: Optical network topology

## K.1 Signal flow in an optical network

Connections to Master or Slave stations or coupling elements, such as star couplers, repeaters, etc. are the user's responsibility. However, the user shall make sure that the various interfaces are compatible with each other.

This Annex K contains the description of optical Medium Attachment Units (MAU) to connect to a fiber optical network with or without echo.

## K.2 Connection to a network with echo

After a delay, the optical MAU receives its own transmit signal from the network again as an echo. Echo signal detection can be used to confirm the status of the physical connection to the optical MAU at the other end of the line (see Figure K.1).

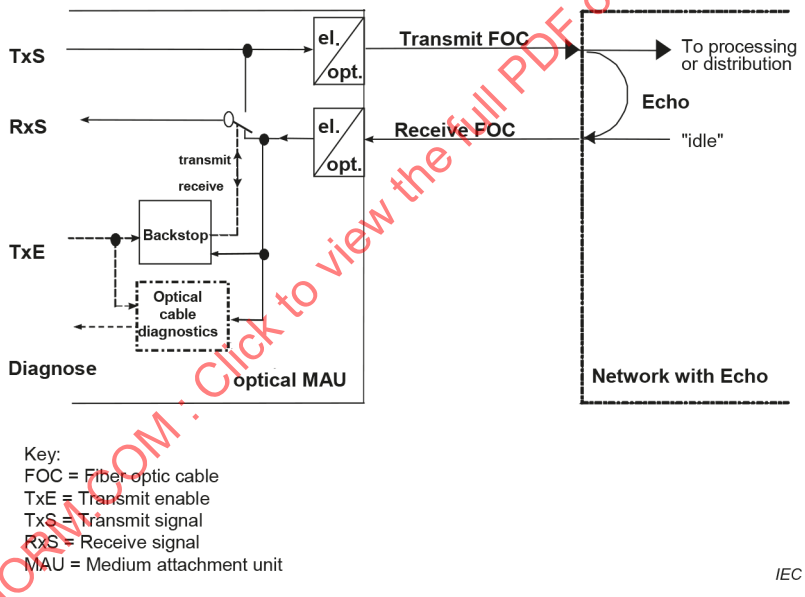


**Figure K.1 – Optical MAU in a network with echo**

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The echo is returned with a delay equal to twice the signal delay to the coupling element (e.g. star coupler) that generates the echo. With a ring structure, the delay corresponds to one cycle of the ring. The receive signal delay, which does not occur in asynchronous transmission networks, shall not cause operating faults or error messages. The transmitting optical MAU shall remove the echo signal from the network. The echo signal shall not be returned to the network by the transmitter again and shall not lead to duplication of the message as a "new" message within a field device.

## K.3 Connection to a network without echo

The optical MAU does not receive its own transmit signal from the network again as an echo in such a network. The receive line remains idle during the transmit procedure as shown in Figure K.2. No information is available on the status of the link.

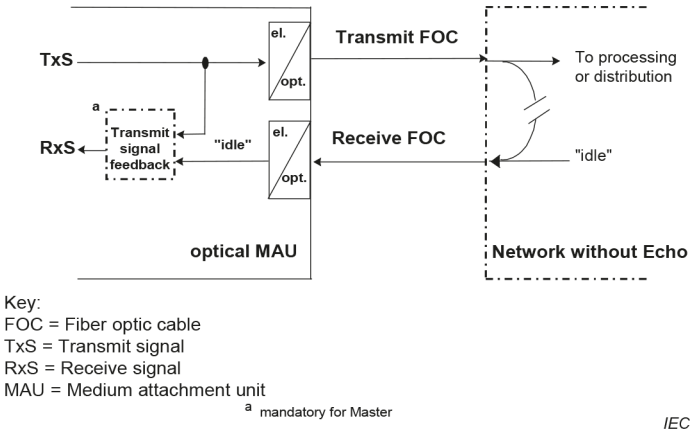


**Figure K.2 – Optical MAU in a network without echo**

Masters shall fulfil the requirements of token acknowledgement locally, for example with hardware feedback (emulation) of the transmit signal.

## K.4 Optical MAU with echo function

An optical MAU with echo function returns the signal received at an input gate to the associated return line as shown in Figure K.3. This allows an appropriate optical MAU at the other end of the optical line to check for its own message by monitoring for the echo.

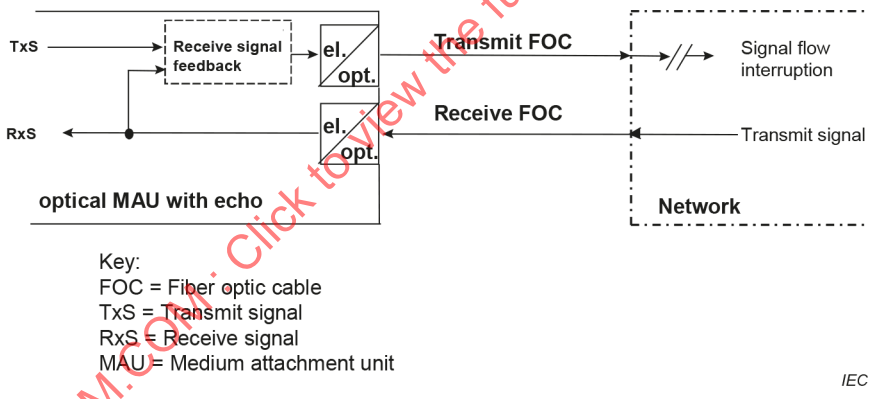


**Figure K.3 – Optical MAU with echo via internal electrical feedback of the receive signal**

## K.5 Optical MAU without echo function

An optical MAU without echo function does not return the signal received at an input gate to the associated return line. The output remains at the idle level (see Figure K.4).

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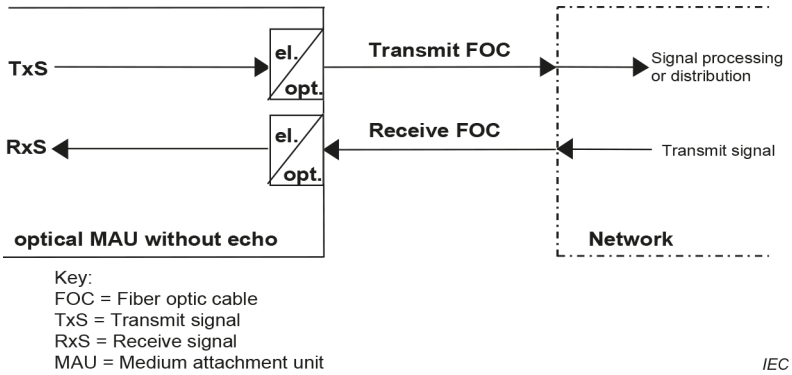


**Figure K.4 – Optical MAU without echo function**

## K.6 Examples of topology

### K.6.1 General

Clause K.6 illustrates some of the network topologies that can be constructed in accordance with this document. This does not imply that these are the only possible topologies.

### K.6.2 Star topology

Central signal distribution using active star couplers results in a star-shaped structure for the optical network with the active star coupler as the central element (see Figure K.5).

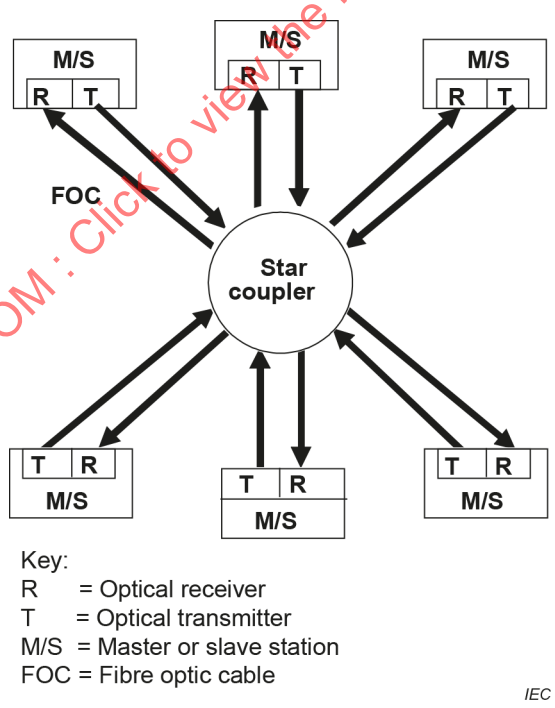


**Figure K.5 – Optical network with star topology**

The active star coupler is used in optical networks as a central signal distributor with signal level restoration. Regeneration of the signal timing (re-timing) is available as an option. The active star coupler requires an electrical power supply. The active star coupler converts optical signals received at an input into electrical signals. Internal signal processing takes place electrically. Electro-optical converters at the output gates transmit an optical signal.

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### K.6.3 Ring topology

A ring structure, as shown in Figure K.6, requires additional control measures in the station. A transmitting station (Master/Slave) shall interrupt the ring logically and maintain the interruption after the end of the telegram until the telegram has passed around the ring once and returned to the transmitting station, where it is discarded.

Stations in receive mode shall output the received signal on the transmit side again.

Stations have to be provided with a protection, which prevents dropping the ring into a statically closed ring. This problem can occur if e.g. a fault spike occurs during an "idle" phase.

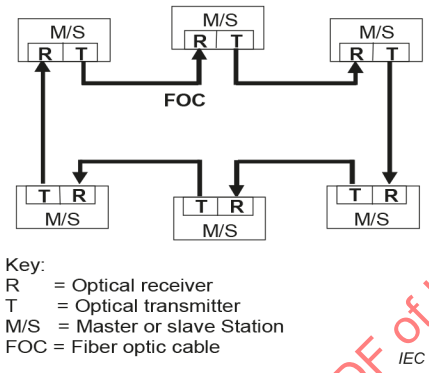


**Figure K.6 – Optical network with ring topology**

### K.6.4 Bus topology

The bus topology is built with type 3×3 star couplers or stations with integrated optical interfaces (see Figure K.7).

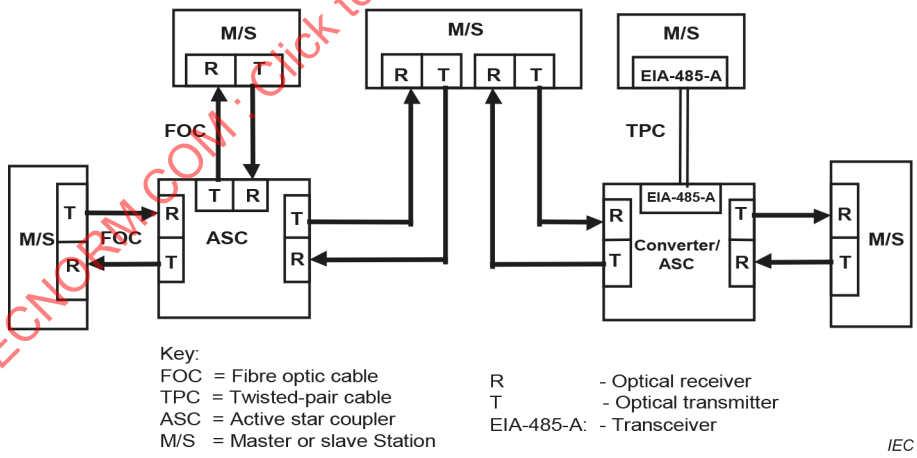


**Figure K.7 – Optical network with bus topology**

### K.6.5 Tree topology

Several active star couplers can be combined to build networks with a tree structure as shown in Figure K.8.

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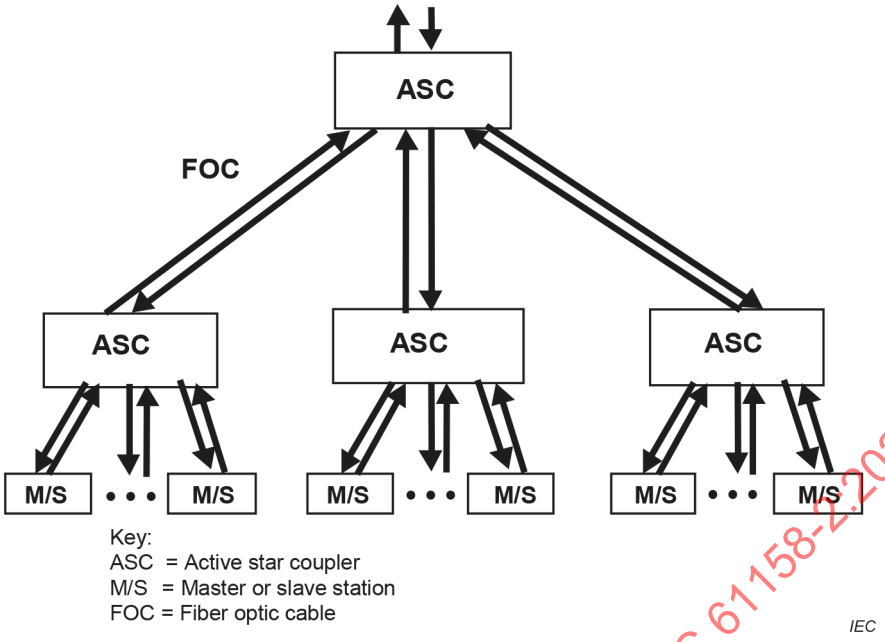


**Figure K.8 – Tree structure built from a combination of star structures**

### K.6.6 TIA-485-A/ fibre optic converter

A TIA-485-A / fiber optic converter is used to connect a station or a subnet based on the TIA-485-A:1998 technology to an optical network segment or an optical Master/Slave station.

Figure K.9 illustrates an application example for a TIA-485-A / fiber optic converter.

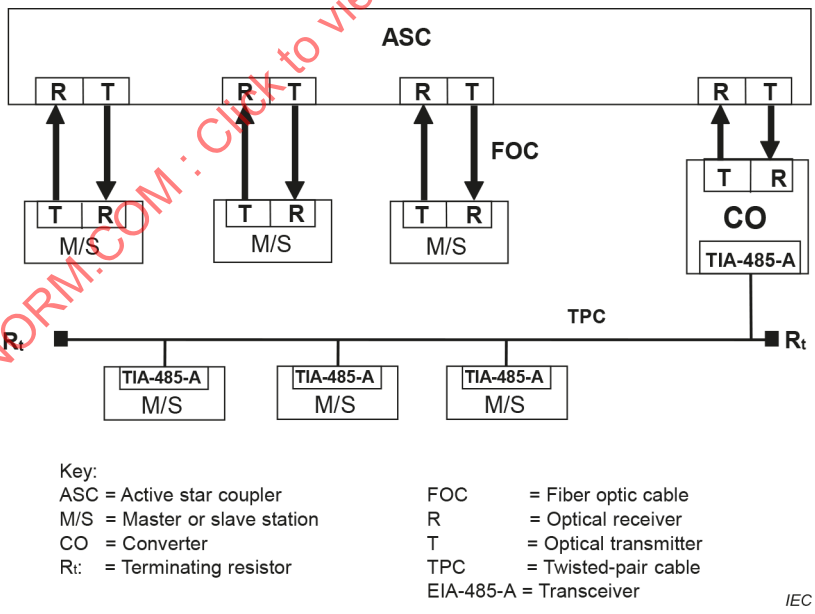


**Figure K.9 – Application example for a TIA-485-A / fiber optic converter**

The TIA-485-A / fiber optic converter can also be implemented internally in a modular active star coupler.

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## K.7 Optical power budget

### K.7.1 General

A fiber-specific optical signal level budget is available between two nodes that can be consumed in the form of attenuation along the optical link.

Specific budget calculations can be carried out using the specifications from the respective manufacturer.

Signal level budget refers to the difference between the output power from the optical transmitter and the input power required by an optical receiver for error-free signal detection. The overall attenuation shall be between the level budgets for overload and sensitivity.

Clause K.7 provide examples of which network extents can be implemented with various fiber types and transmitter power levels.

### K.7.2 Limiting conditions

#### K.7.2.1 General

The following limiting conditions shall be taken into consideration when interpreting the tables and dimensioning the optical links.

#### K.7.2.2 Numerical aperture (NA)

Numerical aperture (for description refer to IEC 60793-2).

#### K.7.2.3 Output power

Output power is the power level in the fiber for a "0" signal for the specified fiber for the entire temperature range giving consideration to sample diffusion and to the losses that are caused by the fiber connection at the transmitter (connector element).

#### K.7.2.4 Receiver limits

These values identify the acceptable signal range (dynamic range) for a "0" signal ("light" ON), whereby "overload" refers to the highest acceptable signal level (= brightest "light") and "sensitivity" refers to the lowest signal level. Moving outside the dynamic range does not necessarily cause interruption of the data transfer, but increases the deviation of signal timing beyond the specified limits that increases the likelihood of transmission errors.

#### K.7.2.5 Level budget

Level budget is the dynamic range resulting from the specified transmitter/receiver combination. The bit error rate (BER) is < $10^{-9}$ within these limits.

#### K.7.2.6 Overall attenuation

Overall attenuation refers to the minimum required attenuation required for overload protection of the receiver or to the maximum allowed attenuation needed to utilize the entire sensitivity of the receiver.

The overall attenuation is composed of:

– fiber attenuation for the fiber optic cable;
– coupling losses for inserted connectors and splices, if applicable;
– a system margin.

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#### K.7.2.7 System reserve

System reserve takes account of the transmitter element's output power loss due to aging. The life expectancy of a transmitter element is usually defined by the time by which the transmitted power has fallen by 3 dB compared to the value for a new element.

When determining the overload immunity of a receiver, it is assumed that this "system reserve" has not been consumed.

#### K.7.2.8 Fiber attenuation

Fiber attenuation refers to the maximum allowable attenuation or to the minimum required attenuation of the fiber optic cable.

#### K.7.2.9 Specific fiber attenuation

Specific fiber attenuation is the maximum or minimum attenuation of the fiber optic cable per length unit. It is dependent on the wavelength of the light.

Attenuation values for fibers are not stipulated in the specifications and shall be obtained from the data sheet for the respective fiber. The values in the tables are typical values based on experience.

The peak wavelength of the emitted light shifts with the operating temperature of the transmitter element. This wavelength shift has to be taken into consideration when determining the limiting values for the specific fiber attenuation.

#### K.7.2.10 Fiber length

The fiber length is calculated by dividing that part of the overall attenuation that is due to fiber attenuation by the specific fiber attenuation.

### K.7.3 62,5/125 µm multi-mode glass fiber

The transmit power level is so chosen that the minimum optical link length is 0 m, i.e. receiver overload cannot occur with the 62,5/125 µm fiber. An example of a level budget calculation for this reference fiber is given in Table K.1.

**Table K.1 – Example link budget calculation for 62,5/125 µm multi-mode glass fiber**

| **Link budget for a 62,5/125 µm multi-mode glass fiber standard link (graded index profile) NA = 0,275** | | | |
|---|---|---|---|
| Transmitter output power | −20 … −15 | | dBm |
| **Receiver limits** | **Overload** | **Sensitivity** | |
| | −10 | −24 | dBm |
| Level budget | 0 | 9 | dB |
| Overall attenuation | 0 | 9 | dB |
| System reserve | 0 | 3 | dB |
| Fiber attenuation | 0 | 6 | dB |
| Specific fiber attenuation | 2,5 | 3,5 | dB/km |
| Fiber length | min. 0 | max. 1 700 | m |

### K.7.4 9/125 µm single mode glass fiber

This fiber type has been included to be able to implement longer optical links.

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The transmit power level is so chosen that the minimum optical link length is 0 m, i.e. receiver overload cannot occur with the 9/125 µm fiber.

The Table K.2 shows typical values in practice, which do not represent specifications.

**Table K.2 – Example link budget calculation for 9/125 µm single mode glass fiber**

| **Link budget for a 9/ 125 µm single mode glass fiber standard link (step index profile) NA = 0,13** | | | |
|---|---|---|---|
| Transmitter output power | −20 … −10 | | dBm |
| **Receiver limits** | **Overload** | **Sensitivity** | |
| | −10 | −27 | dBm |
| Level budget | 0 | 7 | dB |
| Overall attenuation | 0 | 7 | dB |
| System reserve | 0 | 2 | dB |
| Fiber attenuation | 0 | 5 | dB |
| Specific fiber attenuation | 0,3 | 0,5 | dB/km |
| Fiber length | min. 0 | max. 10 000 | m |

### K.7.5 980/1 000 µm multi-mode plastic fiber

Due to its larger diameter, plastic fiber places lower demands on absolute mechanical tolerances during installation. This generally leads to reduced installation costs.

However, due to the much higher fiber attenuation compared to glass fiber, plastic fiber is generally only suitable for relatively short optical links. The wavelength range of the optical signal is chosen to match the minimum attenuation of the plastic material. Numerical example for the level budget is given in Table K.3.

**Table K.3 – Example link budget calculation for 980/1 000 µm multi-mode plastic fiber**

| **Link budget for a 980/1 000 µm plastic fiber standard link (step index profile) NA = 0,47** | | | | | |
|---|---|---|---|---|---|
| **Transmitter output power** | **Standard** | | **Increased** | | |
| Output power | −11 … −5,5 | | −6 … 0 | | dBm |
| **Receiver limits** | **Overload** | **Sensitivity** | **Overload** | **Sensitivity** | |
| | −5,0 | −20,0 | 0 | −20,0 | dBm |
| Level budget | −0,5 | 9,0 | 0 | 14,0 | dB |
| Overall attenuation | 0 | 9,0 | 0 | 14,0 | dB |
| System reserve | 0 | 3,0 | 0 | 3,0 | dB |
| Fiber attenuation | 0 | 6,0 | 0 | 11,0 | dB |
| Specific fiber attenuation | 0,15 | 0,25 (see Note) | 0,15 | 0,25 (see Note) | dB/m |
| Fiber length | min. 0 | max. 24 | min. 0 | max. 44 | m |

NOTE Increased attenuation due to the fiber material and the wavelength shift due to temperature changes in the transmitter element.

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### K.7.6 Multi-mode glass fiber 200/230 µm fiber

This fiber type has been included to be able to implement longer optical links. The numerical example for the level budget is given in Table K.4.

**Table K.4 – Example level budget calculation for 200/230 µm multi-mode glass fiber**

| **Link budget for an 200/230 µm fiber standard link (step index profile) NA = 0,37** | | | |
|---|---|---|---|
| Transmitter output power | −16,0 to −8,0 | | dBm |
| **Receiver limits** | **Overload** | **Sensitivity** | |
| | −8,0 | −22,0 | dBm |
| Level budget | 0 | 6,0 | dB |
| Overall attenuation | 0 | 6,0 | dB |
| System reserve | 0 | 3,0 | dB |
| Fiber attenuation | 0 | 3,0 | dB |
| Specific fiber attenuation | 5 | 10 | dB/km |
| Fiber length | min. 0 | max. 300 | m |

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# Annex L
(informative)

# Type 3: Reference design examples for asynchronous transmission, wire medium, intrinsically safe

## L.1 Bus termination in the communication device

In this version, the bus termination is already in the device by means of the resistors Rt, Ru and Rd, as shown in Figure L.1. Activation is done via the switch S1 for the device which is installed at the end of the bus segment.

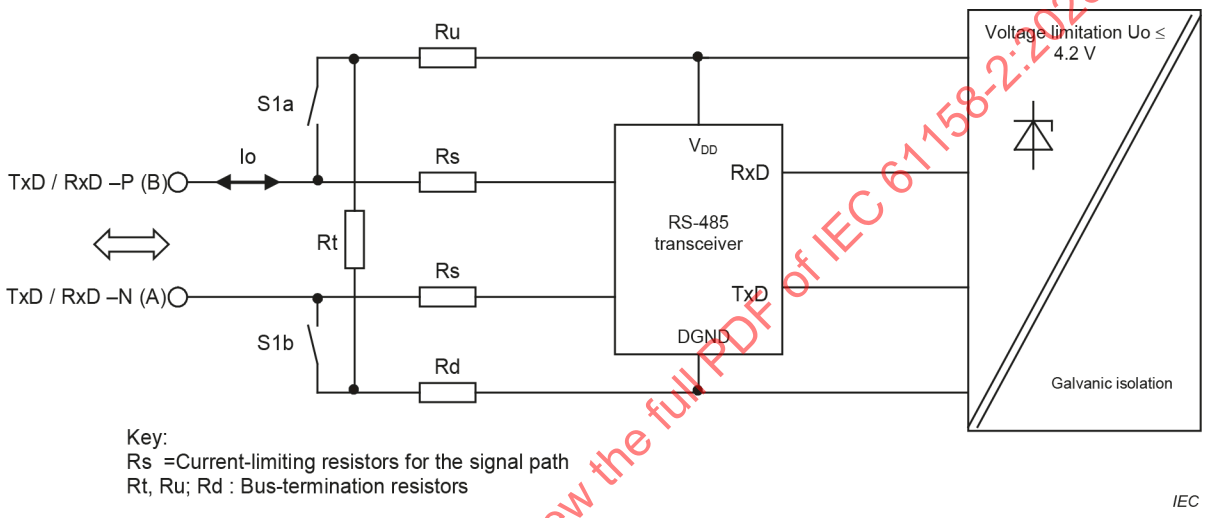


**Figure L.1 – Bus termination integrated in the communication device**

When determining the maximum output current Io, it shall be noted that, on account of the switch S1, the resistor R3 is connected in parallel to R1 and the resistor R4 is connected in parallel to R2.

Here, the safety-related limiting values as described in "PTB-Mitteilungen, 113 Jahrgang, Heft 2/2003, Die Bewertung der Zündfähigkeit eigensicherer Stromkreise anhand eines Rechenverfahrens Abschnitt: Der eigensichere RS 485 Feldbus als Anwendungsbeispiel." shall also be adhered too.

For the design of the components and the required separation distances, the relevant applicable standard shall be met (e.g. IEC 60079-11).

## L.2 Bus termination in the connector

In this version, the bus termination is realised in the connector, as shown in Figure L.2. For this, it is necessary that the communication devices provide the appropriate power supply. Activation is done via the switch S1 for the devices which are installed at the relevant end of the bus segment.

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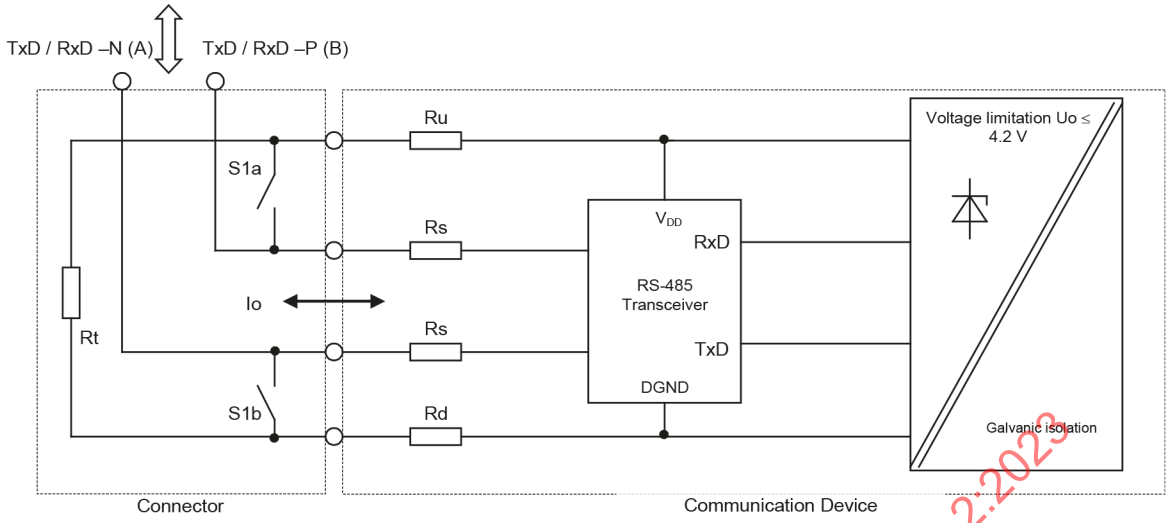


**Figure L.2 – Bus termination in the connector**

## L.3 External bus termination

The auxiliary power supply shall be galvanically isolated from the field bus circuit, as shown in Figure 133. Details of this are provided in 22.2.4.3.

In this version, the bus termination is realised externally in a separate device, as shown in Figure L.3.

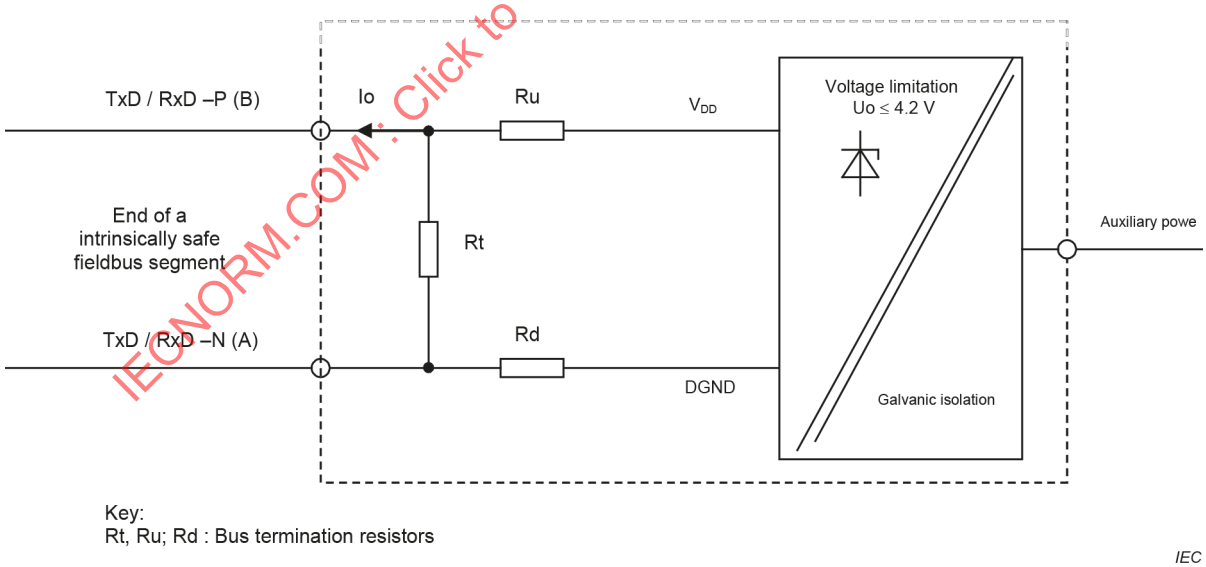


**Figure L.3 – External bus termination**

The auxiliary power supply shall be galvanically isolated from the field bus circuit.

The resistors Ru and Rd are relevant for the calculation of the maximum output current $I_o$. In this context, the safety-related limiting values for external bus terminations shall be adhered too. Regarding to the design of the components and the necessary separation distances, the relevant applicable standard (e.g. IEC 60079-11) shall be applied.

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# Annex M
(normative)

# Type 8: Connector specification

## M.1 External connectors for wire medium

### M.1.1 Subminiature D connector pin assignment

The connector pin assignment is shown in Figure M.1, Figure M.2 and Table M.1.

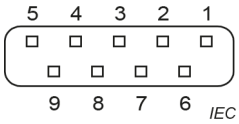


**Figure M.1 – Outgoing interface 9-position female subminiature D connector at the device**

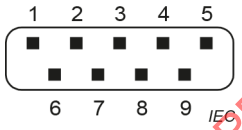


**Figure M.2 – Incoming interface 9-position male subminiature D connector at the device**

**Table M.1 – Pin assignment of the 9-position subminiature D connector**

| Pin number | Signal line |
|---|---|
| 1 | DO |
| 2 | DI |
| 3 | GND |
| 4 | - |
| 5 | - |
| 6 | /DO |
| 7 | /DI |
| 8 | - |
| 9 | - |

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### M.1.2 Terminal connector pin assignment

Figure M.3 shows the terminal connector position at the device and pin assignments of the terminal connector are shown in Table M.2.

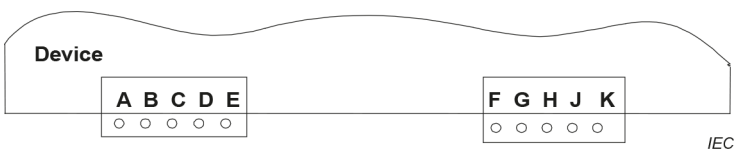



**Figure M.3 – Terminal connector at the device**

**Table M.2 – Pin assignment of the terminal connector**

| Incoming interface | | | Outgoing interface | |
|---|---|---|---|---|
| Pin | Standard | | Pin | Standard |
| A | /DO1 | | F | /DO2 |
| B | DO1 | | G | DO2 |
| C | /DI1 | | H | /DI2 |
| D | DI1 | | J | DI2 |
| E | GND1 | | K | GND |

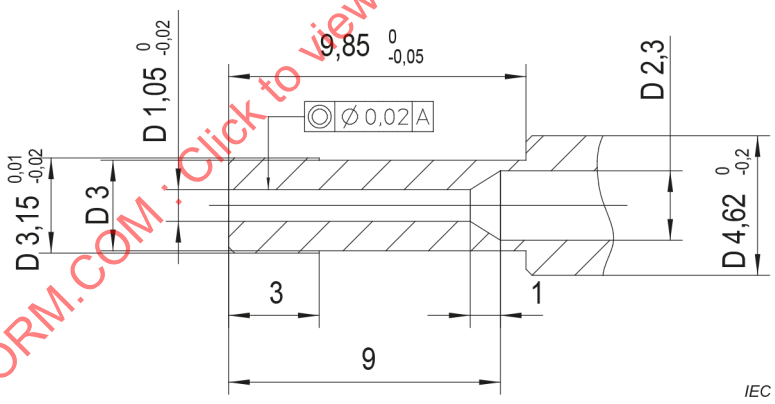
A separate terminal for protective earth shall be provided.

The sequence of terminal points should be observed.

## M.2 External connectors for fiber optic medium

A network connector that is outside the enclosure of the device and therefore requires protection against the electromagnetic, chemical and physical environment shall be specified as an external connector.

If a degree of protection of IP20 or less is used for the device having an optical MAU implemented the connector used for the CPIC at the device level should be mechanically compatible with a F-SMA type connector as specified in IEC 61754-22. The ferrule of an optical F-SMA connector for polymer optical fiber (980/1 000 µm) is shown in Figure M.4.




NOTE All measures in mm.

**Figure M.4 – Ferrule of an optical F-SMA connector for polymer optical fiber (980/1 000 µm)**

## M.3 External connectors for hybrid connectors for IP65 applications

If a hybrid connector for applications with a degree of protection of IP65 or higher is used for the device having an optical MAU implemented, this connector used for the CPIC at the device level should be as shown in Figure M.5 and Figure M.6 with the connector dimension specified in Table M.3.

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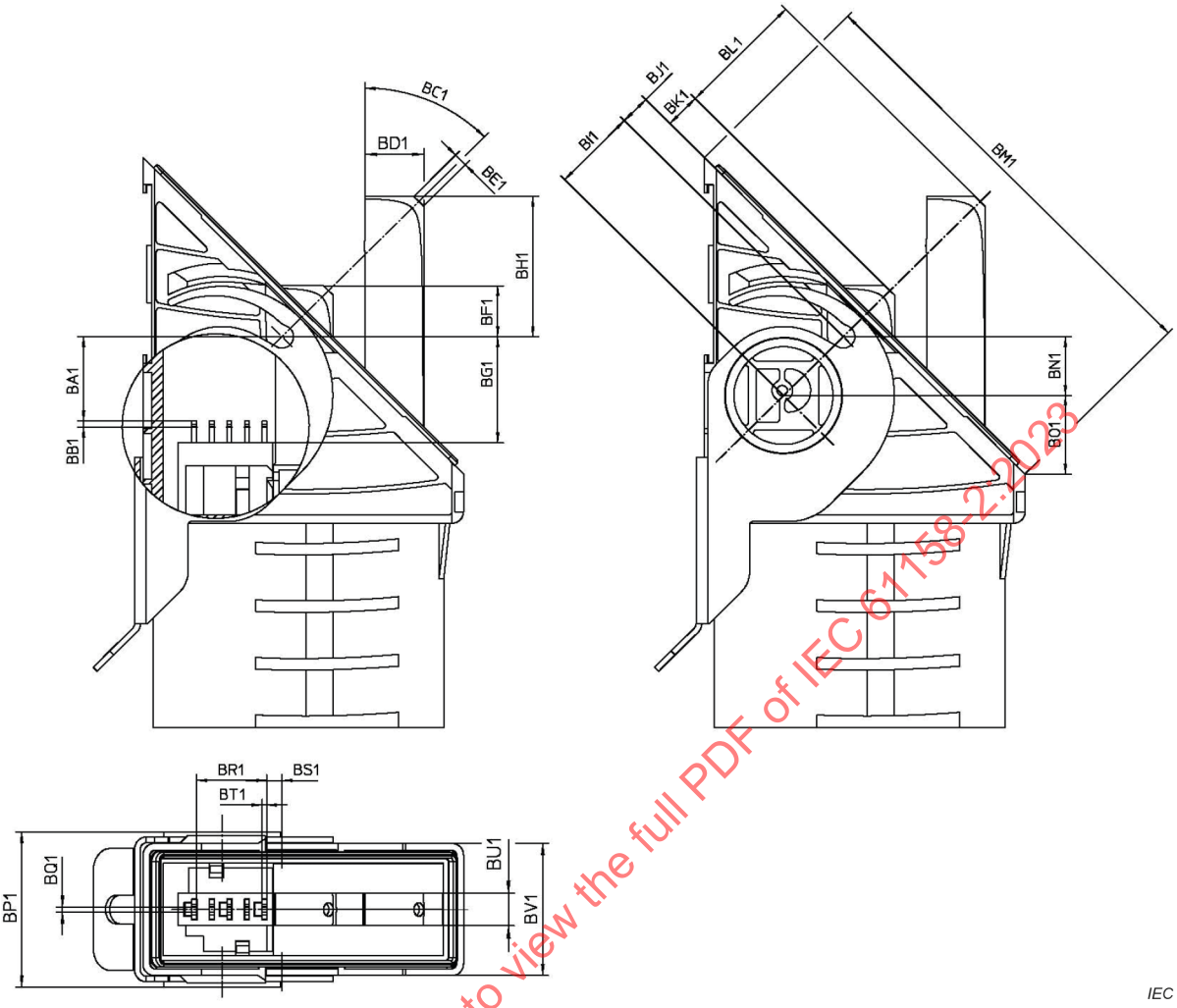


**Figure M.5 – Type 8 fiber optic hybrid connector housing**

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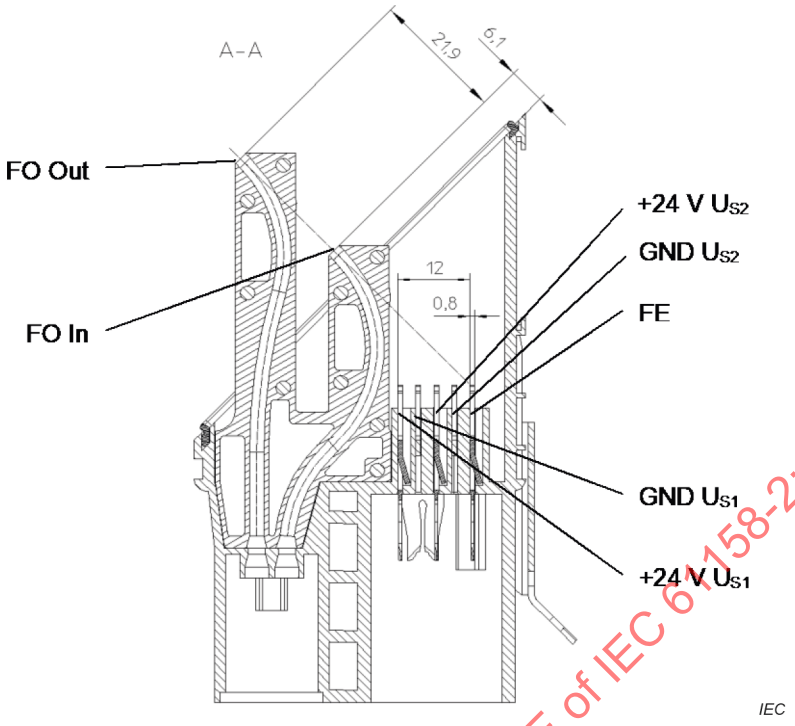


**Key:**

$U_{S1}$ = Sensor and bus module power supply

$U_{S2}$ = Actuator power supply

FO in = connection to the FO transmitter

FO out = Connection to the FO receiver

**Figure M.6 – Type 8 fiber optic hybrid connector assignment**

The electrical contacts for the power supplies should be capable of supporting a continuous maximum current of 16 A at 24 V.

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**Table M.3 – Type 8 fiber optic hybrid connector dimensions**

| Letter | Max. mm | Min. mm | Nominal mm |
|---|---|---|---|
| BA1 | 14,9 | 14,5 | 14,7 |
| BB1 | 1,2 | 1 | 1,1 |
| BC1 | 45,5 | 44,5 | 45 |
| BD1 | 10,2 | 9,8 | 10 |
| BE1 | 2,5 | 2,3 | 2,4 |
| BF1 | 9 | 8,6 | 8,8 |
| BG1 | 18,7 | 18,3 | 18,5 |
| BH1 | 24,5 | 24,1 | 24,3 |
| BI1 | 14,7 | 14,3 | 14,5 |
| BJ1 | 5,3 | 5,1 | 5,2 |
| BK1 | 6,3 | 5,9 | 6,1 |
| BL1 | 22,1 | 21,7 | 21,9 |
| BM1 | 78 | 77,6 | 77,8 |
| BN1 | 10,45 | 10,05 | 10,25 |
| BO1 | 13,85 | 13,45 | 13,65 |
| BP1 | 27,2 | 26,8 | 27 |
| BQ1 | 0,95 | 0,75 | 0,85 |
| BR1 | 12,2 | 11,8 | 12 |
| BS1 | 2,7 | 2,5 | 2,6 |
| BT1 | 0,9 | 0,7 | 0,8 |
| BU1 | 5,7 | 5,5 | 5,6 |
| BV1 | 23,2 | 22,8 | 23 |

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# Annex N
(normative)

## Type 16: Connector specification

Connectors for fiber optic cables shall

- correspond to F-SMA standard (see IEC 61754-22);
- have a quality level of at least 5;
- have a metallic connector ring.

The transmitter and receiver components shall be built into light-proof housings.

In addition, it is recommended that fiber optic cables have a strain relief.

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# Annex O
(normative)

# Type 16: Optical network topology

## O.1 Topology

The topology shall consist of optical point-to-point transmission lines and subscribers. A transmission line shall consist of fiber optic cables having no optical branches. Transmission shall take place in only one direction. The master and the slaves are part of the network (subscribers).

Figure O.1 shows the structure in connection with the control unit and the devices. The control unit may encompass one or more masters, as needed by the application. A master shall handle only one network on the physical layer as well as in the overlying protocol layers. Slaves shall be used to connect the devices to the optical fiber network. On the physical layer, a slave can represent the connection of one or more devices to the optical fiber network. Logically, one slave with several devices shall act the same as several slaves with one device each. Although the slaves are connected to each other physically through the optical fiber network, all transmission of information takes place directly between the master and the slaves. A star-shaped topology is created if every master has only one slave connected to itself.

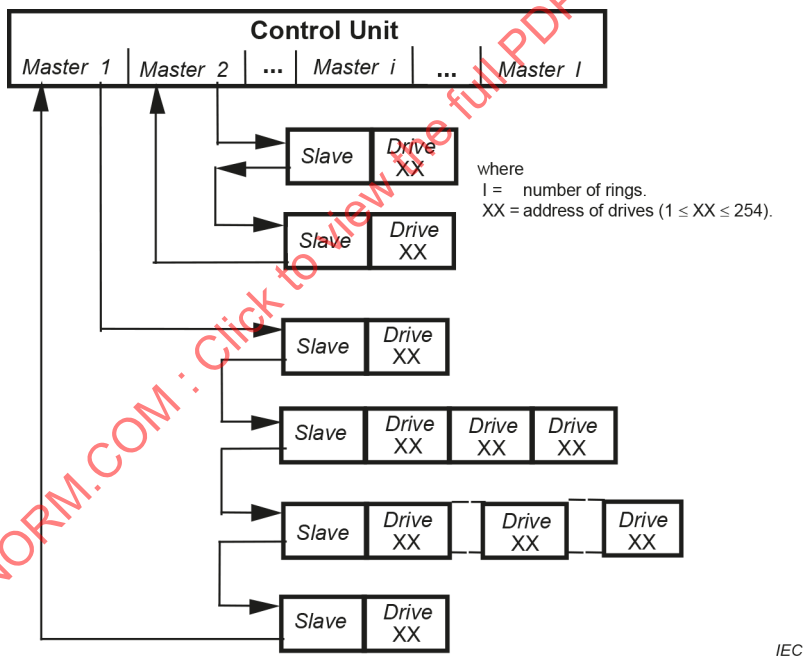


**Figure O.1 – Topology**

The physical arrangement of slaves in the network shall be independent from the device address set for the slave, as well as from the timing sequence of transmitting the acknowledge telegrams.

NOTE The number of devices in a network is M = K. The sequence of the AT is labeled as 1, 2, …, M and the sequence of the device data records in the MDT is labelled as 1, 2, … K.

The Types CP16/1 and CP16/2 interface determine any exchange of information within a network. Any cooperation of networks is controlled by the control unit and is not subject to this specification.

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## O.2 Optical power budget

### O.2.1 Optical signals on the transmission line

Optical power levels on the transmission line have units of dBm or µW which are related as follows:

– level [dBm] = 10 × log (level [µW] / 1 000 µW):

– level [µW] = 10 level [dBm] / 10 dBm × 1 000 µW.

The optical signals given in Table O.1, Table O.2 and Table O.4 for the transmitter, the receiver, and the transmission line are measured with a plastic fiber cable (POF) with a 1 mm core diameter and a length of 1 m or with a glass fiber cable (HCS) with 200 µm diameter and a length of 1 m as specified in Table O.3.

Optical levels and edges (status changes) along the transmission line are specified by means of the following parameters:

a) $P_{TmaxL}$, the maximum transmission power at an optically low level. If the optical signal falls below this level, it is at a logic low state;

b) $P_{TminH}$, the minimum transmission power at an optically high level. If the optical signal goes above this level, it is at a logic high state;

c) $P_{TmaxH}$, the maximum transmission power at an optically high level. Stationary signals shall never exceed this limit. A rising optical edge, however, may dynamically exceed the upper limit of the optically high level. This makes it possible to accent the rising edge (minimizing the rise time). Both the magnitude, as well as the duration of the excess signal level are limited;

d) $k_{os}$, factor for optical power overshoot. This parameter indicates the factor by which the maximum optical transmission power may be exceeded dynamically. The excess power level is only permissible during an optical status change from low to high (rising signal edge).

NOTE PRxxx is used to express the PTxxx equivalent for a receiver.

The optical signal shall pass through $P_{TmaxL}$ to $P_{TminH}$ in a monotonic manner (which means that the signal noise is less than 100 nW = −40 $dB_m$). Therefore, the logic high level between $P_{RmaxL}$ and $P_{RminH}$, can be recognized definitely without generating additional signal changes.

### O.2.2 Transmitter specifications

Unless stated otherwise, these specifications shall be valid throughout the temperature range from 0 °C to +X0 °C.

A transmitter shall follow the specifications in Table O.1.

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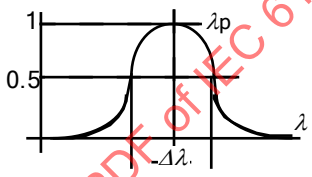
**Table O.1 – Transmitter specifications**

| Position | Attenuation at 650 nm | | |
|---|---|---|---|
| **Fiber type** | **POF** | | **HCS** |
| **Optical transmission power** | **Low** | **High** | **High** |
| $P_{TmaxL}$ | −31,2 dBm | −28,2 dBm | −33,2 dBm |
| | 0,75 µW | 1,5 µW | 0,5 µW |
| $P_{TminH}$ | −10,5 dBm | −7,5 dBm | −18 dBm |
| | 90 µW | 180 µW | 16 µW |
| $P_{TmaxH}$ | −5,5 dBm | −3,5 dBm | −10 dBm |
| | 280 µW | 450 µW | 100 µW |
| **Transmitting diode wavelength** | | | |
| Peak wavelength | $\lambda_{pk}$ = 640 nm to 675 nm | | |
| Spectral bandwidth | $\Delta\lambda$ ≤ 30 nm (25 °C) | | |
| Optical spectrum |  | | |
| $k_{os}$ | 120 % | | |
| Temperature range | 0 °C to 70 °C | | |
| NOTE All data are for $\lambda_{pk}$ (which is $\lambda_p$ in the above inset drawing). | | | |

### O.2.3 Receiver specifications

Unless stated otherwise, these specifications are valid throughout the temperature range from 0 °C to +70 °C.

In order to process the data correctly, the receiver shall meet the requirements shown in Table O.2. Since the bandwidth of the fiber optic cable is relatively wide, distortion of the optical signals is insignificant.

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**Table O.2 – Receiver specifications**

| Wavelength | 650 nm | |
|---|---|---|
| **Fiber type** | **Plastic fiber POF** | **Glass fiber HCS** |
| $P_{RmaxL}$ | −31,2 dBm | −33,2 dBm |
| | 0,75 µW | 0,5 µW |
| $P_{RminH}$ | −20 dBm | −22 dBm |
| | 10 µW | 6,3 µW |
| $P_{RmaxH}$ | −5 dBm | −7 dBm |
| | 316 µW | 200 µW |
| Dynamic power ($P_{RmaxH}$ to $P_{RminH}$) | 15 dB | |
| Bit error rate | ≤ $10^{-9}$ | |
| Temperature range | 0 °C to 70 °C | |
| NOTE All data are for $\lambda_{pk}$ | | |

### O.2.4 Fiber optic cable

The fiber optic cable can consist of plastic or glass with a step index profile or graded index profile. An example is shown in Figure O.2 and Table O.3.

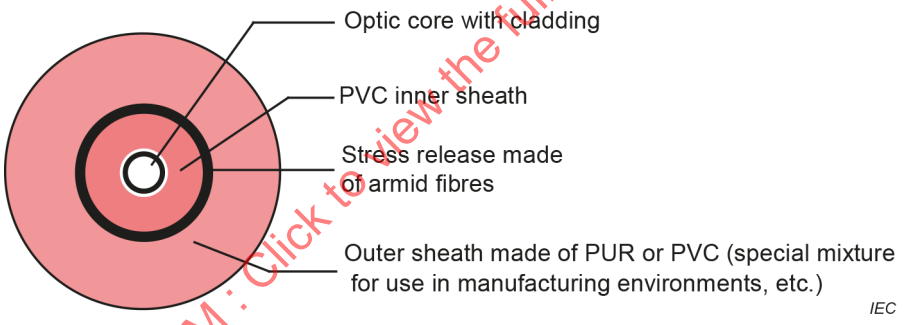


**Figure O.2 – Structure of a single-core cable (example)**

**Table O.3 – Cable specifications (example)**

| | **Plastic fiber POF** | **Glass fiber HCS** |
|---|---|---|
| Core diameter | 980 µm | 200 µm |
| Cladding diameter | 1 000 µm | 230 µm |
| Numeric aperture | 0,47 | 0,37 |
| Bandwidth | ≥ 5 MHz × 1 km | ≥ 10 MHz × 1 km |

### O.2.5 System data of the optical transmission path

The optical power levels are shown in Figure O.3 and shall be in accordance with values in Table O.4.

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**Table O.4 – System data of the optical transmission line at 650 nm**

| Fiber type | | POF | | HCS |
|---|---|---|---|---|
| **Optical transmission power (see 30.1)** | | **Low** | **High** | **High** |
| Transmission power | $P_{TmaxL}$ | −31,2 dBm | −28,2 dBm | −33,2 dBm |
| | | 0,75 µW | 1,5 µW | 0,5 µW |
| | $P_{TminH}$ | −10,5 dBm | −7,5 dBm | −18 dBm |
| | | 90 µW | 180 µW | 16 µW |
| | $P_{TmaxH}$ | −5,5 dBm | −3,5 dBm | −10 dBm |
| | | 280 µW | 450 µW | 100 µW |
| Received power | $P_{RmaxL}$ | −31,2 dBm | | |
| | | 0,75 µW | | |
| | $P_{RminH}$ | −20 dBm | | |
| | | 10 µW | | |
| | $P_{RmaxH}$ | −5 dBm | | |
| | | 315 µW | | |
| | Dynamic power ($P_{RmaxH}$ to $P_{RminH}$) | 15 dB | | |
| System value | $P_{TminH}$ to $P_{RminH}$ | 9,5 dB | 12,5 dB | 4 dB |
| System reserve (including lifetime of transmitting diode) | | ≥ 5,1 dB | | ≥ 2 dB |
| Line attenuation (System value - System reserve) | | ≤ 4,4 dB | ≤ 7,4 dB | ≤ 2 dB |
| Measuring cable attenuation (typical) | | 0,2 dB/m | 0,2 dB/m | 10 dB/km |
| Cable length | | ≤ 22 m | ≤ 37 m | ≤ 200 m |
| Transmission rate (NRZI) | | 2 Mbit/s, 4 Mbit/s, 8 Mbit/s and 16 Mbit/s | | |
| Bit error rate | | $\leq 10^{-9}$ | | |
| Temperature range | | 0 °C to 70 °C | | |

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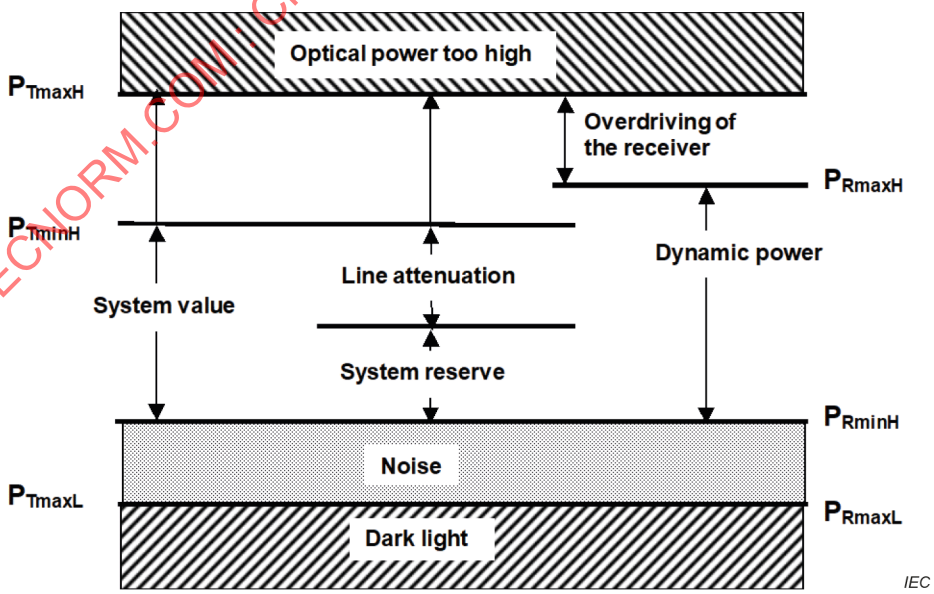


**Figure O.3 – Optical power levels**

# Annex P
(informative)

# Type 16: Reference design example

## P.1 Functional principles of the repeater circuit

Figure P.1 shows an example of an implementation of the signal-regeneration function from the repeater circuit. The primary task of this circuit consists of retrieving the clock RCLK from the NRZI-coded input signal IN. This may be accomplished e.g., by means of a digital phase-locked loop (DPLL). In addition, by sampling the input signal IN at appropriate times, a regenerated received signal RxD can be generated. The NRZI-coded signal is especially useful in the network structure.

The circuit consists of eight flip-flops and a combinational logic PLA. The flip-flops are driven by a common clock CX. This clock signal is generated by a crystal oscillator having 16 times the frequency of the data rate, which is 32 MHz at 2 Mbit/s transmission rate.

It is also possible to implement DPLLs having different sampling rates. In order to match the following condition, a sampling rate of at least 12 times is needed:

$$0 \leq t_{cadreal} \leq \frac{t_{bitnom}}{11}$$

Flip-flop 1 is used to initially synchronize the input signal. Flip-flop 2 is used for edge detection; it is always the case that if IN1 = 1 and IN2 = 0, a positive edge has been found. Flip-flops 5-8 in conjunction with the combinatorial logic are used to implement a finite-state machine.

The status diagram of Figure P.2 illustrates the behavior of the DPLL. States Z = 0 through Z = 15 correspond to the binary values which are given by the output signals of the flip-flops 5 to 8.

Depending on the status number (Z = 0 ... 15) in which E (event: light-on edge detected) or E* (event: no light-on edge detected) is detected, the DPLL reacts by repeating or skipping a status. If E is found to be in the state Z = 0, the DPLL does not repeat or skip (i.e., the DPLL is synchronized). Input signals are not sampled at the theoretical mean of the bit cell but in their shifted position. This enables the system to operate even with relatively strong distorted signals. During the transition from Z = 3 to Z = 4, RCLK = 1 is set. During the transition from Z = 10 or Z = 11 to Z = 12 and from Z = 11 to Z = 13, RCLK = 0 is set and the output signal RxD is set equal to the synchronized input signal IN1.

Figure P.3 illustrates the timing of various signals.

In general, the signal becomes distorted mainly by electrical-to-optical conversion and vice versa. In Figure P.3, it is shown what the signal IN1 looks like ideally, and what its typical shape is during minimum and maximum transmission power. The assumption is made that a series of NRZI-coded zeros is transferred. This corresponds to a rectangular signal with the period $2 \times t_{BIT}$.

Increasing transmission power eventually overdrives the receiver. The electrical signal level corresponding to the optical "light-on" remains at the receiver output longer than the generating electrical signal at the transmitter's input. Since the signal IN1 is not symmetric, it is useful to synchronize the phase lock loop on one signal edge only. For this purpose, the light-on edge seems to be more stable. Depending on the physical circumstances (i.e., inverted or non-inverted receiver) either the positive or the negative edge can be used as the input signal of the DPLL.

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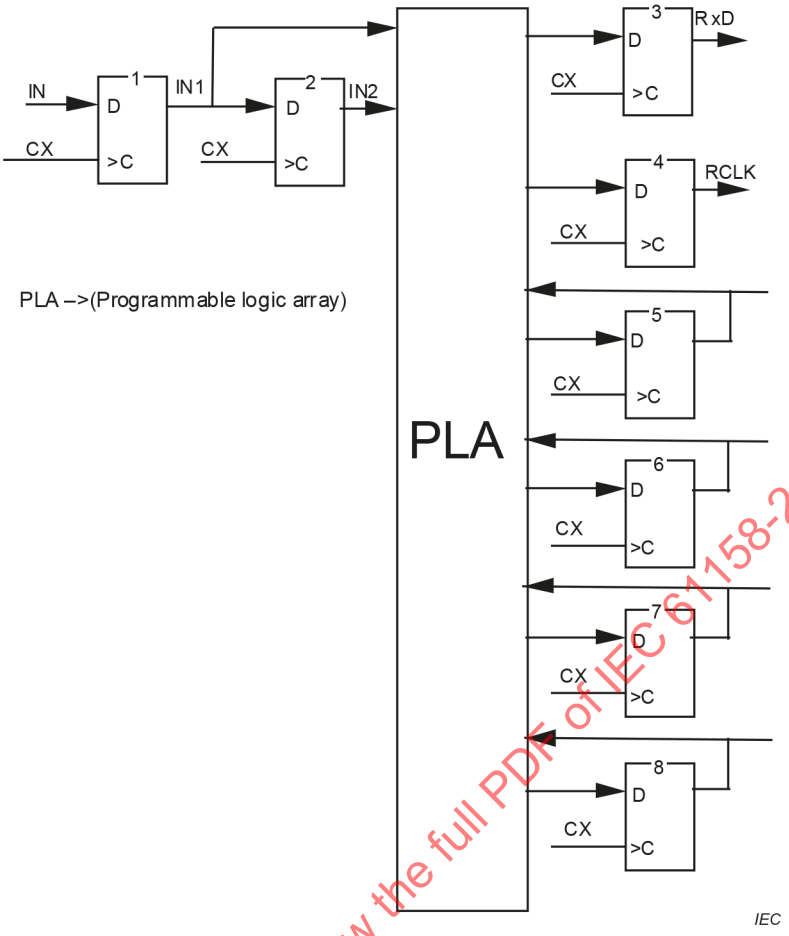


**Figure P.1 – Example of an implemented DPLL**

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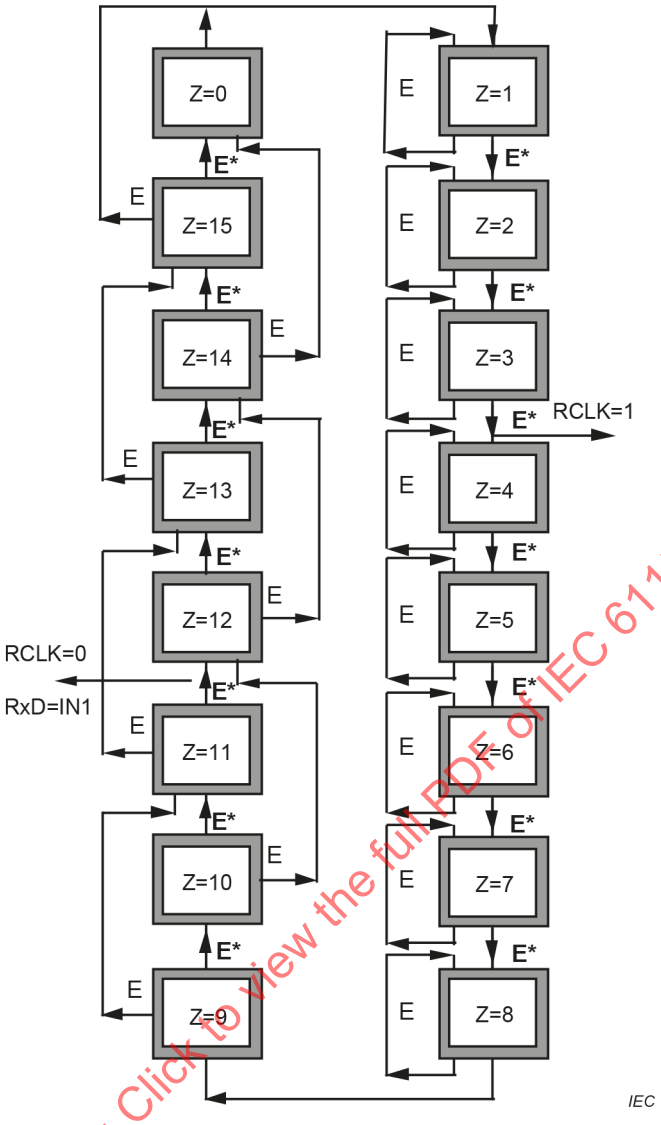


**Key:**

E = event that light-on edge is detected

E* = event that no light-on edge is detected.

**Figure P.2 – DPLL status diagram**

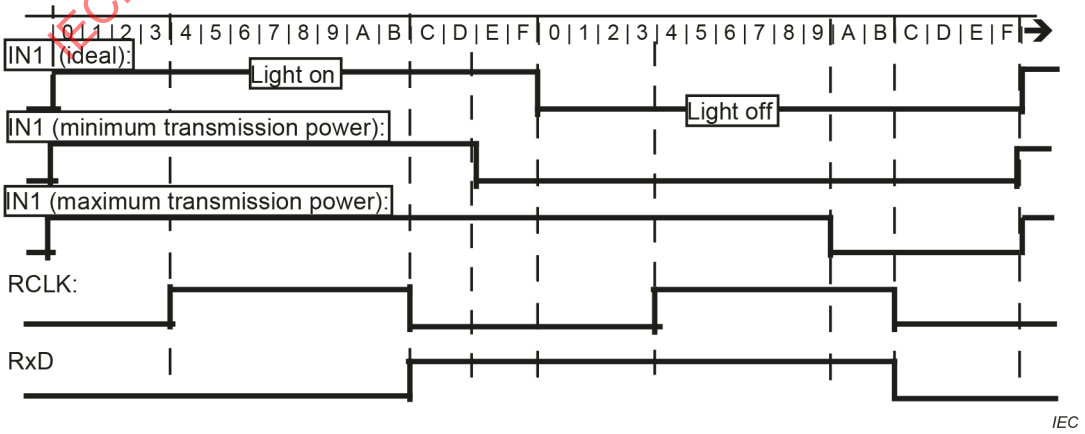


**Figure P.3 – DPLL timing**

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## P.2 Attenuation on the transmission line

Clause P.2 shows which factors contribute to the attenuation along the transmission line.

Two levels of maximum allowable attenuation along the line are specified. A transmitter can be switched to drive a transmission line with "low attenuation" or "high attenuation". This reduces the effects of the large attenuation range (0 dB to 7,4 dB).

The following factors contribute to attenuation:

- the fiber optic cable
- possible additional couplings (e.g. wall breakthroughs)

The additional variable couplings do not include inserted attenuation due to F-SMA plug connectors on the transmitter output and receiver input.

The transmission "low attenuation" should be selected for a short transmission line without additional couplings (e.g., 2 dB attenuation along the line) whereas "high attenuation" is selected for a long transmission line with additional couplings (e.g., 7 dB attenuation along the line). When designing the line, care shall be taken that the maximum attenuation along the line does not exceed the power levels as defined by high and low attenuation, i.e. the level of the transmission power shall eventually be adapted to the expected attenuation along the line.

Attenuation due to the couplings is often specified by technical data for the plugs. Attenuation due to the fiber optic cable cannot be determined so simply. The reason is that the specific attenuation of the fiber optic cable is not constant in the range of the specified wavelength range. For instance, a cable with a specified attenuation of 220 dB/km may in fact have this rating for only a narrow range of wavelengths, around 650 nm. This specific attenuation rating can easily increase to a value in excess of 350 dB/km (at wavelengths of approximately 635 nm and approximately 680 nm).

Consider that the wavelength radiated by the transmitting diode shifts to longer wavelengths at increasing temperatures ($\lambda p$ and $\Delta\lambda$ increase), significant portions of the emitted light become attenuated by the fiber optic cable.

In order to determine the exact attenuation due to the fiber optic cable, the product of attenuation and radiated light power has to be integrated over the wavelength.

A 30 m long fiber optic cable with a typical attenuation rating of 220 dB/km may have an attenuation interval of 6 dB to 9 dB over the entire temperature range of 0 °C to +55 °C (due to shifted wavelength).

Another uncertainty factor contributing to attenuation along the line is assembly. A cleanly mounted and polished plug has a very low inserted attenuation, compared to a poorly installed plug.

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# Annex Q
(normative)

# Type 18: Connector specification

## Q.1 Overview

Only Type 18-PhL-P defines specific connectors.

## Q.2 Device connector

The required dimensions of the Type 18-PhL-P device connector are shown in Figure Q.1 for a right angle and Figure Q.2 for a straight board mount connector.

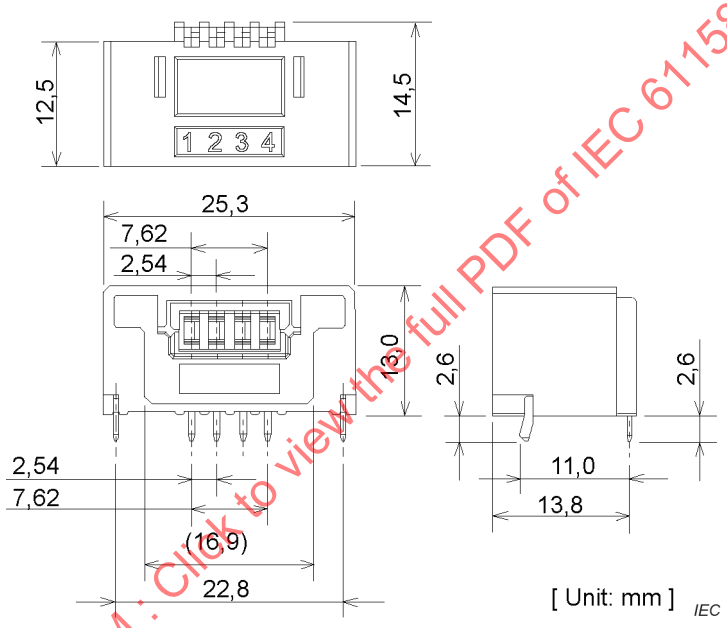


**Figure Q.1 – PhL-P device connector r-a**

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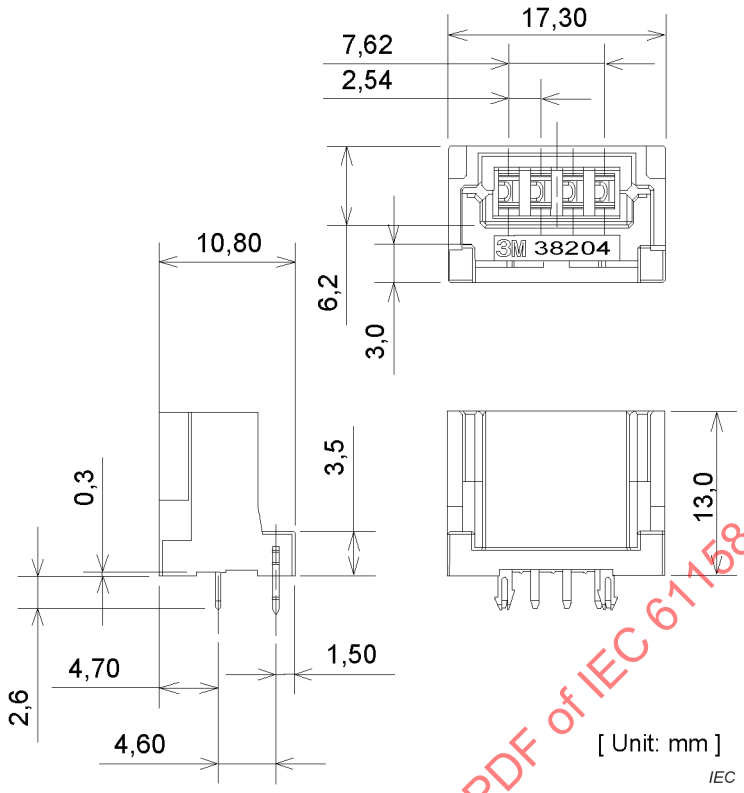


**Figure Q.2 – PhL-P device connector straight**

## Q.3 Flat-cable connector

The required dimensions of the Type 18-PhL-P flat cable connector are shown in Figure Q.3 and Figure Q.4.

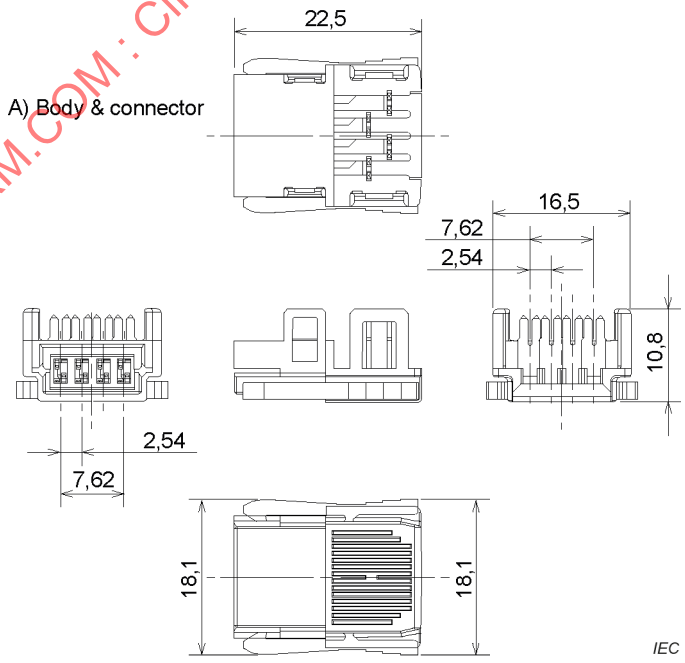


**Figure Q.3 – PhL-P flat cable connector and terminal cover - body and connector**

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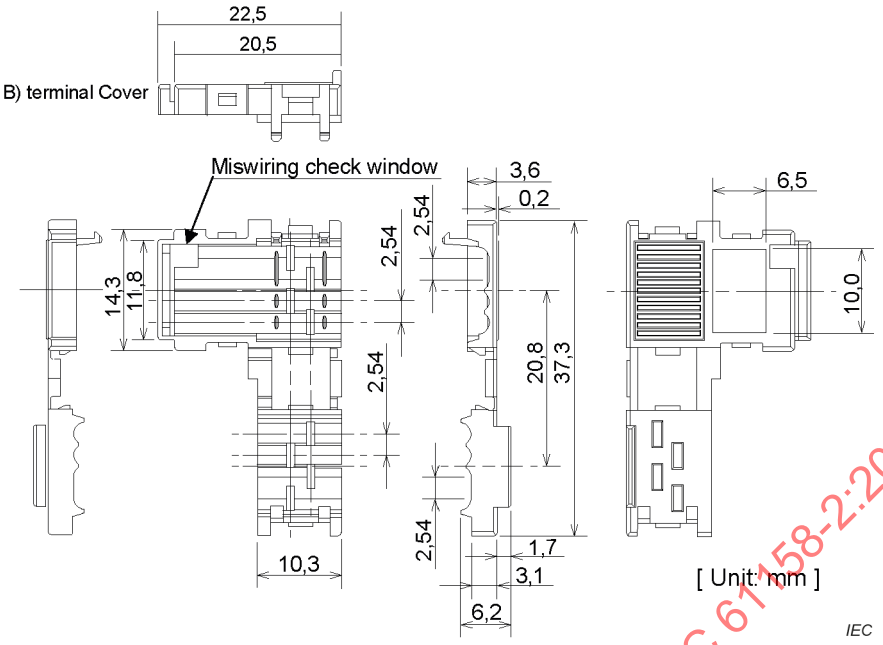


**Figure Q.4 – PhL-P flat cable connector and terminal cover - terminal cover**

## Q.4 Round cable connector

The required dimensions of the Type 18-PhL-P round cable connector are shown in Figure Q.5 and Figure Q.6. This connector is applicable to both styles of Type 18-PhL-P round cable.

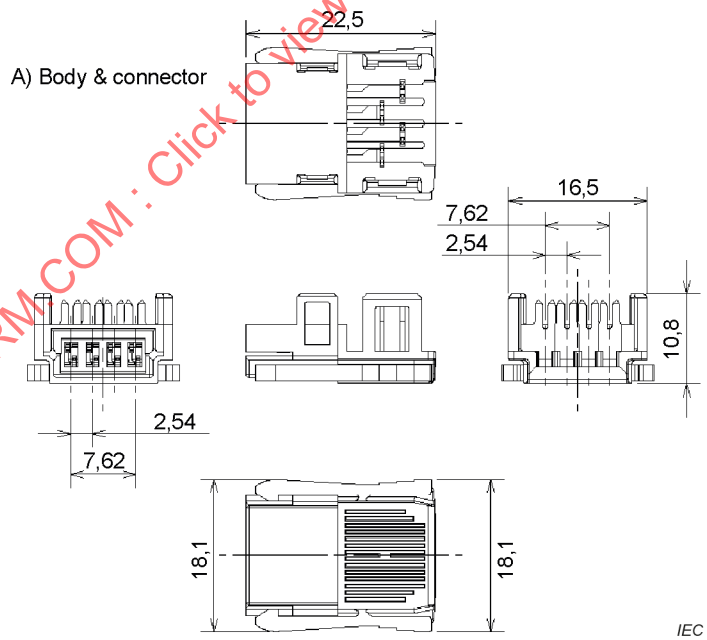


**Figure Q.5 – Type 18-PhL-P round cable connector body**

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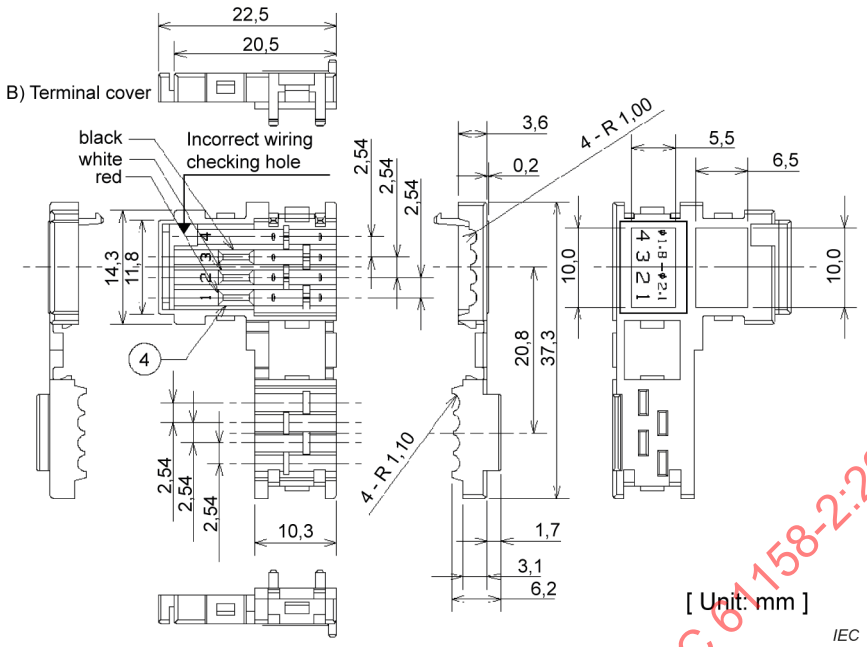


**Figure Q.6 – Type 18-PhL-P round cable connector terminal cover**

## Q.5 Round cable alternate connector

The required dimensions of the Type 18-PhL-P round cable alternate connector is shown in Figure Q.7 and Figure Q.8.

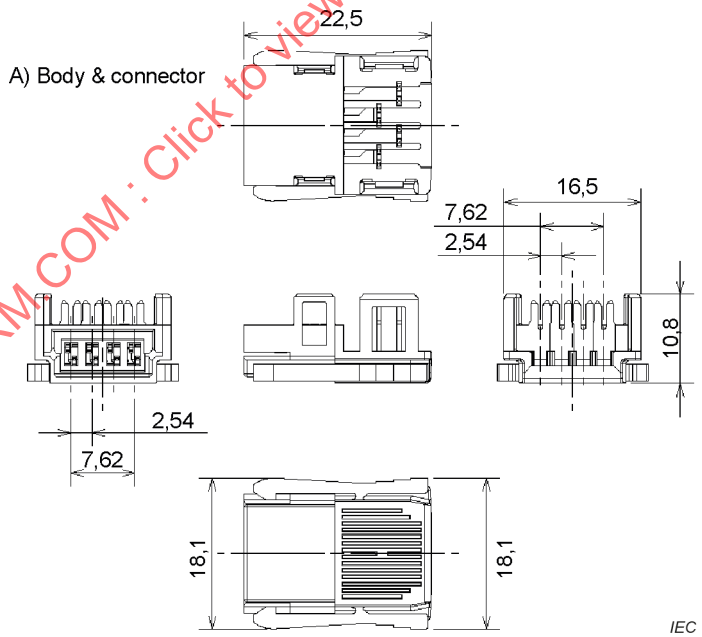


**Figure Q.7 – Type 18-PhL-P round cable alternate connector and body**

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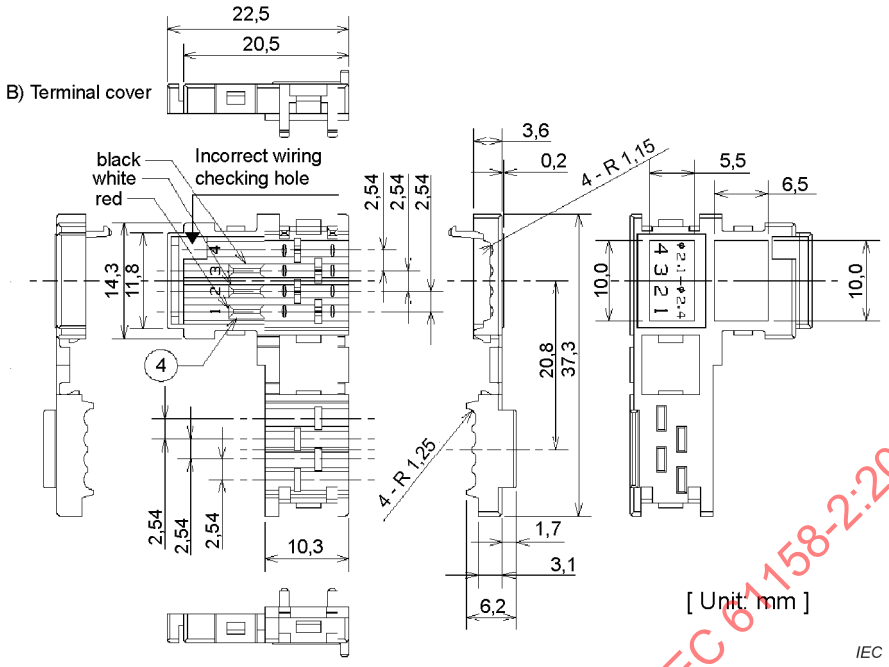


**Figure Q.8 – Type 18-PhL-P round cable alternate connector terminal cover**

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# Annex R
(normative)

# Type 18: Media cable specifications

## R.1 Type 18-PhL-B cable

The 3-core twisted-pair cable Type 18-PhL-B medium is specified in Table R.1.

**Table R.1 – PhL-B cable specifications**

| Item | | Specifications |
|---|---|---|
| Cable type | | Shielded twisted cable |
| Outer diameter | | 8,0 mm or less |
| Number of cores | | 3 |
| Conductor size | | 20 AWG |
| Insulation size | | 0,55 mm to 0,80 mm |
| Drain line | | 20 lines/0,18 mm or 24 lines/0,18 mm<br>Insert separately or in a bundle between the ground cable bundle and aluminium tape. |
| Conductor resistance (20 °C) | | 37,8 Ω/km or less |
| Insulation resistance | | 10 000 MΩ/km or more |
| Dielectric withstand voltage | | 500 VDC 1 min |
| Electrostatic capacity (1 kHz) | | 60 nF/km or less |
| Impedance characteristic | 1 MHz | 110 Ω ± 15 Ω |
| | 5 MHz | 110 Ω ± 6 Ω |
| Attenuation (20 °C) | 1 MHz | 1,6 dB/100 m or less |
| | 5 MHz | 3,5 dB/100 m or less |
| Cross section | Twisted drain | See Figure R.1 |
| | Non-twisted drain | See Figure R.2 |

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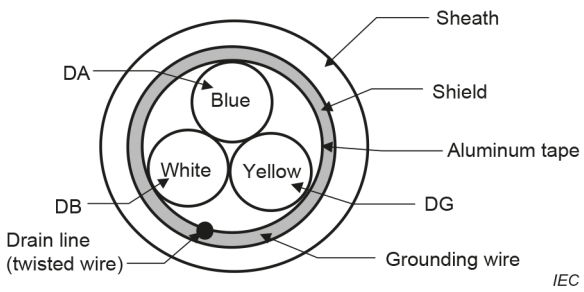


**Figure R.1 – PhL-B cable cross-section twisted drain**

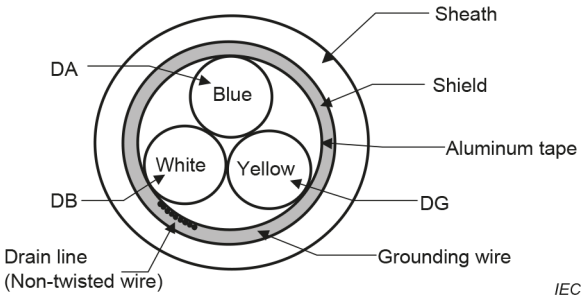


**Figure R.2 – PhL-B cable cross-section non-twisted drain**

## R.2 Type 18-PhL-P cable

### R.2.1 Flat cable

The 4-core unshielded flat cable Type-18-PhL-P medium is specified in Table R.2.

**Table R.2 – PhL-P flat cable specifications**

| Item | | Unit | Specification | |
|---|---|---|---|---|
| Cable type | | - | Flat cable | |
| Number of wire cores | | - | 4 | |
| Conductor | Material | - | Tinned, annealed copper wire (collective twisting) | |
| | AWG | - | 18 | |
| | Construction | Lines/mm | 43/0,16, 34/0,18, 30/0,18 | |
| | Standard outline | mm | 1,20 to 1,21 | |
| | Pitch between twisted lines | mm | 24,9 or less | |
| Insulating material | Material | - | Flexible resin | |
| | Standard thickness | mm | 0,66 to 0,67 | |
| | Outline (major axis × major axis) | mm | 2,54 ± 0,15 × 10,16 ± 0,40 | |
| | Line-to-line pitch | mm | 2,54 ± 0,10 | |
| Conductor resistance (at 20 °C) | | Ω/km | 23,4 or less | |
| Insulation resistance (at 20 °C) | | MΩ/km | 10 or more | |
| Withstand voltage | | - | 500 VAC, 1 min | |
| Characteristic impedance (reference value) | | Ω | 1 MHz | 130 ± 25 |
| | | | 2 MHz | |
| Attenuation amount (reference value) | | dB/100 m | 1 MHz | 3,04 or less |
| | | | 2 MHz | 4,83 or less |
| Electrostatic capacity (reference value) | | nF/km | 1 kHz | 55 or less |
| Cross section - with key (recommended) | | - | See Figure R.3 | |
| Cross section - without key | | - | See Figure R.4 | |
| Polarity marking | | - | See Figure R.5 | |

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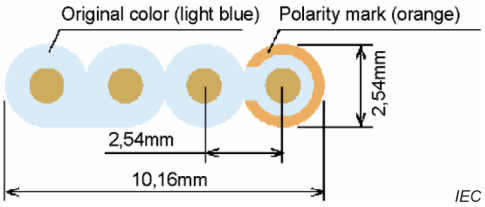


**Figure R.3 – PhL-P flat cable cross section – with key**

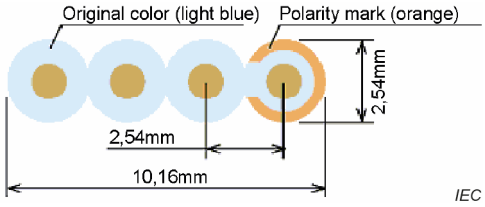


**Figure R.4 – PhL-P flat cable cross section – without key**

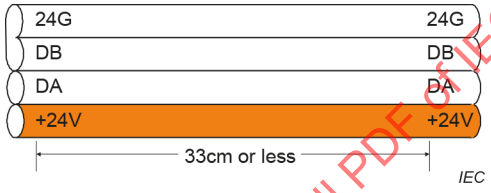


**Figure R.5 – PhL-P flat cable polarity marking**

### R.2.2 Round cable – preferred

The preferred 4-core unshielded round cable for the Type-18-PhL-P medium is specified in Table R.3. This cable type is also known as VCTF cord.

**Table R.3 – PhL-P round cable specifications – preferred**

| Item | | Unit | Specification |
|---|---|---|---|
| Cable type | | - | Polyvinyl chloride sheathed round cable |
| Number of wire cores | | - | 4 |
| Conductor | Nominal cross-sectional area | $mm^2$ | 0,75 |
| | Number of wires/diameter of a wire | wire/mm | 30/0,18 |
| | Outer diameter | mm | 1,1 |
| Insulator | Thickness | mm | 0,6 |
| | Outer diameter (approx.) | mm | 2,3 |
| Sheath | Thickness | mm | 1,0 |
| | Finish outer diameter (approx.) | mm | 7,6 |
| Conductor resistance (at 20 °C) | | Ω/km | 25,1 |
| Cross-section | | - | See Figure R.6 |

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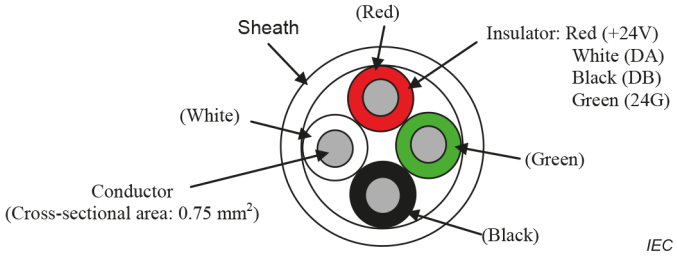


**Figure R.6 – Round cable – preferred; cross section**

### R.2.3 Round cable – alternate

The alternate 4-core unshielded round cable for the Type-18-PhL-P medium is specified in Table R.4.

**Table R.4 – PhL-P round cable specifications – alternate**

| Item | | Unit | Specification | |
|---|---|---|---|---|
| Number of wire cores | | - | 4 | |
| Conductor | Cross-sectional area | $mm^2$ | 0,75 | |
| Insulator | Outer diameter | mm | 1,8 to 2,4 | |
| Conductor resistance (at 20 °C) | | Ω/km | 35 or less | |
| Conductor resistance (at 20 °C) (reference value) | | MΩ/km | 5 or more | |
| Withstand voltage (reference value) | | - | 500 VAC, 1 min | |
| Characteristic impedance (reference value) | | Ω | 1 MHz | 90 ± 30 |
| | | | 2 MHz | |
| Drop in decibel level (reference value) | | db/100 m | 1 MHz | 4 or less |
| | | | 2 MHz | 5 or less |
| Electric capacity (reference value) | | nF/km | 1 MHz | 100 or less |
| Cross-section | | - | See Figure R.7 | |

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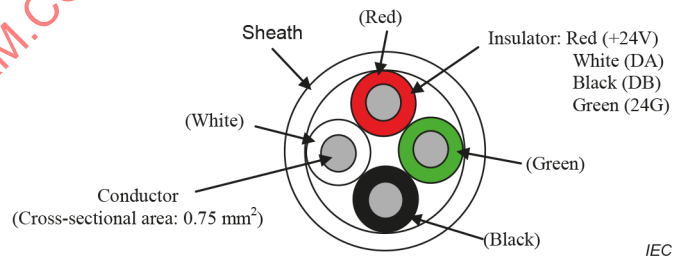


**Figure R.7 – Round cable – alternate; cross-section**

# Annex S
(normative)

# Type 24: Connector specification

## S.1 Overview

This annex specifies following two types of connectors based on media:

– Type 24-1 connector for twisted-pair wire medium, up to 10 Mbit/s;
– Type 24-2 connector for Ethernet based medium;
– Type 24-3 connector for twisted-pair wire medium, up to 32 Mbit/s.

## S.2 Type 24-1 connector

### S.2.1 Type 24-1 device connector

The dimensions of Type 24-1 device connector (1 row) are shown in Figure S.1.

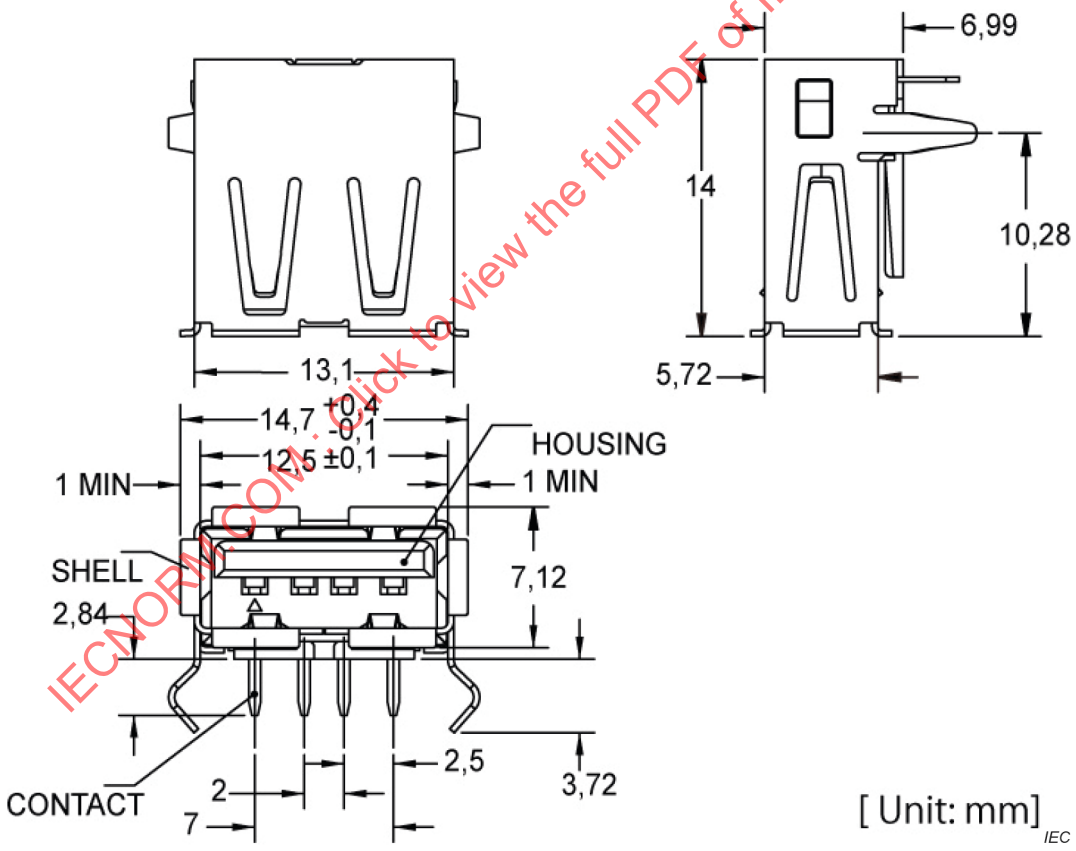


**Figure S.1 – Type 24-1 device connector dimensions (1 row)**

The dimensions of Type 24-1 device connector (2 rows) are shown in Figure S.2.

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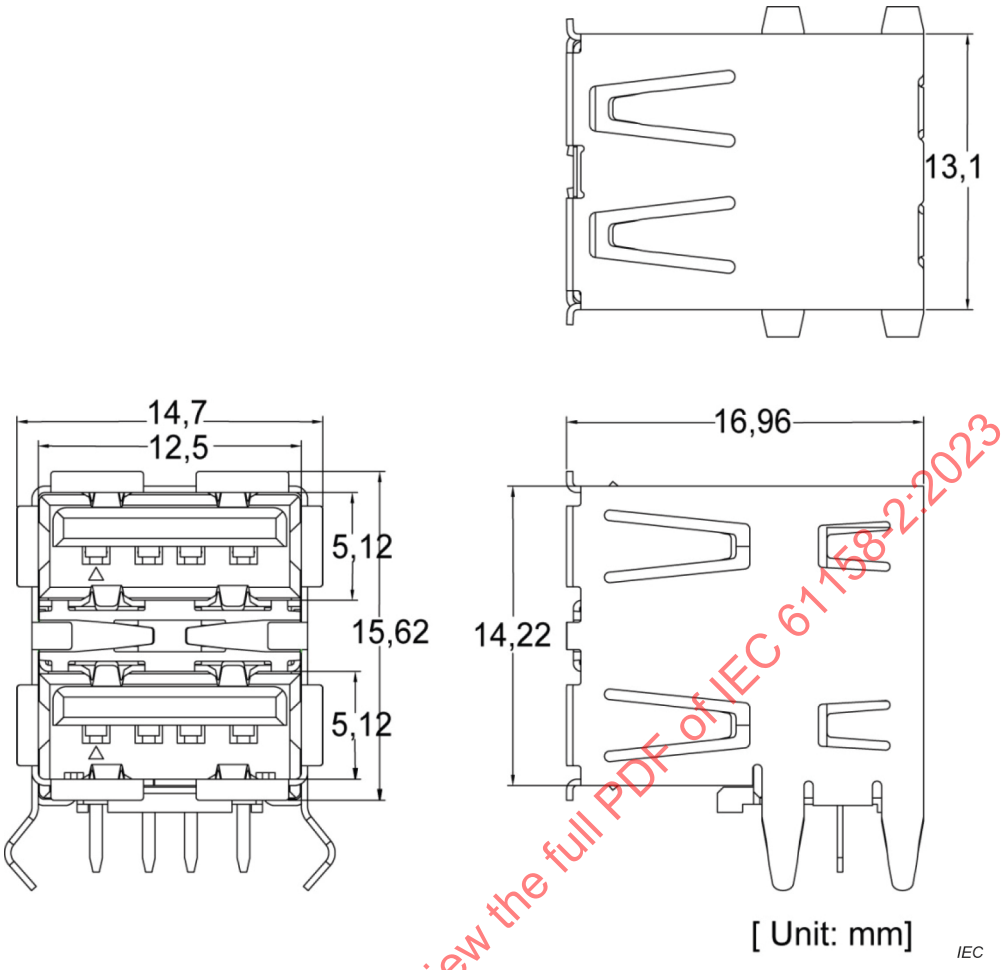


**Figure S.2 – Type 24-1 device connector dimensions (2 rows)**

### S.2.2 Type 24-1 cable connector

The dimensions of Type 24-1 cable connector are shown in Figure S.3.

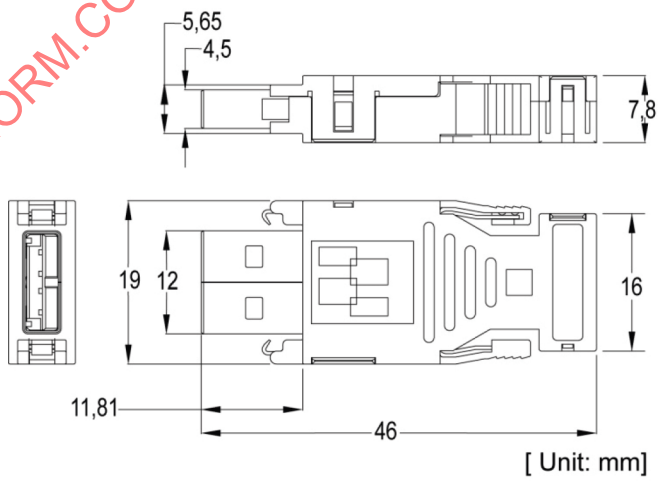


**Figure S.3 – Type 24-1 cable connector dimensions**

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## S.3 Type 24-2 connector

### S.3.1 Type 24-2 device connector

This device connector is specified IEC 61076-3-122.

### S.3.2 Type 24-2 cable connector

This cable connector is specified IEC 61076-3-122.

## S.4 Type 24-3 connector

### S.4.1 Type 24-3 device connector

The dimensions of Type 24-3 device connector are shown in Figure S.4, Figure S.5, Figure S.6, Figure S.7, Figure S.8, and Figure S.9. This device connector is specified IEC 61076-3-122.

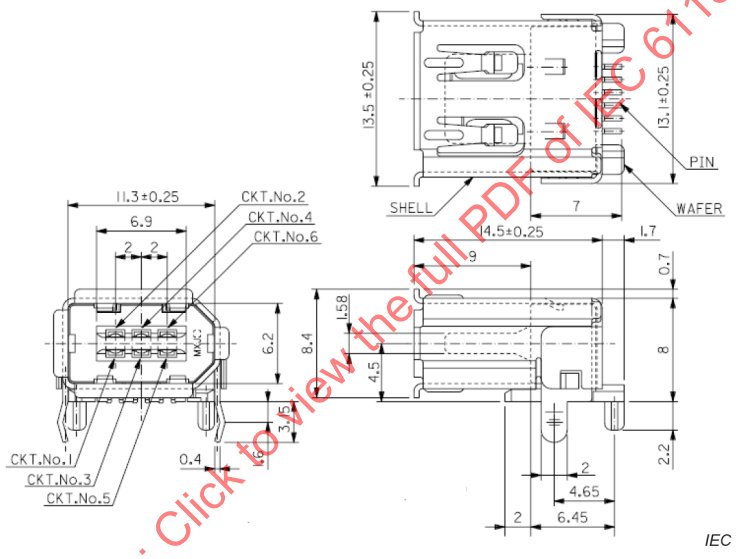


**Figure S.4 – Type 24-3 device 6 pin connector (surface mount type) dimensions**

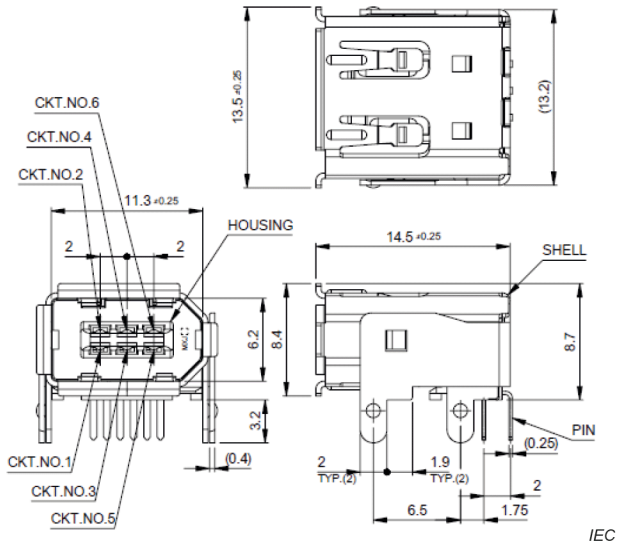


**Figure S.5 – Type 24-3 device 6 pin connector (through-hole mount type) dimensions**

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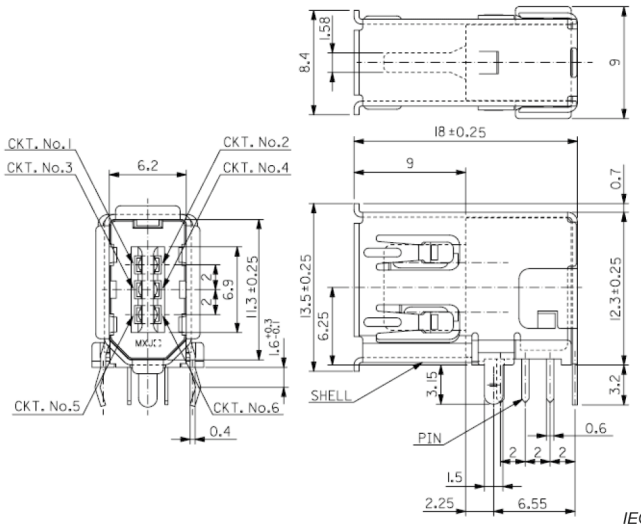


**Figure S.6 – Type 24-3 device 6 pin connector (upright through-hole mount type) dimensions**

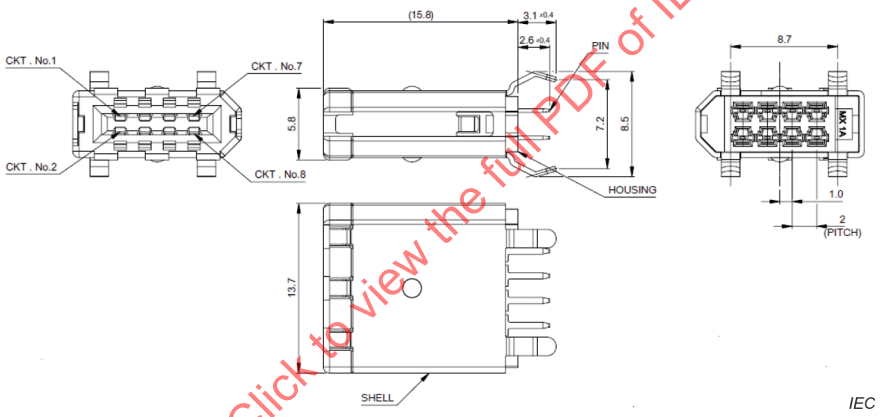


**Figure S.7 – Type 24-3 device 8 pin male connector dimensions**

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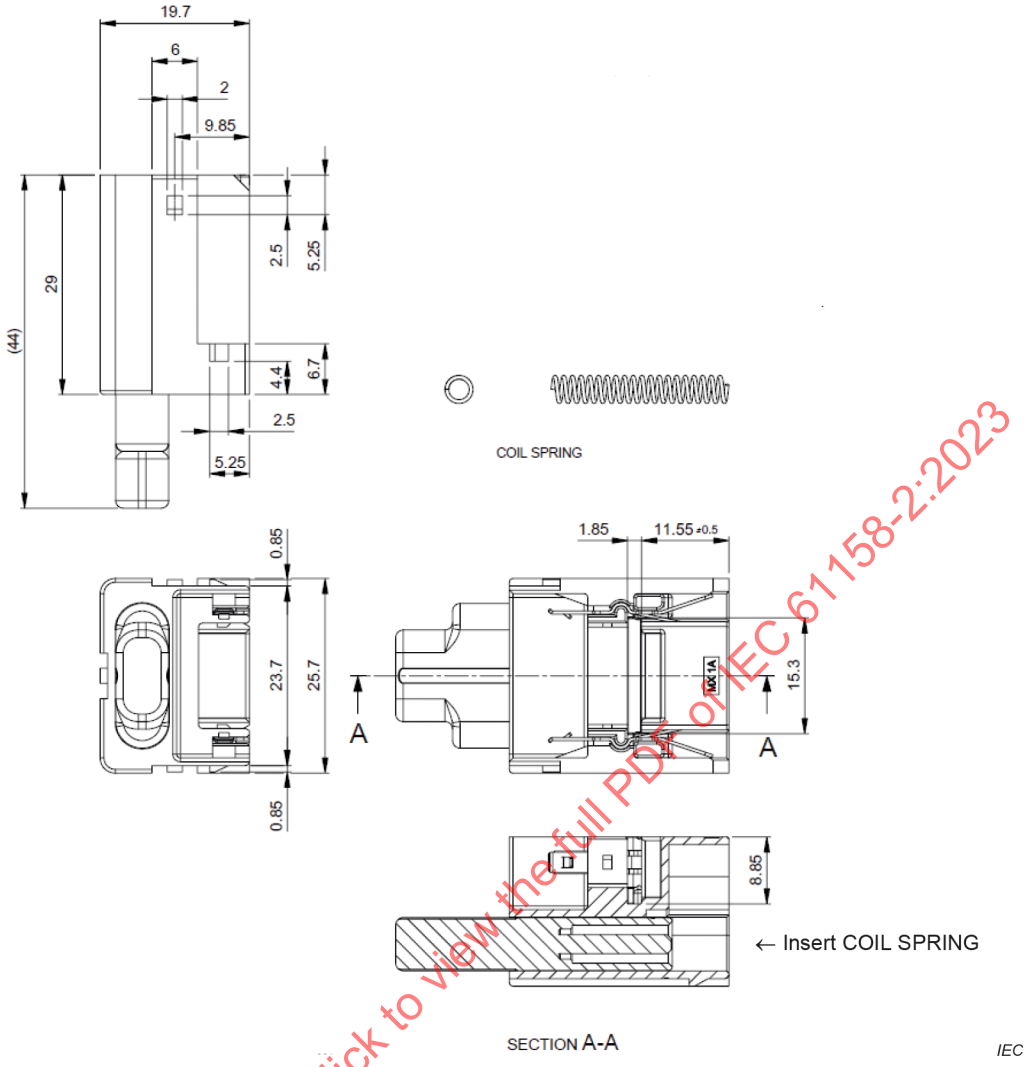


**Figure S.8 – Type 24-3 ejector dimensions for device 8 pin male connector**

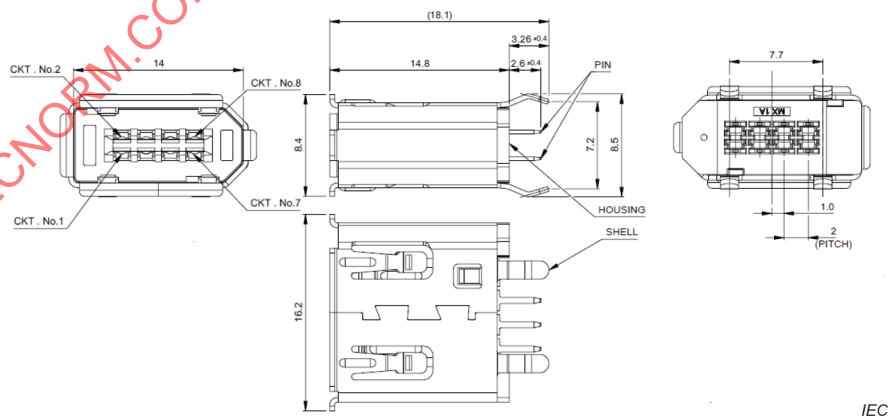


**Figure S.9 – Type 24-3 device 8 pin female connector dimensions**

### S.4.2 Type 24-3 cable connector

The dimensions of Type 24-3 cable connector are shown in Figure S.10, Figure S.11, Figure S.12, and Figure S.13.

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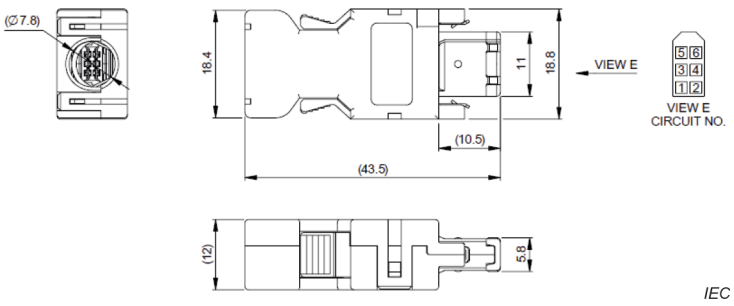


**Figure S.10 – Type 24-3 cable 6 pin male connector dimensions**

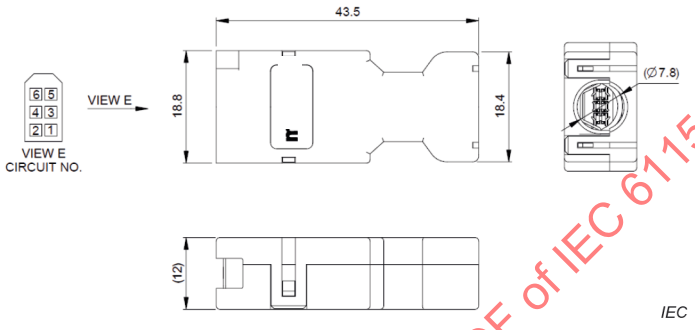


**Figure S.11 – Type 24-3 cable 6 pin female connector dimensions**

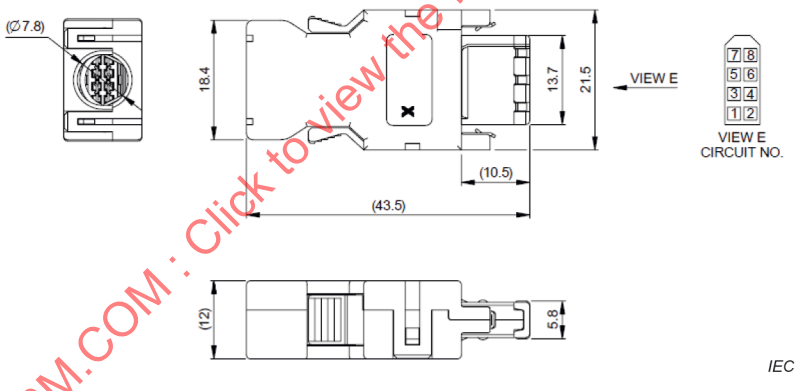


**Figure S.12 – Type 24-3 cable 8 pin male connector dimensions**

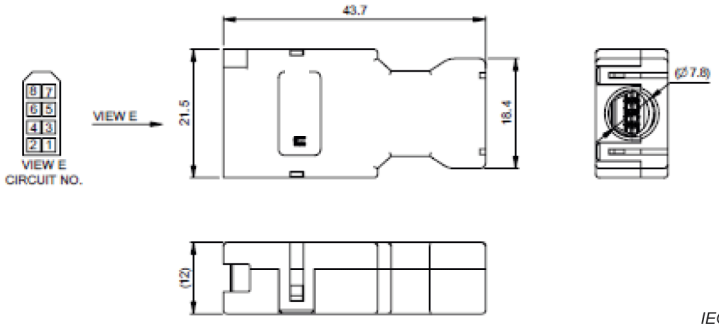


**Figure S.13 – Type 24-3 cable 8 pin female connector dimensions**

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# Annex T
(informative)

# Type 20: Network topology, cable characteristics and lengths, power distribution through barriers, and shielding and grounding

## T.1 Topology examples

### T.1.1 General

The devices conforming to this document can be used in networks with various topologies. This annex provides some of the examples.

### T.1.2 Point-to-point current input network

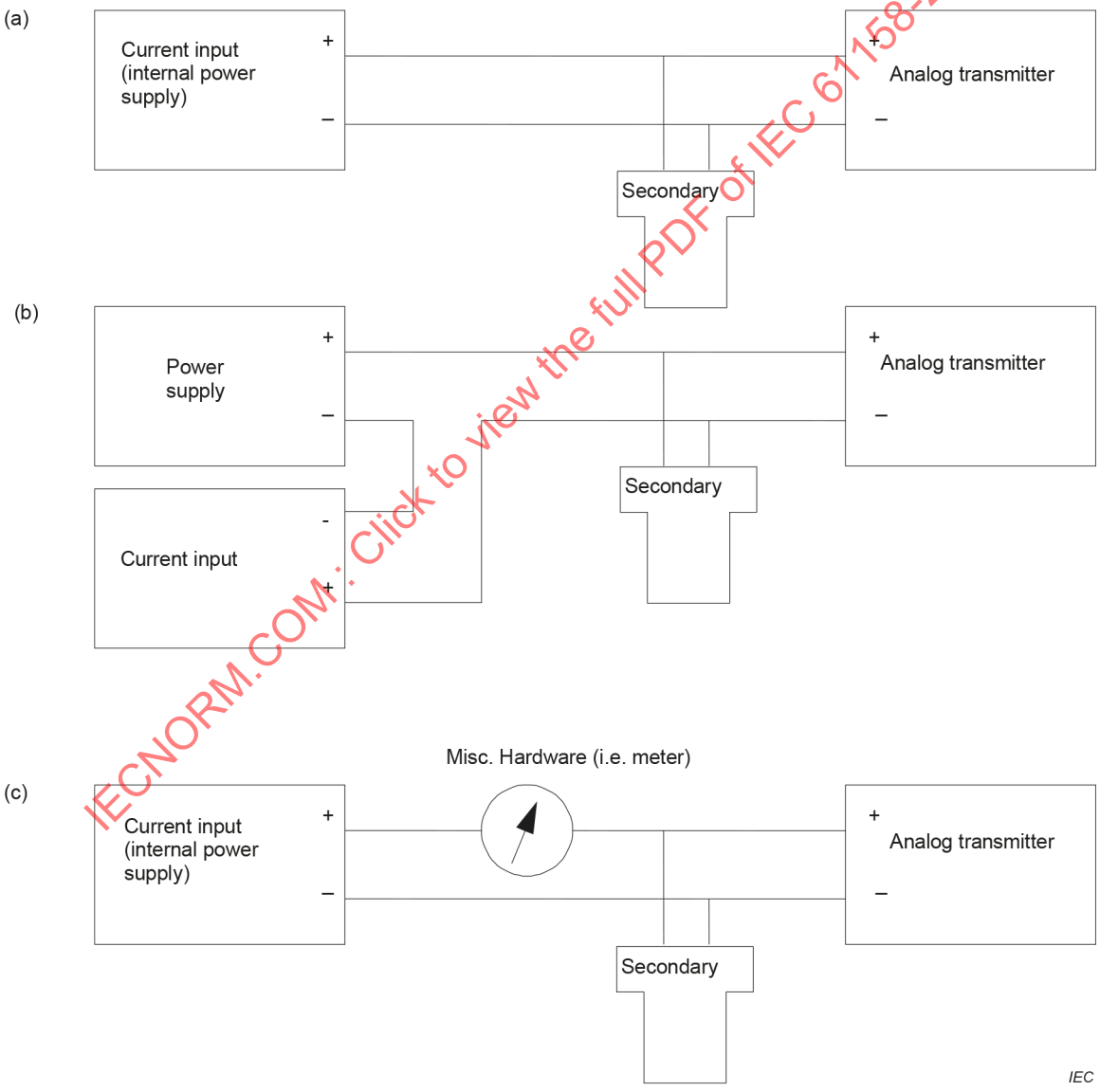


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**Figure T.1 – Point-to-point current input network**

Figure T.1 shows a network with one Analog transmitter, one current input device and one secondary device - see 34.3.3 for connection types. The current input device in Figure T.1 a) and Figure T.1 c) has an internal power supply for the network. The topology of Figure T.1 b) uses a separate power supply. There can be other entity (meter) in the network as shown in Figure T.1 c), because it has low impedance in series with the cable.

### T.1.3 Point-to-point current output network

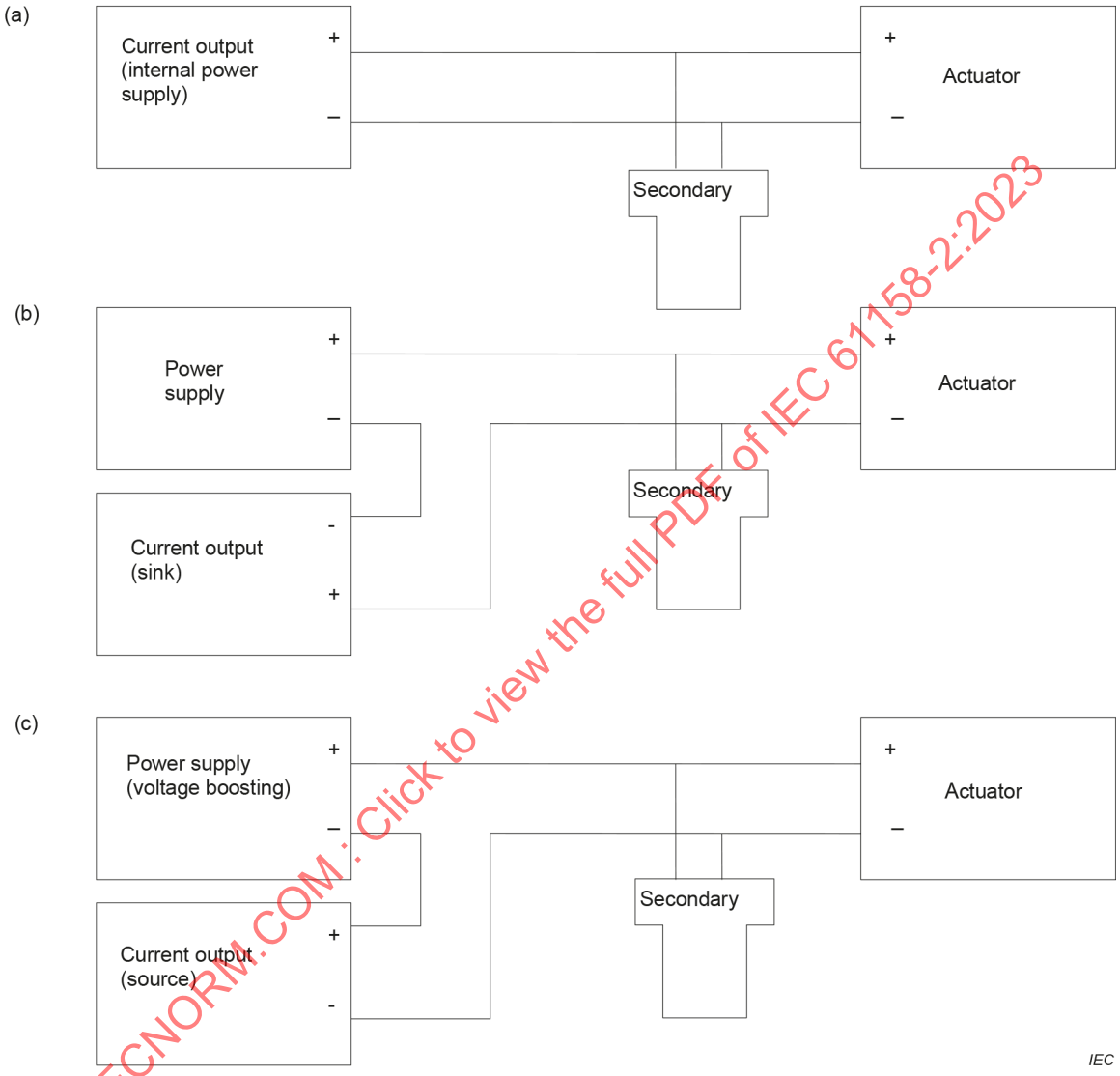


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**Figure T.2 – Point-to-point current output network**

Figure T.2 shows a network with one Actuator, one output device and one secondary device - see 34.3.3 for connection types. The current output device in Figure T.2 a) has internal power supply for the network.

### T.1.4 Multi-drop network

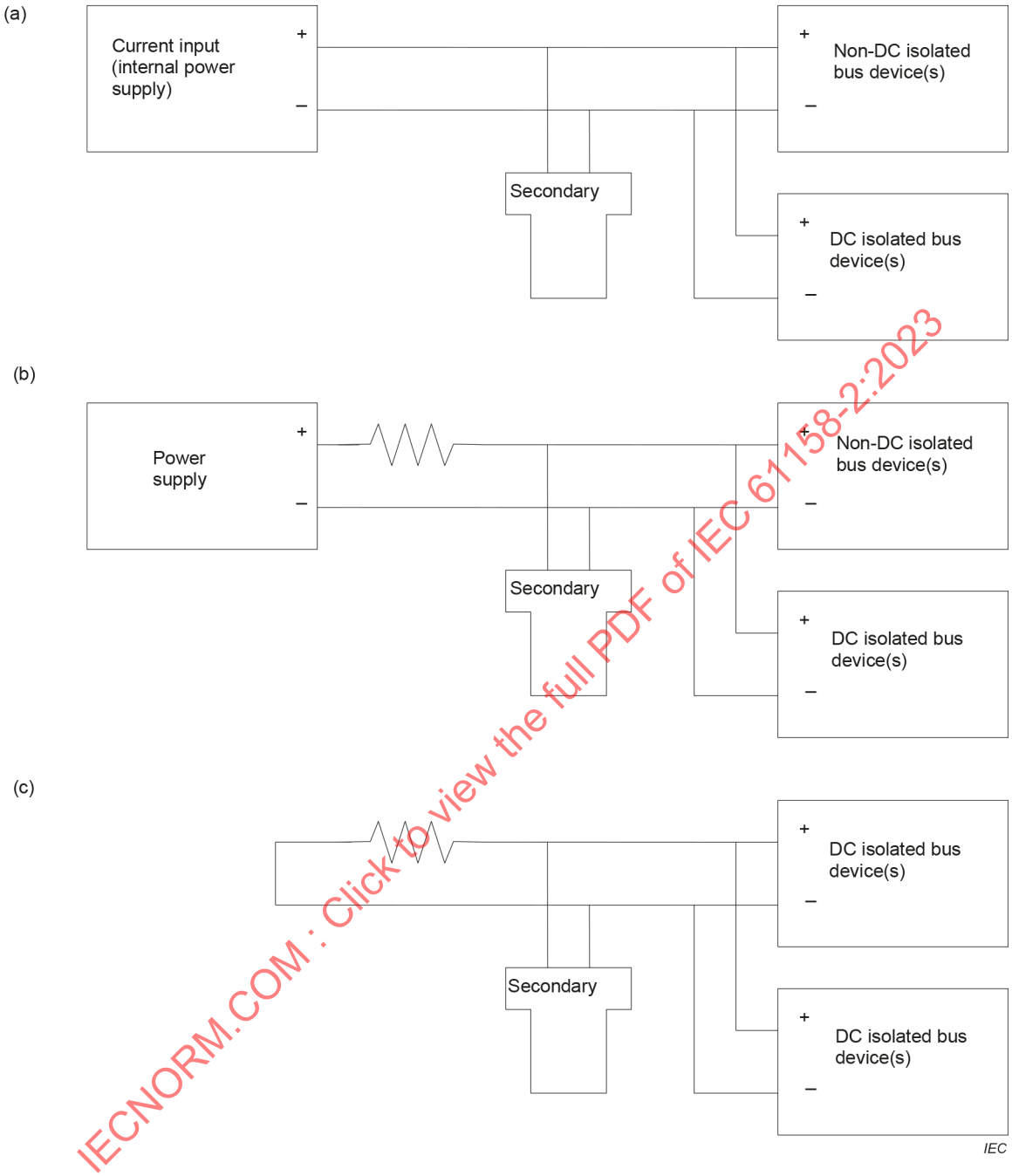


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**Figure T.3 – Multi-drop network**

Figure T.3 shows a multi-dropped network with two slaves. As shown in Figure T.3 b) and c), it is not necessary to connect any current input device. But it is necessary to have current sensing resistor in the network. The power supply is required only if the network has at least one device that draws DC current.

### T.1.5 Multi-drop network with analog signaling

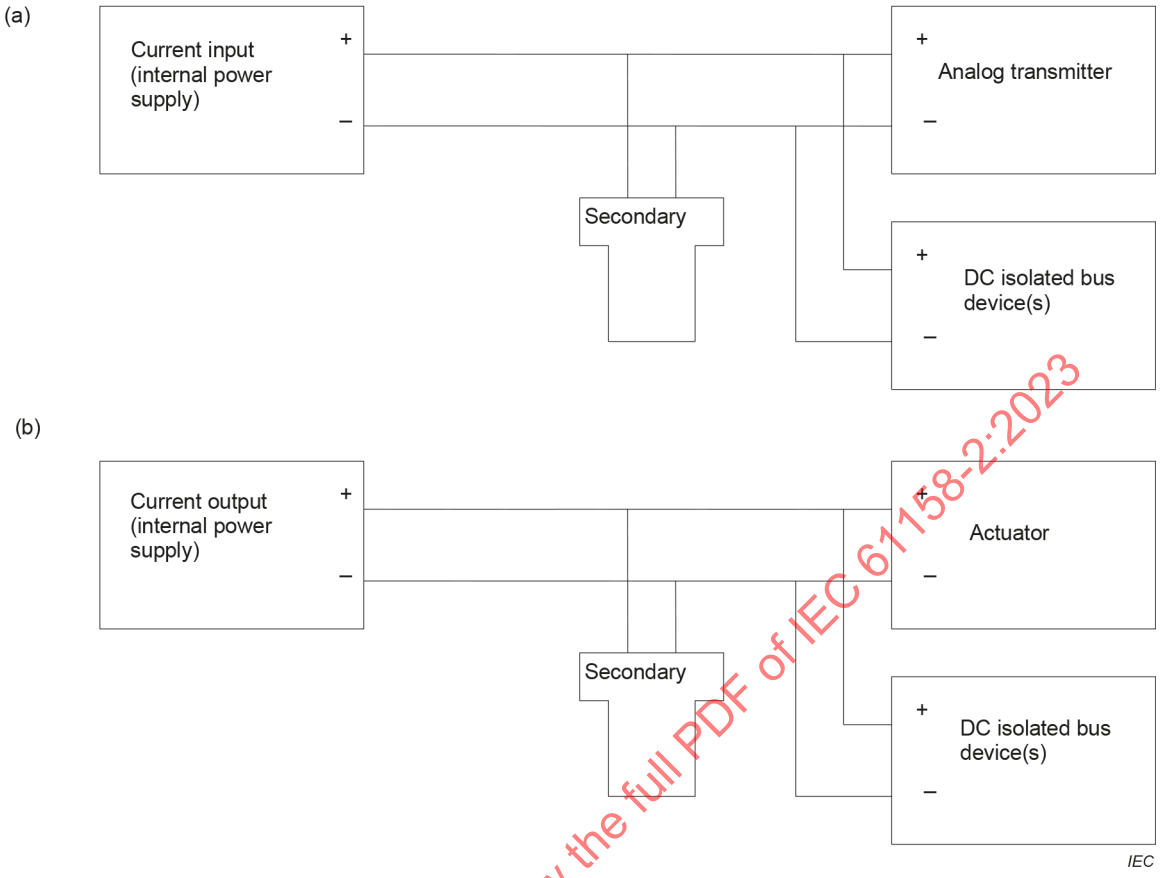


**Figure T.4 – Multi-drop network with analog signaling**

Figure T.4 shows a multi-dropped network with one slave that uses analog signaling and one slave that does not. It is necessary to connect a current input device for Analog transmitter as shown in Figure T.4 a), or current output device for Actuator.

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### T.1.6 Series connected network

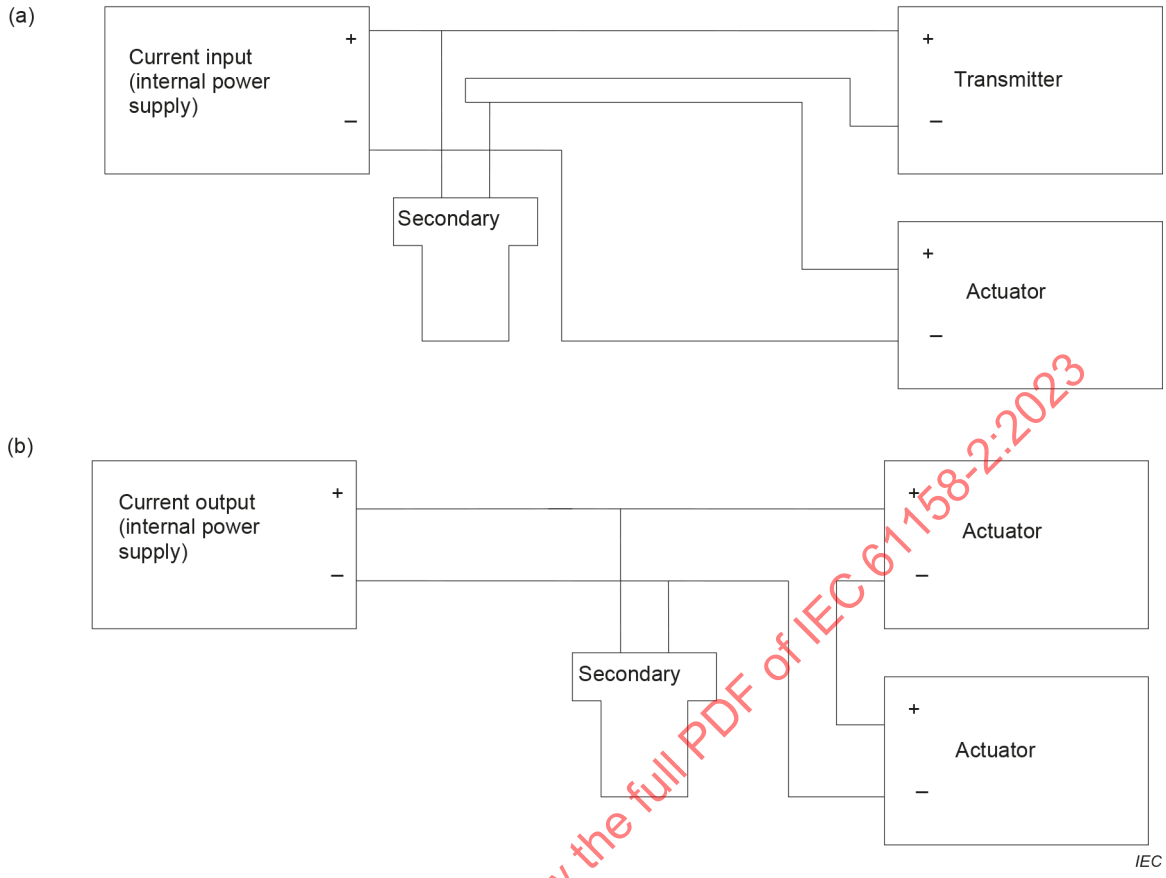


**Figure T.5 – Series connected network 1**

Figure T.5 shows a series connected network with two slaves, one secondary device and one current input or current output device. The secondary device has to be connected across high impedance device as shown in Figure T.5 a). If the network does not have a high impedance device as shown in Figure T.5 b), then the secondary has to be connected across the current output device. If this rule is not followed, then communication with all devices is not possible.

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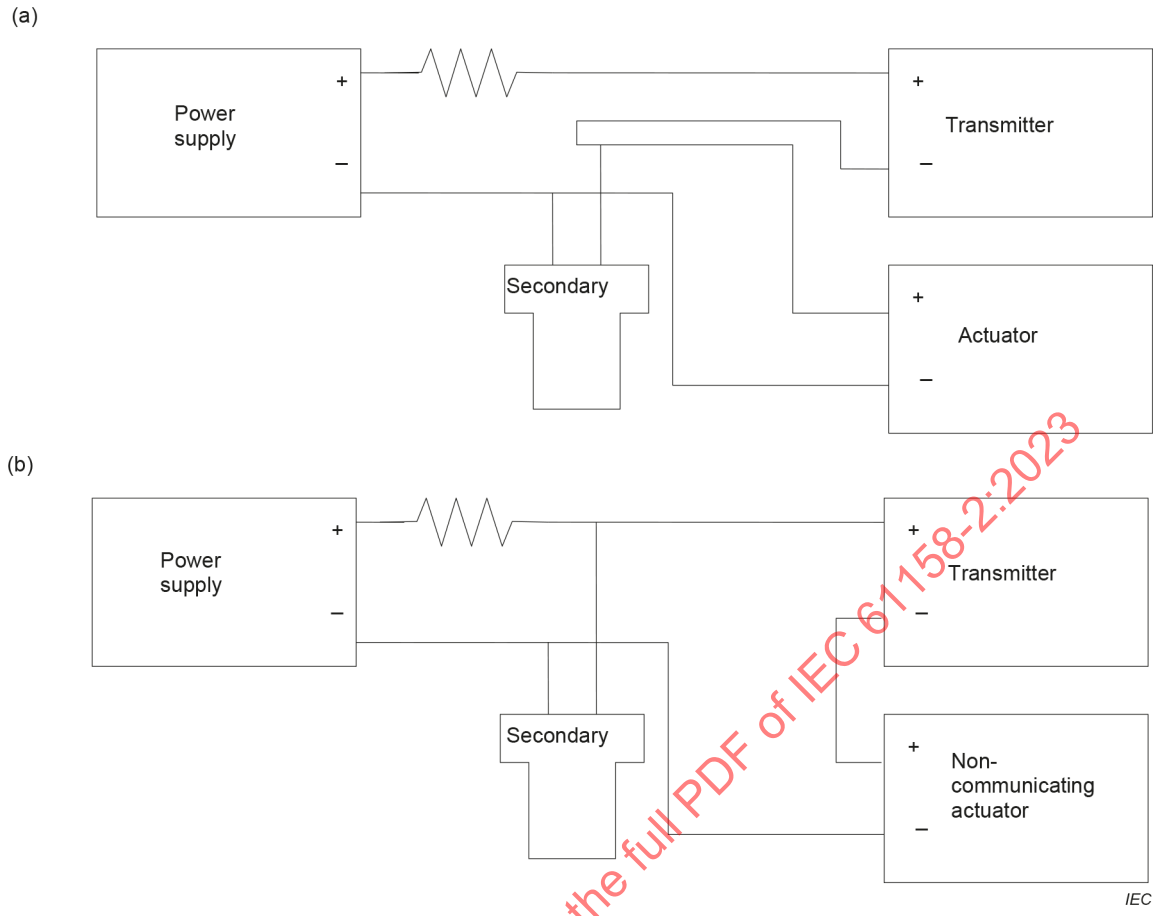


**Figure T.6 – Series connected network 2**

Figure T.6 shows a series connected network with two slaves, one secondary device and no current input or current output device. The secondary device has to be connected across one of the devices. If this rule is not followed, then communication with all devices is not possible. It is possible to connect a non-communicating device as shown in Figure T.6 b).

The communicating Actuator in all of series connected networks is a low impedance device. To achieve the longest cable length, it is necessary to match its impedance with the impedance of the other low impedance device in the network – the series sense resistor or the current input or current output device.

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## T.2 Cable description and specifications

### T.2.1 General

The preferred cable is a single or multiple, twisted pair with overall shield. Single and multiple-pair may be combined in a given network provided all the devices at one end (typically the control room end) of the multi-pair cable share a common shield or chassis ground, and the overall shield is connected to this ground. Unshielded cable should be used only if it is known that the ambient noise or crosstalk is low enough to keep the communication error rate below acceptable limit. The following are the preferred minimum conductor sizes:

- Total cable length up to 1 500 m - 0,51 mm diameter,

  NOTE 1 This is the same as 24 AWG wire.

- Total cable length more than 1 500 m - 0,81 mm diameter

  NOTE 2 This is the same as 20 AWG wire.

### T.2.2 Single pair cable length

#### T.2.2.1 Parameters

The maximum length of cable for a network is dependent on the characteristics of the devices connected to the network and the characteristics of the cable to be used. For all cable length estimates, the parameters defined in Table T.1 are required.

**Table T.1 – Device and cable parameters**

| Symbol | Parameter name | Parameter description |
|---|---|---|
| $\sum C_{dev}$ | Parallel device capacitance | Sum of the equivalent device capacitance ($C_{dev}$) values of all connected devices |
| $\sum R_{dev}$ | Parallel device resistance | Parallel combination of the equivalent device resistance ($R_{dev}$) values of all connected devices |
| $R_{ser}$ | Miscellaneous series impedance | Sum of the maximum impedance over frequency range of 500 Hz to 10 kHz, of all devices connected in series between two communicating devices |
| $C_{cbl}$ | Cable capacitance per unit length | The capacitance from one conductor to all other conductors (including the shield if shielded) |
| $R_{cbl}$ | Cable resistance per unit length | The resistance of both the conductors in series |

#### T.2.2.2 Procedure

Determine the parameter values defined in T.2.2.1. The $C_{dev}$ and $R_{dev}$ are provided by the device manufacturer. Typically, there is only one low impedance device in the network for example, the current input device in an analog transmitter loop and it dominates the value of $\sum R_{dev}$. The effect of high impedance device connected to the network is usually negligible in calculating the $\sum R_{dev}$. Therefore, the $R_{dev}$ of the single low-impedance device may be used for the parallel device resistance value. A typical non-intrinsically safe loop does not have miscellaneous series impedance. Passive IS barriers and current indicators are examples of series devices. Series topologies such as field devices with PID capability or split-ranged actuator devices, are analyzed by treating one of the field devices as a miscellaneous series resistance while analyzing the network for the other. The values of $C_{cbl}$ and $R_{cbl}$ are provided by the cable manufacturer. After the parameter values are known, the charts shown in Figure T.7 to Figure T.27 are used to find the maximum cable length that can be used. It may be necessary to interpolate the values in the charts for actual parameter values.

Figure T.7 shows the maximum cable length that can be used for a network with one slave device and a 250 Ω series sense resistor. An ideal network has dominant low impedance device of 250 Ω, high impedance devices of 100 kΩ or larger and a cable with low capacitance.

Figure T.8, Figure T.9, Figure T.10 and Figure T.11 show the total allowable cable capacitance for a network that contains multiple devices and no miscellaneous series impedance. The maximum cable length can be calculated from the allowable cable capacitance value. Figure T.12, Figure T.13, Figure T.14 and Figure T.15 show the total allowable cable capacitance for a network that contains multiple devices and various values of series impedance for a cable with capacitance to resistance ratio of 1 000. Figure T.16, Figure T.17, Figure T.18 and Figure T.19 show the total allowable cable capacitance for a network that contains multiple devices and various values of series impedance for a cable with capacitance to resistance ratio of 2 000. Figure T.20, Figure T.21, Figure T.22 and Figure T.23 show the total allowable cable capacitance for a network that contains multiple devices and various values of series impedance for a cable with capacitance to resistance ratio of 5 000. Figure T.24, Figure T.25, Figure T.26 and Figure T.27 show the total allowable cable capacitance for a network that contains multiple devices and various values of series impedance for a cable with capacitance to resistance ratio of 10 000.

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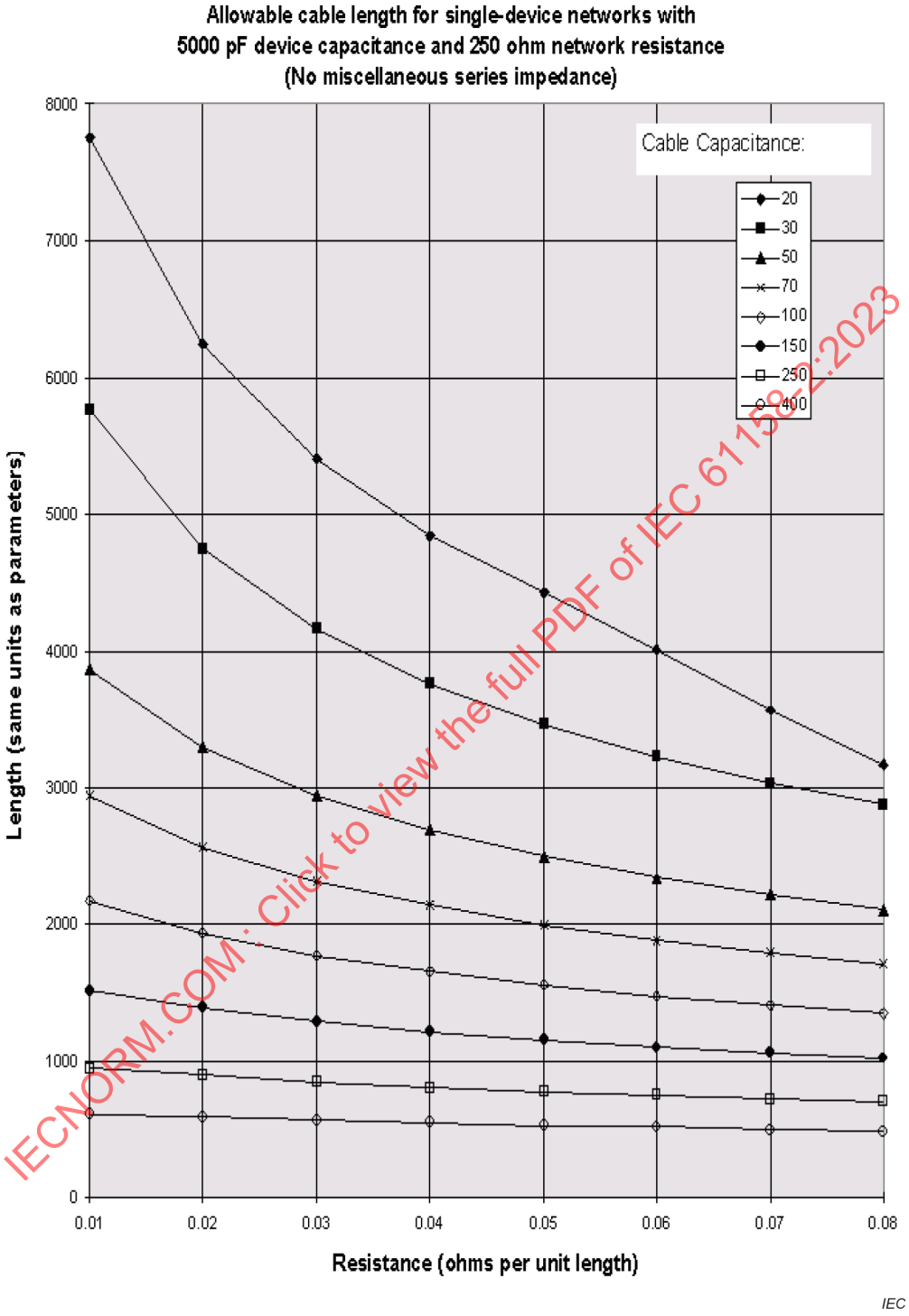


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**Figure T.7 – Cable length for single slave device network**

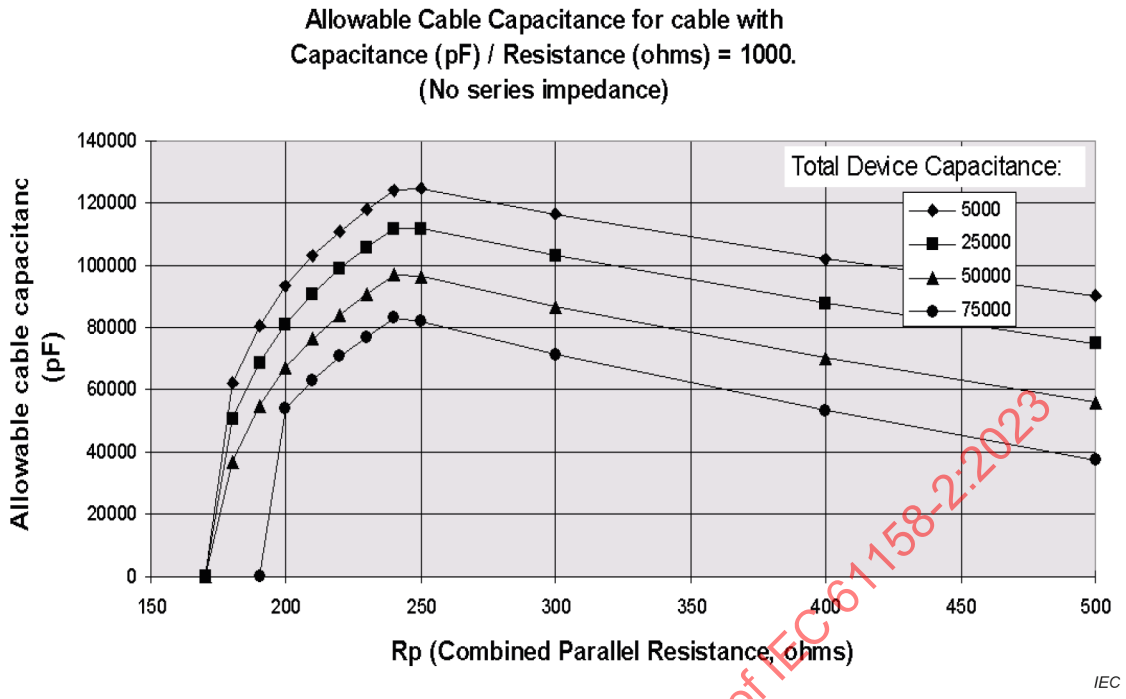


**Figure T.8 – Cable capacitance for $C_{cbl}/R_{cbl}$=1 000**

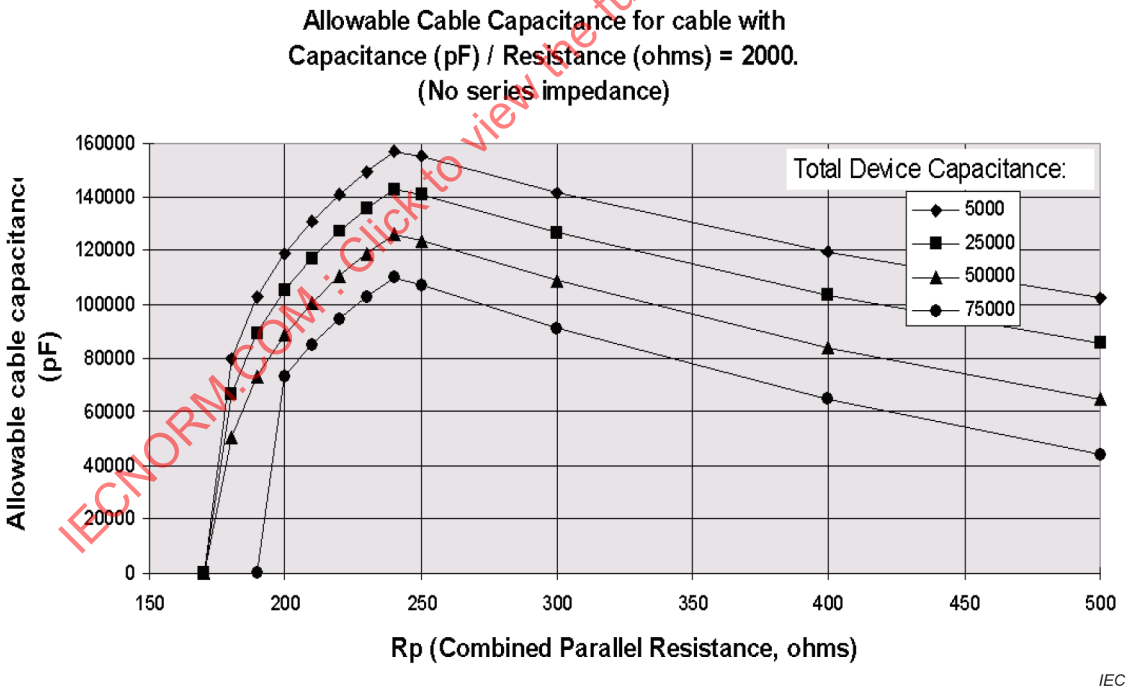


**Figure T.9 – Cable capacitance for $C_{cbl}/R_{cbl}$=2 000**

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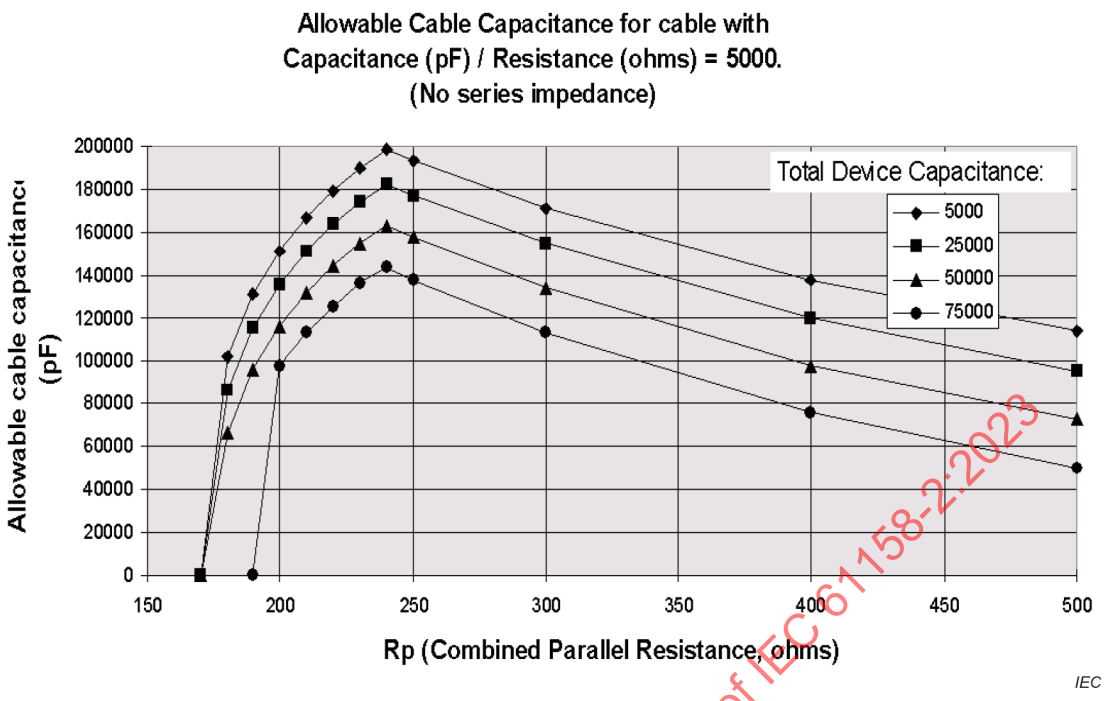


**Figure T.10 – Cable capacitance for $C_{cbl}/R_{cbl}$=5 000**

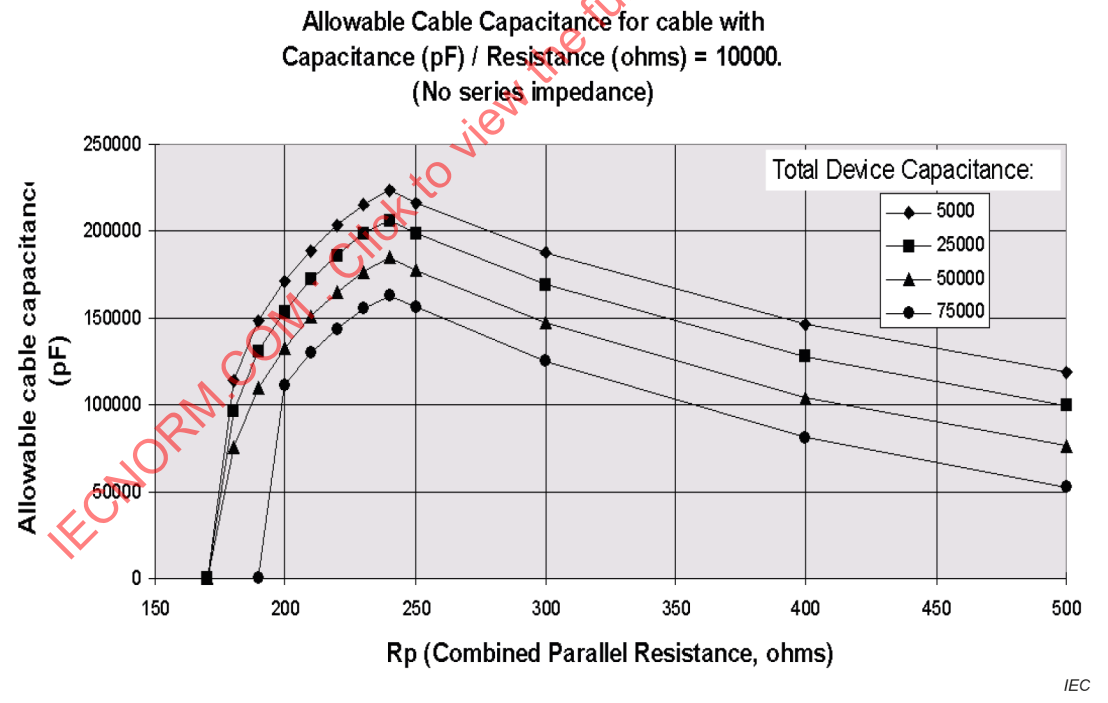


**Figure T.11 – Cable capacitance for $C_{cbl}/R_{cbl}$=10 000**

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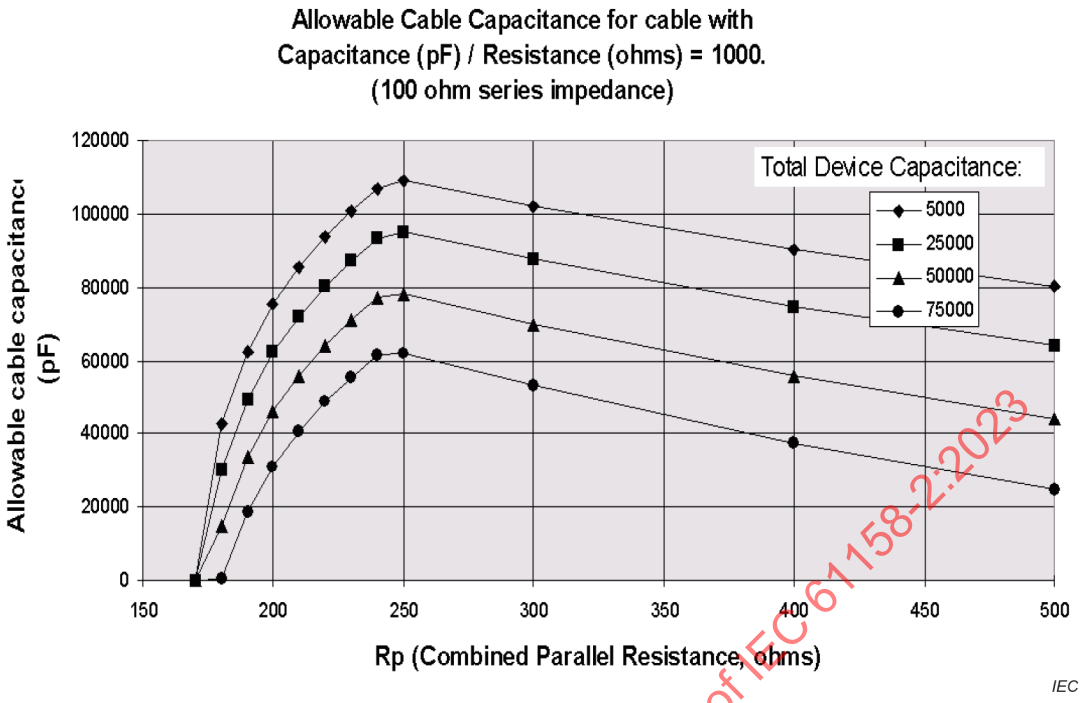


**Figure T.12 – Cable capacitance for $C_{cbl}/R_{cbl}$=1 000, 100 Ω series resistance**

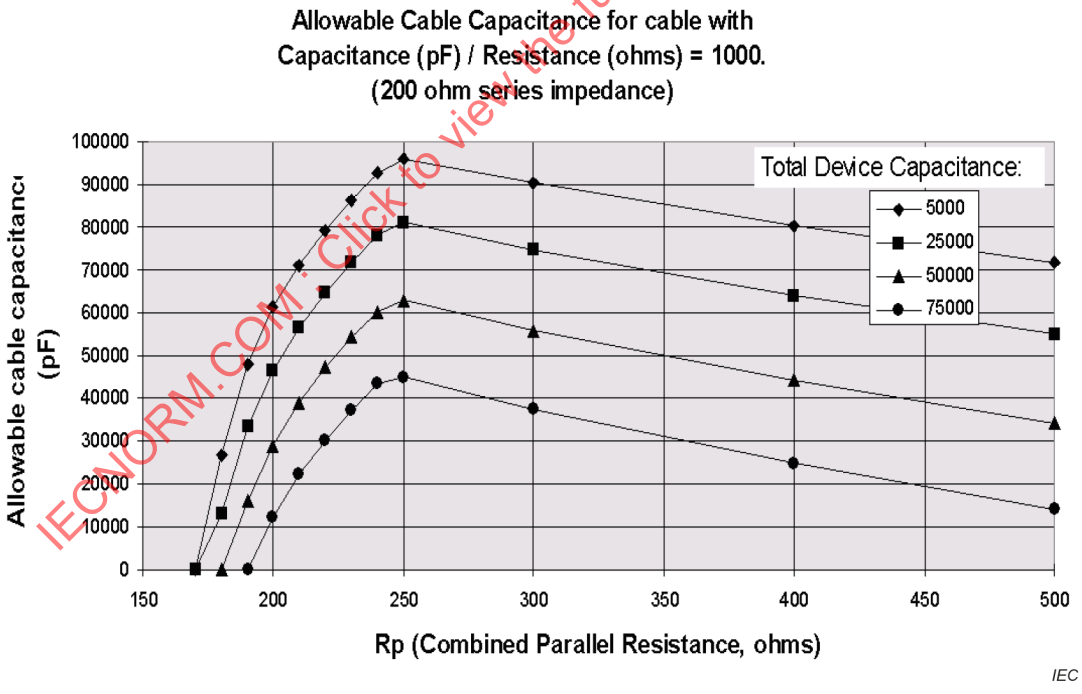


**Figure T.13 – Cable capacitance for $C_{cbl}/R_{cbl}$=1 000, 200 Ω series resistance**

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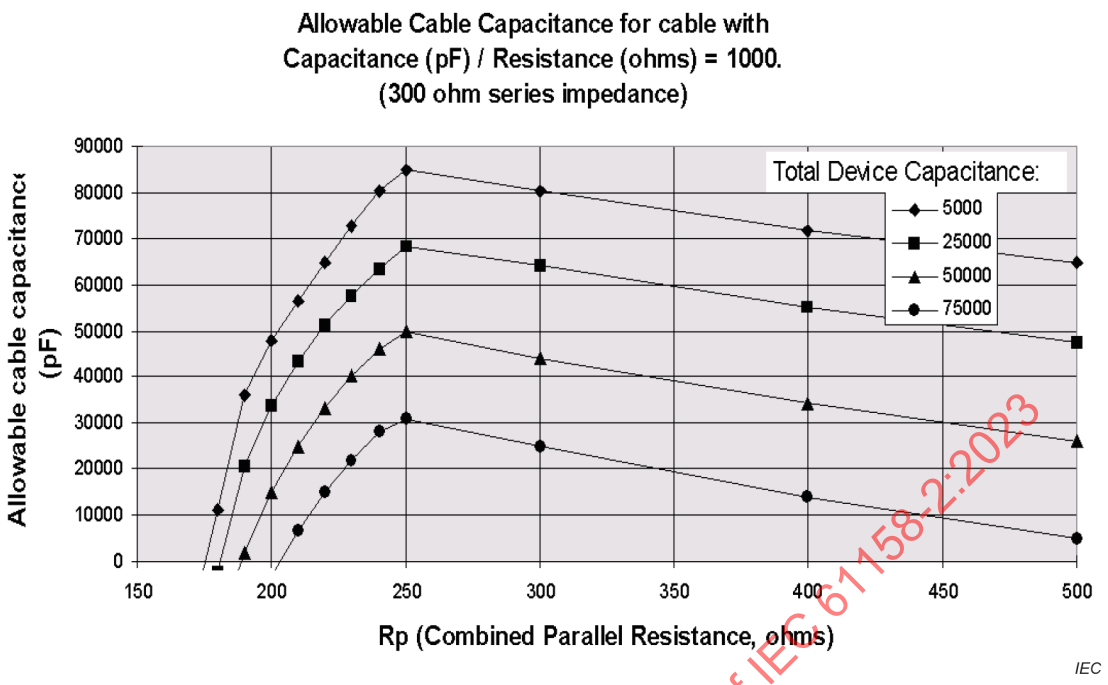


**Figure T.14 – Cable capacitance for $C_{cbl}/R_{cbl}$=1 000, 300 Ω series resistance**

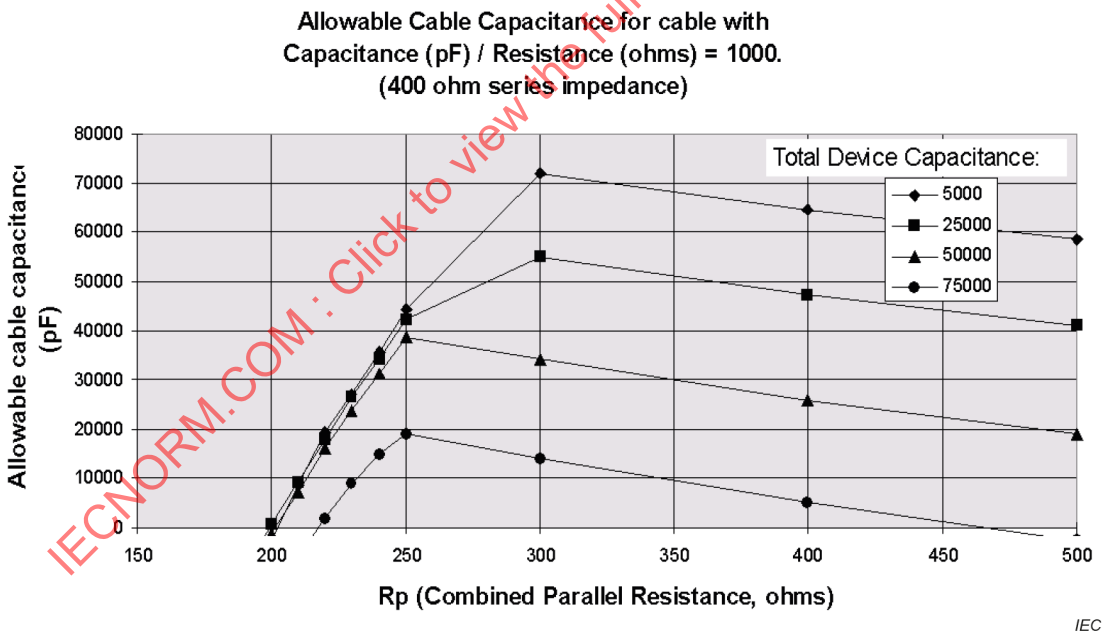


**Figure T.15 – Cable capacitance for $C_{cbl}/R_{cbl}$=1 000, 400 Ω series resistance**

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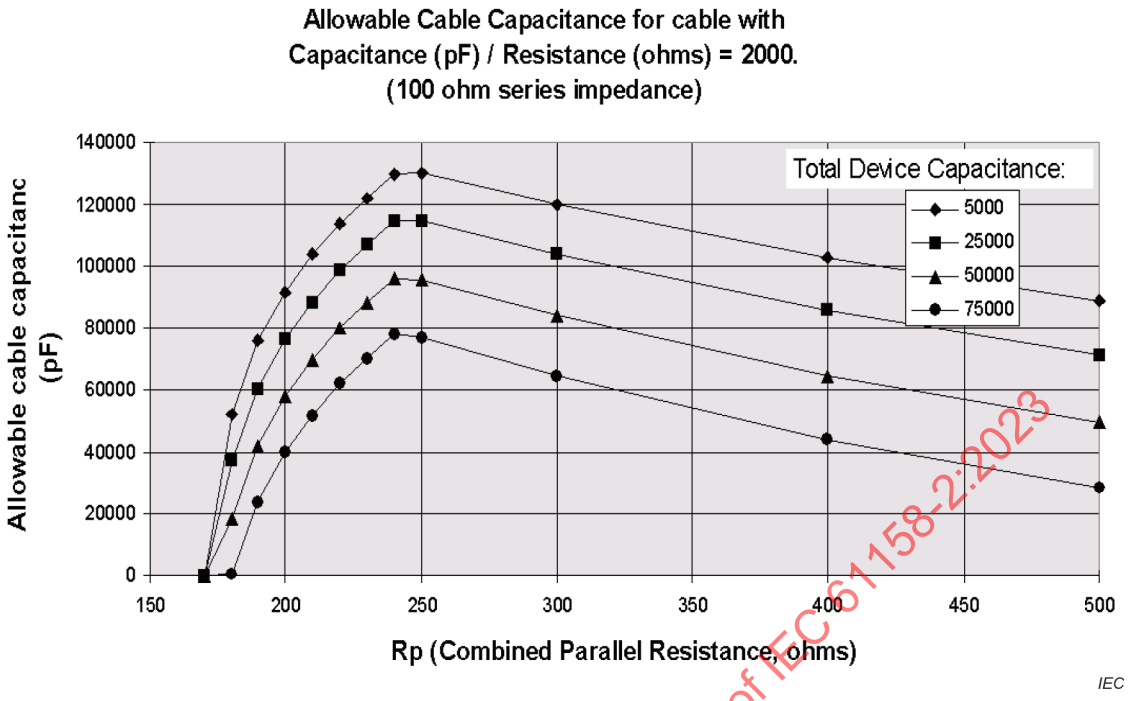


**Figure T.16 – Cable capacitance for $C_{cbl}/R_{cbl}$=2 000, 100 Ω series resistance**

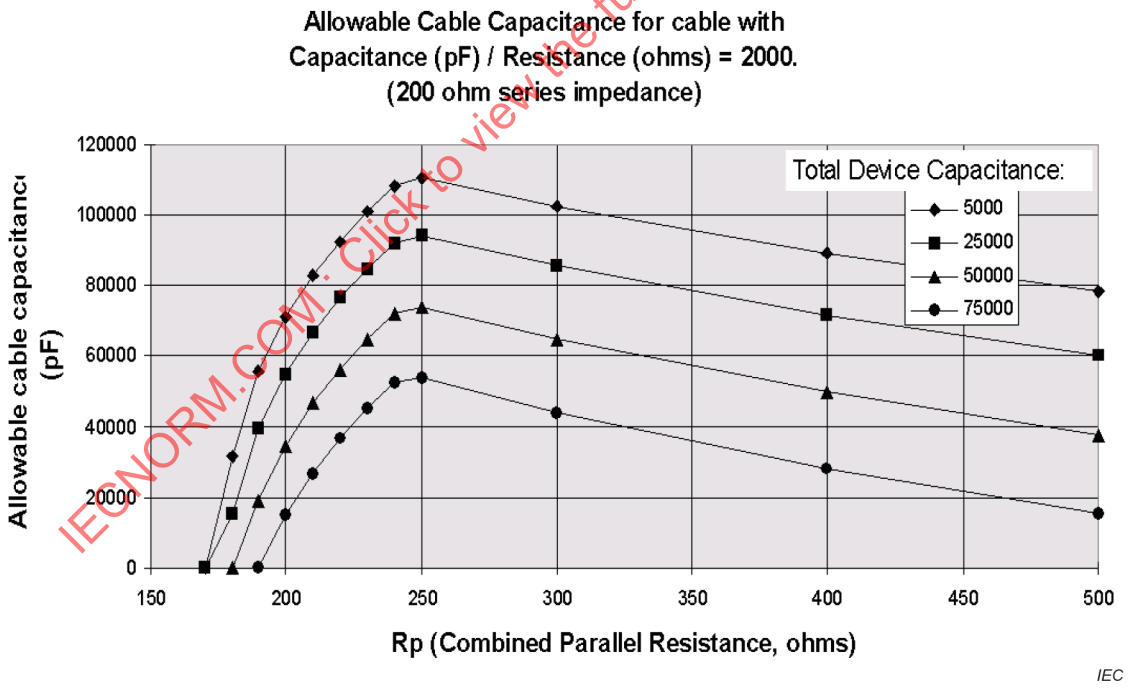


**Figure T.17 – Cable capacitance for $C_{cbl}/R_{cbl}$=2 000, 200 Ω series resistance**

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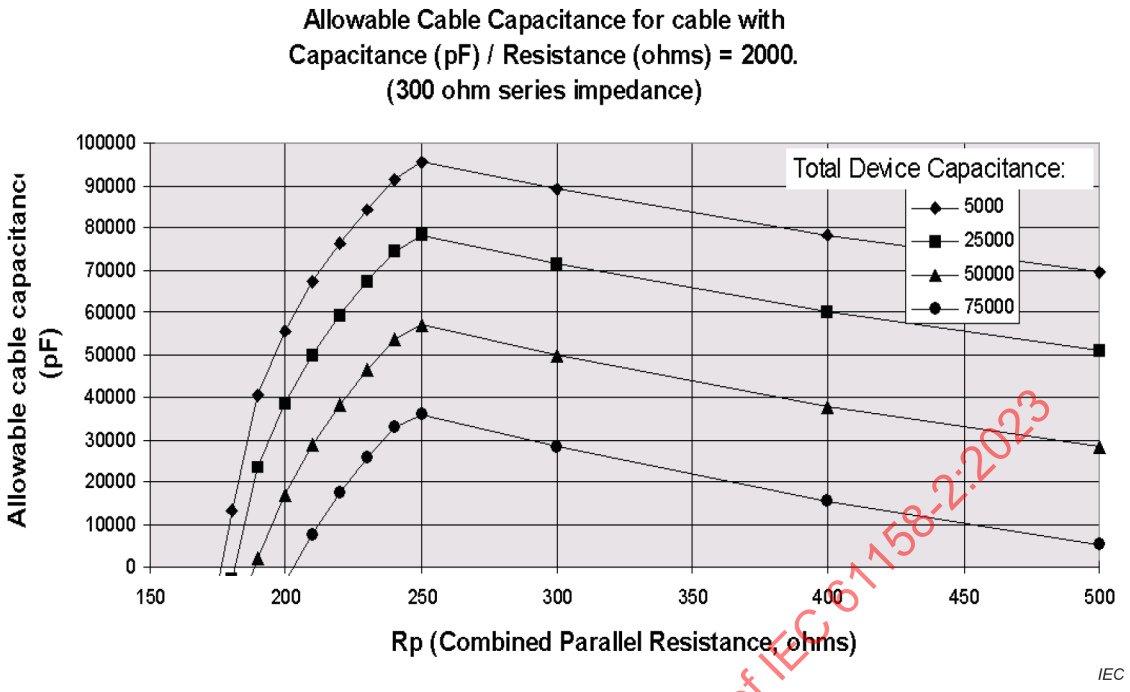


**Figure T.18 – Cable capacitance for $C_{cbl}/R_{cbl}$=2 000, 300 Ω series resistance**

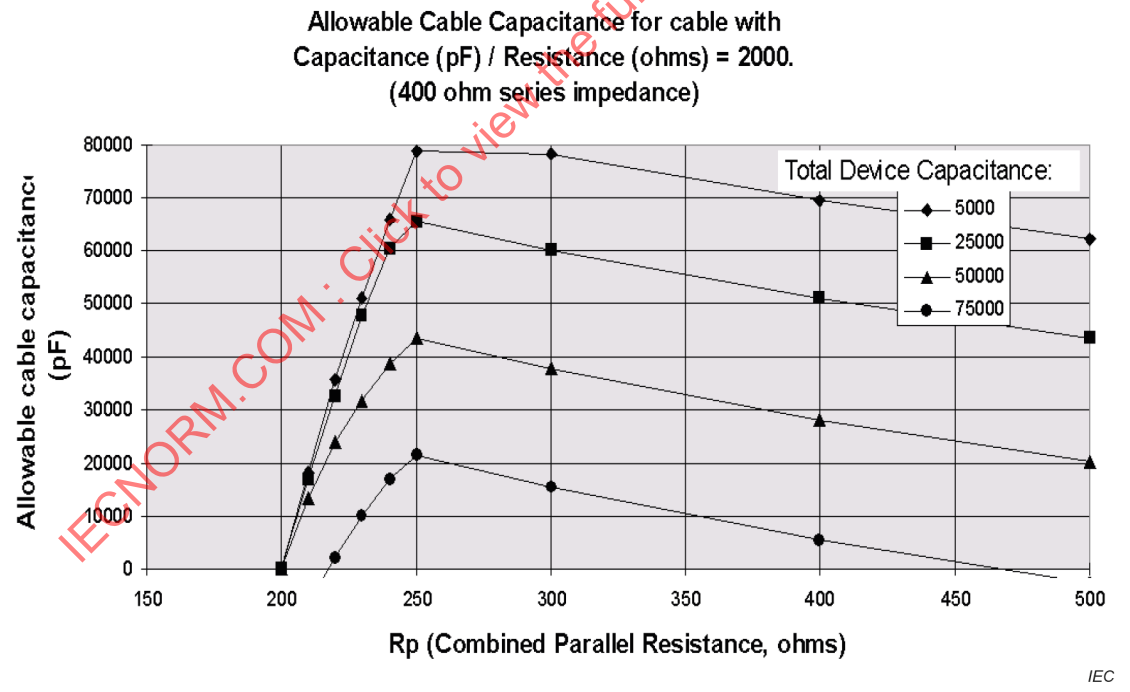


**Figure T.19 – Cable capacitance for $C_{cbl}/R_{cbl}$=2 000, 400 Ω series resistance**

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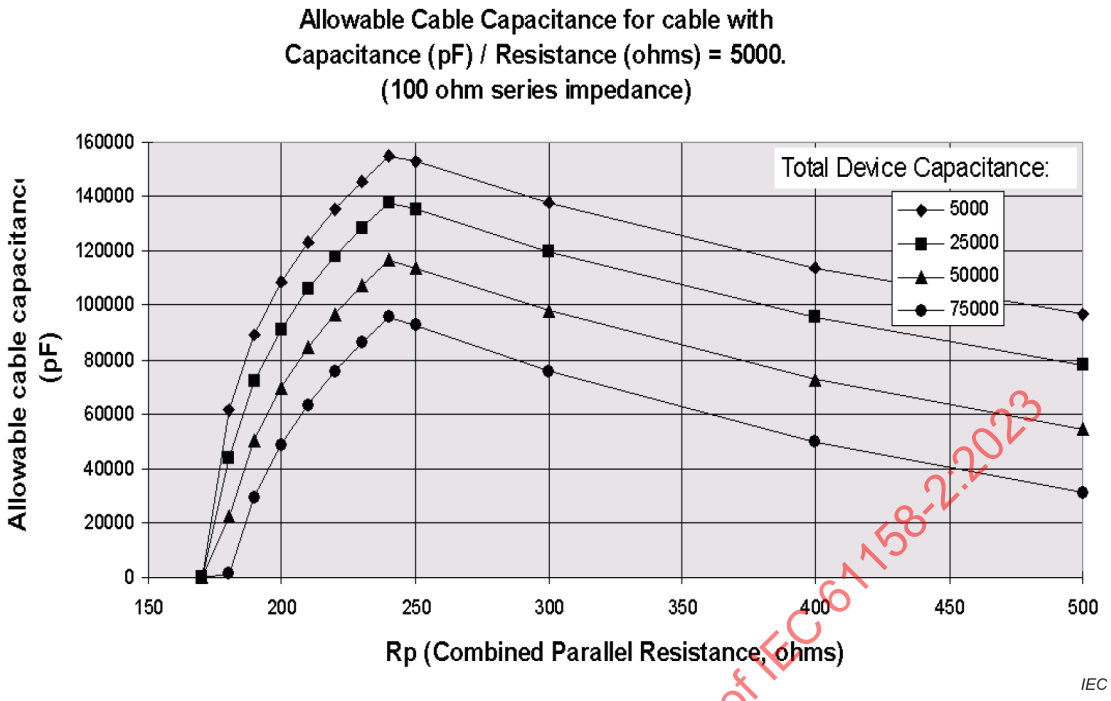


**Figure T.20 – Cable capacitance for $C_{cbl}/R_{cbl}$=5000, 100 Ω series resistance**

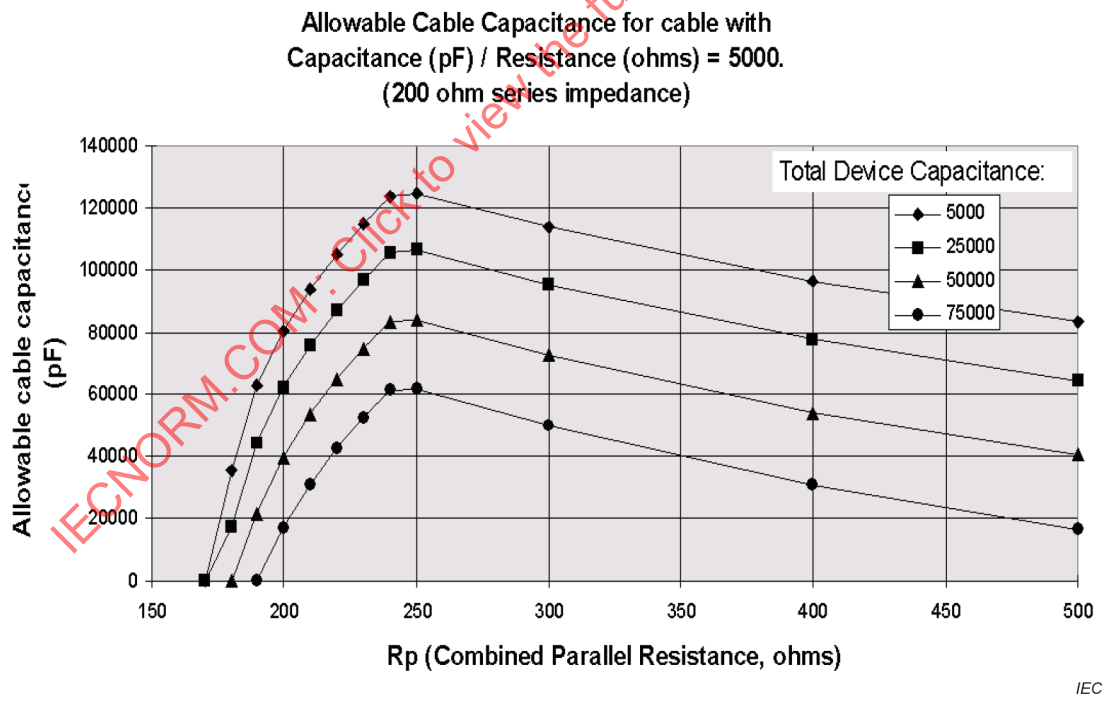


**Figure T.21 – Cable capacitance for $C_{cbl}/R_{cbl}$=5 000, 200 Ω series resistance**

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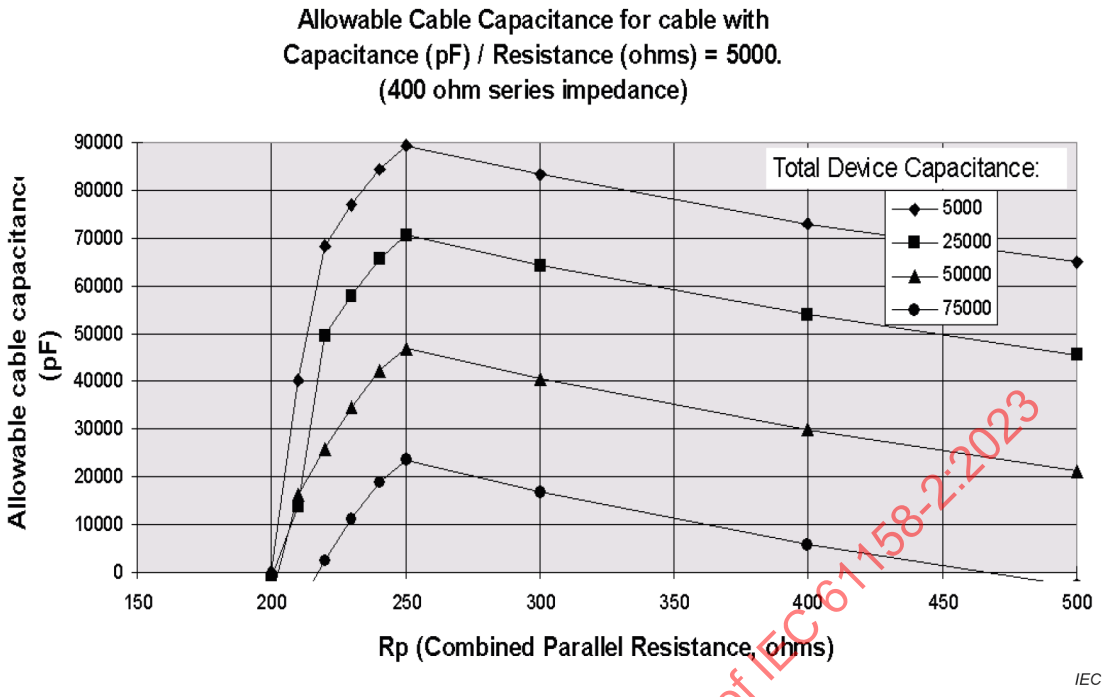


**Figure T.22 – Cable capacitance for $C_{cbl}/R_{cbl}$=5 000, 300 Ω series resistance**

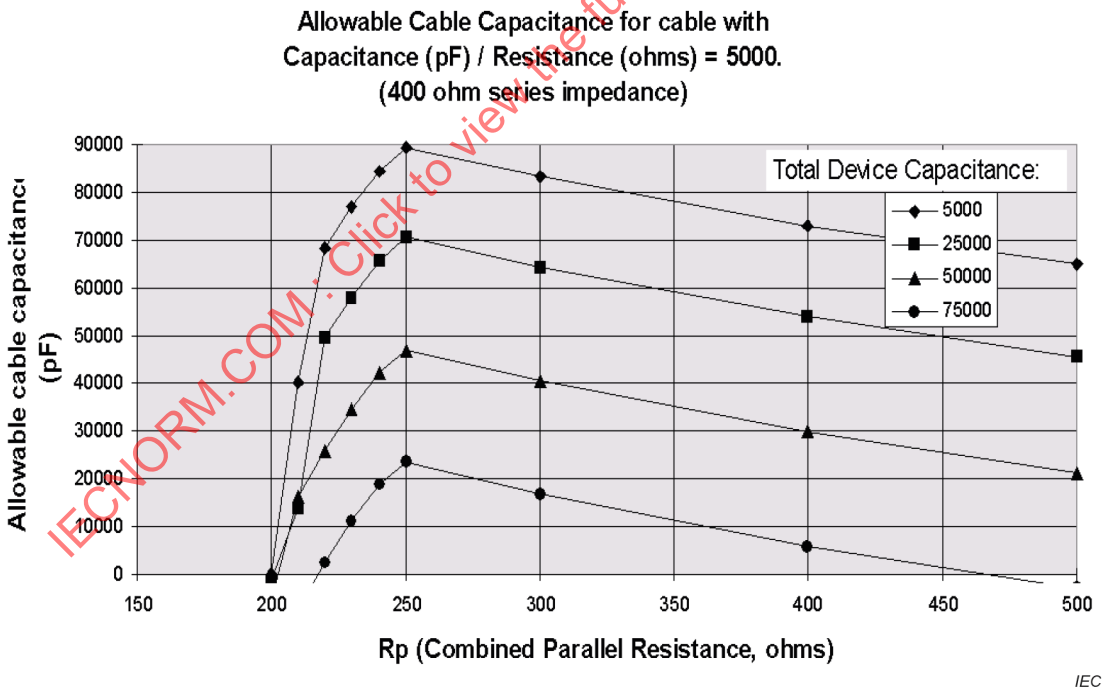


**Figure T.23 – Cable capacitance for $C_{cbl}/R_{cbl}$=5 000, 400 Ω series resistance**

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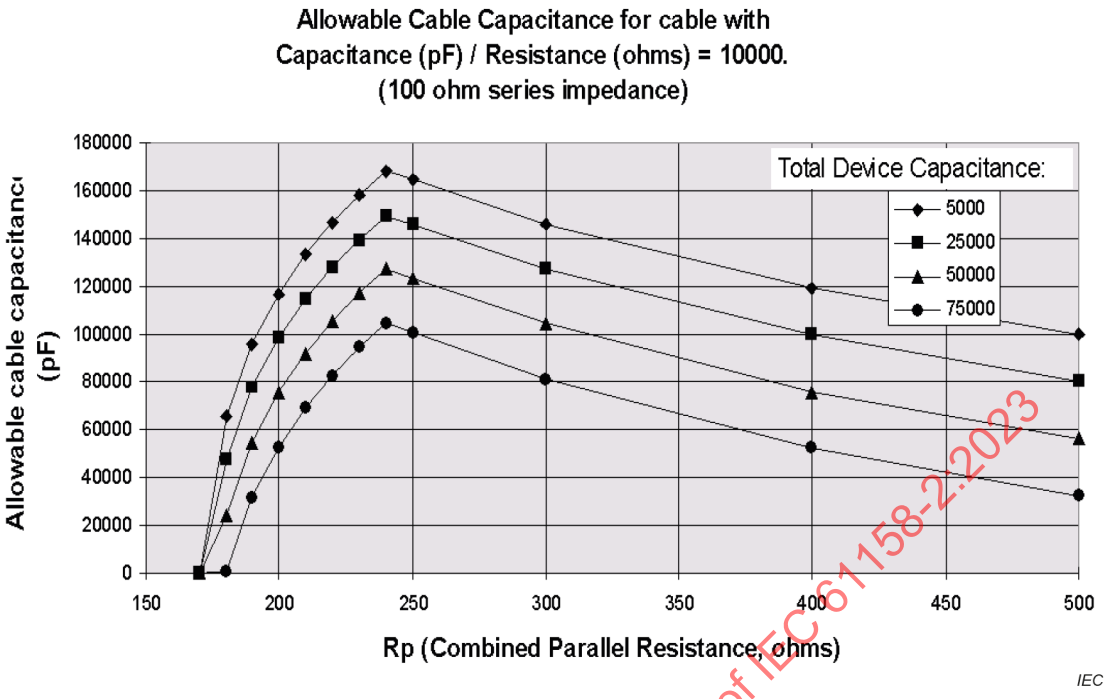


**Figure T.24 – Cable capacitance for $C_{cbl}/R_{cbl}$=10 000, 100 Ω series resistance**

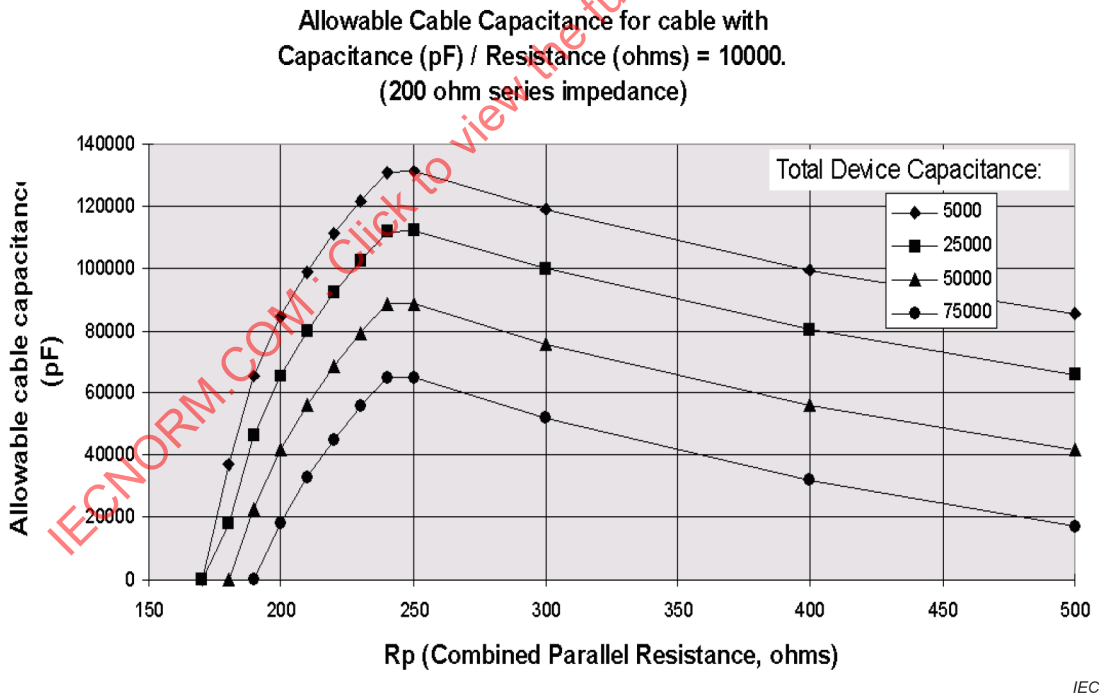


**Figure T.25 – Cable capacitance for $C_{cbl}/R_{cbl}$=10 000, 200 Ω series resistance**

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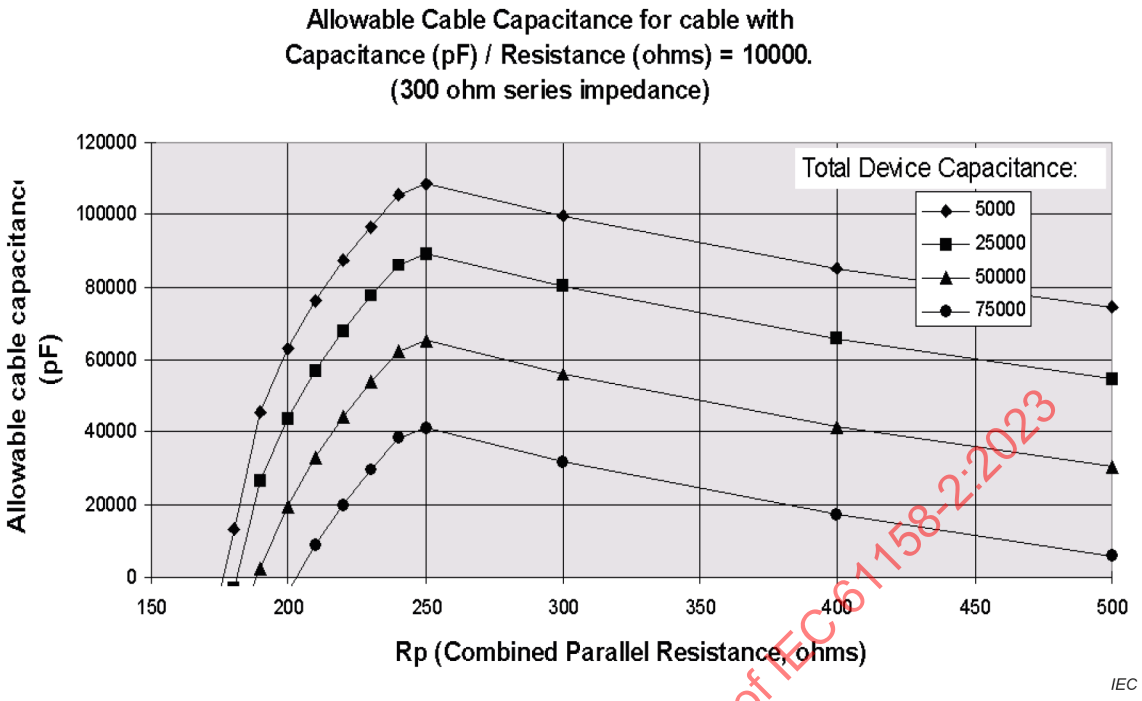


**Figure T.26 – Cable capacitance for $C_{cbl}/R_{cbl}$=10 000, 300 Ω series resistance**

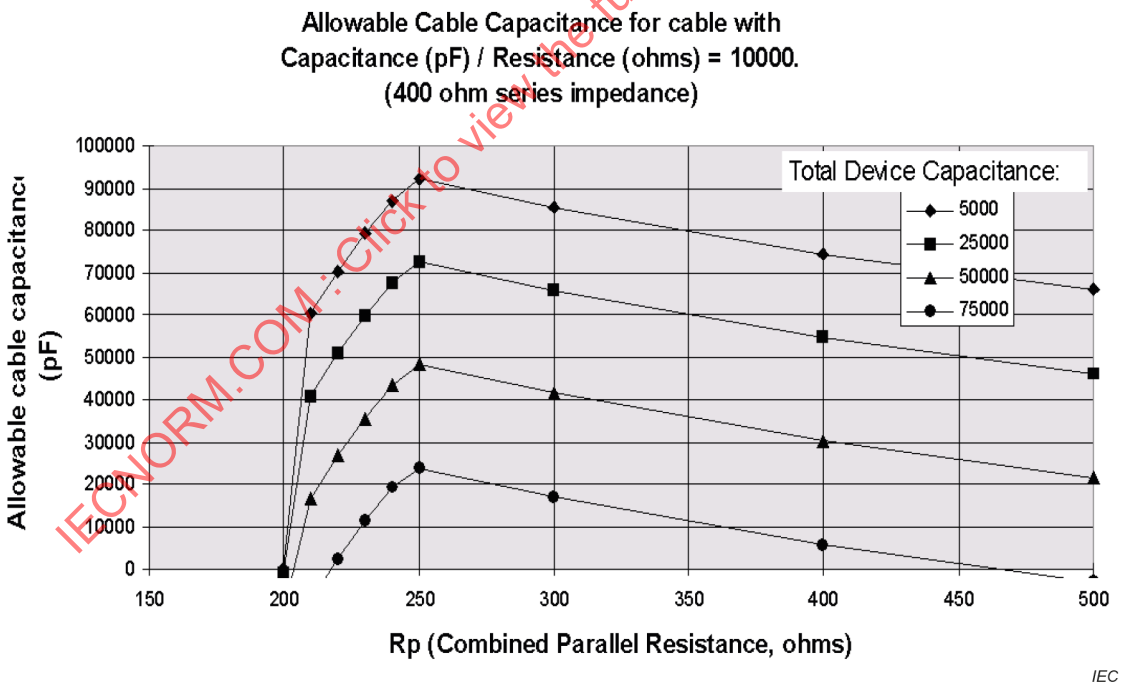


**Figure T.27 – Cable capacitance for $C_{cbl}/R_{cbl}$=10 000, 400 Ω series resistance**

### T.2.2.3 Cable length calculation examples

#### T.2.2.3.1 Example 1

The network has:

- Single device with capacitance $C_{dev}$ = 5 000 pF,

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- Parallel device resistance $\sum R_{dev}$ = 250 Ω,
- Cable capacitance $C_{cbl}$ = 150 pF/m,
- Cable resistance $R_{cbl}$ = 0,05 Ω/m

NOTE This is the same resistance as that of a 22 AWG wire.

Use Figure T.7 to interpolate for $C_{cbl}$ = 150 pF/unit length. The maximum cable length is 1 200 m.

#### T.2.2.3.2 Example 2

The network has:

- Three devices with capacitance $C_{dev}$ = 5 000 pF, 10 000 pF and 10 000 pF,
- These three devices with resistance $R_{dev}$ = 100 kΩ each,
- One low impedance device with $R_{dev}$ = 250 Ω,
- No series device,
- Cable capacitance $C_{cbl}$ = 400 pF/m, and
- Cable resistance $R_{cbl}$ = 0,0368 Ω/m (0,800 mm wire).

Therefore the calculated parameters are:

- Parallel device capacitance $\sum C_{dev}$ = 5 000 + 10 000 + 10 000 = 25 000 pF,
- Parallel device resistance $\sum R_{dev}$ = 250 Ω,
- Series impedance $R_{ser}$ = 0,
- Cable $C_{cbl}/R_{cbl}$ = 400 / 0,0368 = 10 869.

The cable capacitance/resistance ratio is rounded to the nearest value of 10 000. Using Figure T.11, the allowable cable capacitance is 200 000 pF. The maximum cable length is calculated by dividing the allowable cable capacitance by the capacitance per unit length of the cable. In this example, the maximum allowable cable length is (200 000 pF) / (400pF/m) = 500 m.

#### T.2.2.3.3 Example 3

The network has:

- Three devices with capacitance $C_{dev}$ = 5 000 pF, 10 000 pF and 10 000 pF,
- These three devices with resistance $R_{dev}$ = 100 kΩ each,
- One low impedance device with $R_{dev}$ = 250 Ω,
- One series device with 100 Ω resistance,
- Cable capacitance $C_{cbl}$ = 400 pF/m, and
- Cable resistance $R_{cbl}$ = 0,0368 Ω/m (0,800 mm wire).

Thus, the network is same as in T.2.2.3.2, except that one series device has been added. Therefore the calculated parameters are:

- Parallel device capacitance $\sum C_{dev}$ = 5 000 + 10 000 + 10 000 = 25 000 pF,
- Parallel device resistance $\sum R_{dev}$ = 250 Ω,
- Series impedance $R_{ser}$ = 100 Ω,

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- Cable $C_{cbl}/R_{cbl}$ = 400 / 0,0368 = 10 869.

The cable capacitance/resistance ratio is rounded to the nearest value of 10 000. Using Figure T.24, the allowable cable capacitance is 145 000 pF. The maximum cable length is calculated by dividing the allowable cable capacitance by the capacitance per unit length of the cable. In this example, the maximum allowable cable length is (145 000 pF) / (400pF/m) = 362,5 m.

### T.2.3 Multi-pair cable length

If multi-pair cable is used with single-pair cable to form a network, the total length of cable in this network is determined as the lowest of the following values:

a) 1 500 m,

b) the length as determined using procedure of T.2.2.2 for single pair cable and

c) the length as determined using procedure of T.2.2.2 for single pair cable using the highest value parallel network resistance for all networks using the other cables in the multi-pair cable.

## T.3 Power distribution through barriers

The network power supply is usually located at the current input device and can be connected as shown in Figure T.28. It shows configurations with no barrier (Figure T.28 a)), two barriers (Figure T.28 b)) and one barrier (Figure T.28 c)).

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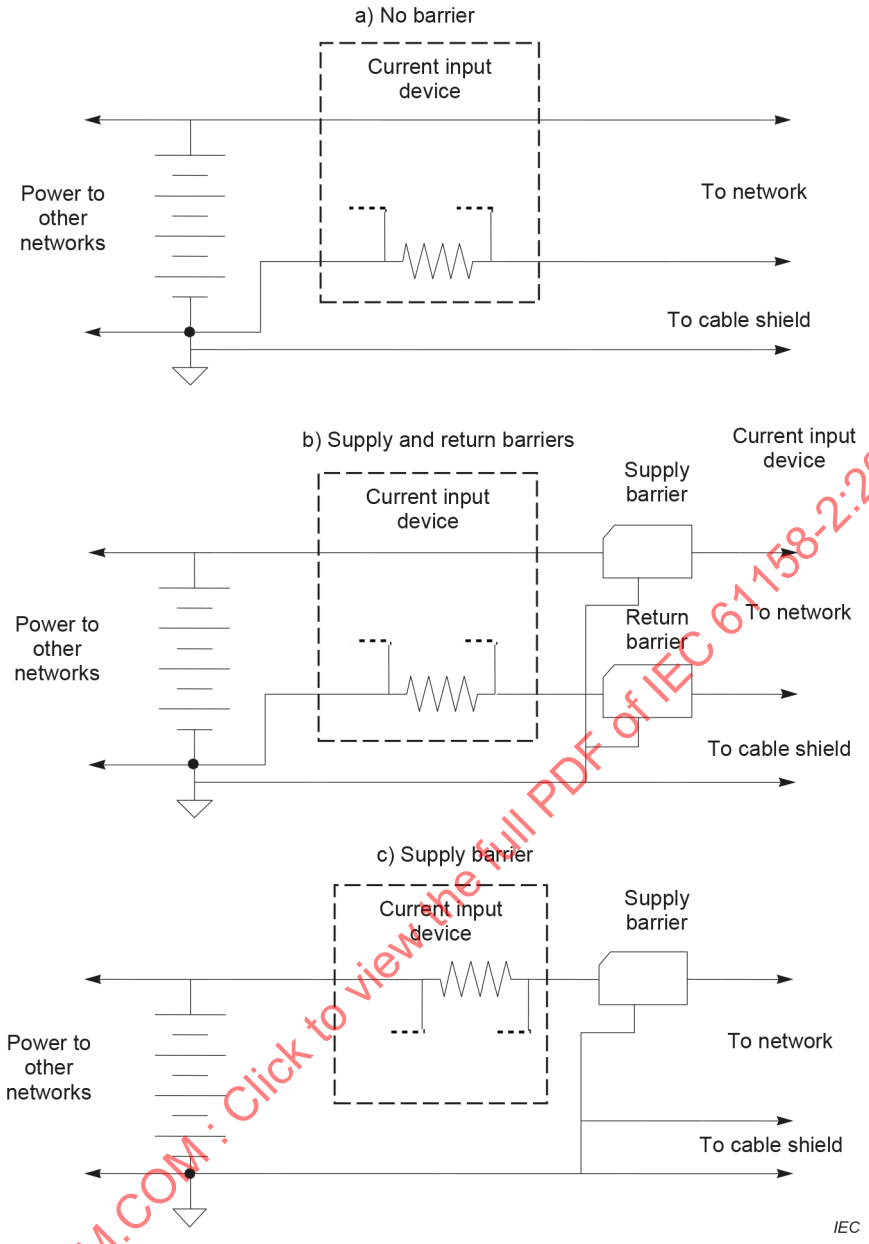


**Figure T.28 – Network power supply connections**

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If a network power supply is not used, it should be replaced by an impedance network not exceeding the permitted power supply impedance specified in 34.10.1. A single network power supply may power more than one network, provided that it is connected to multiple networks as shown in Figure T.28.

Device that requires power from sources other than the network may be powered by twisted pairs in the same multi-pair cable that carries signal pairs, provided that variation in current consumption of these devices is within the limit specified in 34.7.2.

## T.4 Shielding and grounding

This annex shows the preferred grounding schemes. The cable shield should be grounded at only one point. This is usually done in the control room at or near the source of loop power. However, the ground connection may alternatively occur in a junction box or other suitable location in the field area. Care has to be taken to avoid an inadvertent connection of grounded metal objects to the shield.

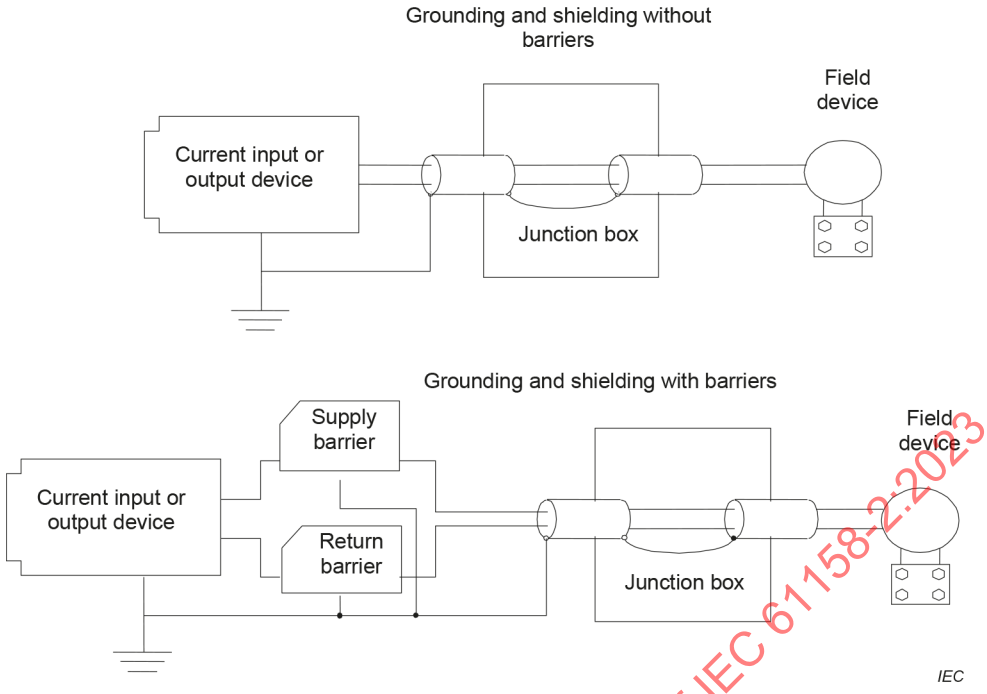


**Figure T.29 – Grounding and shielding**

Multiple networks that share a common connection should be grounded at the respective primary master or analog controller.

A cable shield is usually left open (unconnected) at a field device. Alternatively, the shield may be connected to the field device housing or the internal shield surrounding the device's circuits under either of the following conditions:

a) the device housing or the internal shield is isolated from ground, or

b) the connection of shield to ground is the only point in the network at which the shield is grounded.

For junctions not located at a signaling element, the shields of all cables brought to the junction are usually connected. To surround otherwise exposed wiring, cable shields may be connected to junction boxes and wiring panels, if the junction boxes or panels are isolated from ground or if the connection to ground is the only point at which the network shield is grounded.

Other grounding and shielding arrangements may be used if the coupling and EMI does not interfere with the digital signaling.

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# Annex U
(informative)

# Type 24: Media cable specifications and Network topologies twisted-pair wire medium

## U.1 Network

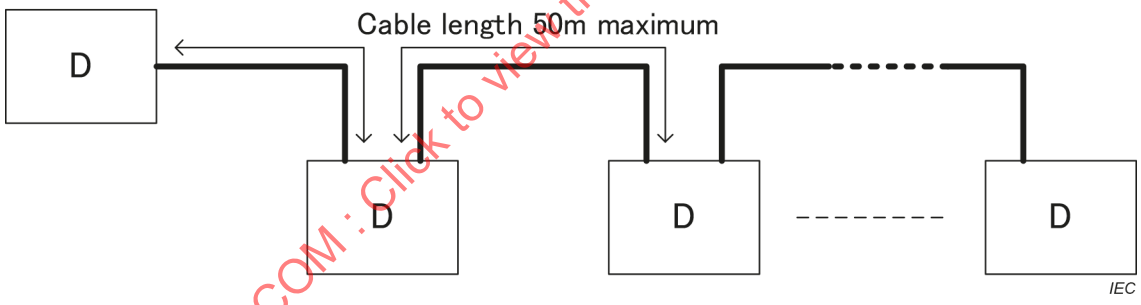
### U.1.1 Component

This MAU option (for Type 24-3) operates in a network that consists of the following components:

– cables;
– connectors;
– devices (containing at least one communication element);
– taps;
– power adaptors.

### U.1.2 Topology

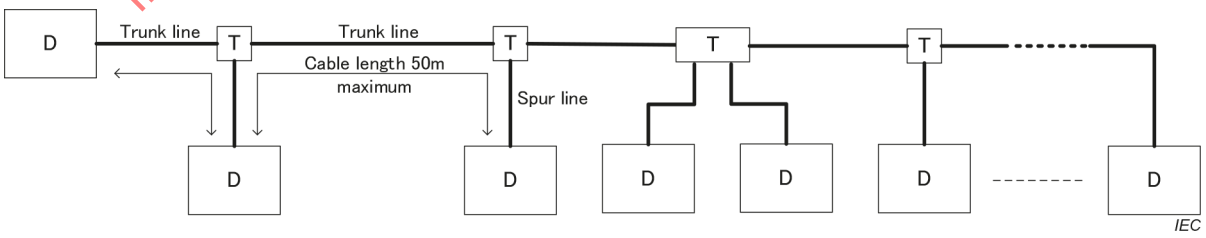
In Type 24-3, MAU shall operate by a node having one or two ports in one of the following four types of topology: a Linear topology, a T-branch topology, a topology with a combination of Linear and T-branch and a Point-to-point topology. Up to 14 fieldbus devices can be connected directly. The total length of cable connecting devices shall not exceed 50 m. Network examples are shown in Figure U.1, Figure U.2, Figure U.3, and Figure U.4.




**Key**

D Device

**Figure U.1 – Type 24-3 network with linear connection**




**Key**

D Device

T Tap

**Figure U.2 – Type 24-3 network with T-branch connection**

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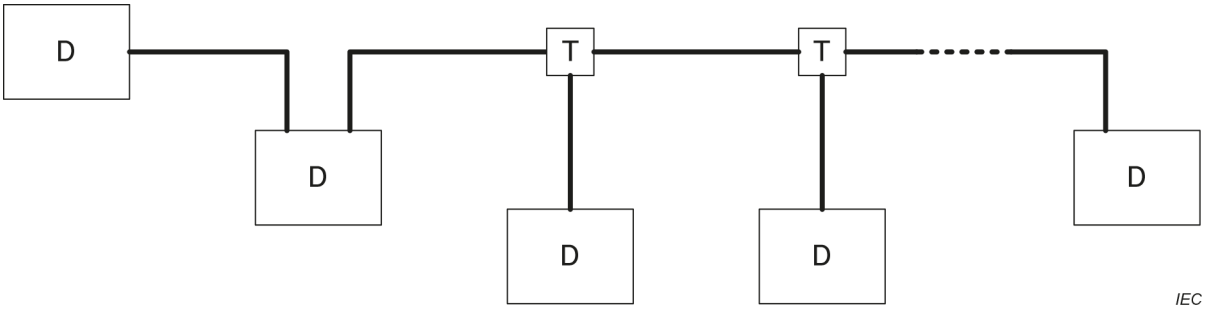


**Key**

D Device

T Tap

**Figure U.3 – Type 24-3 network with a combination of linear connections and T-branch connections**

**Key**

D Device

**Figure U.4 – Type 24-3 network with point-to-point connection**

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## U.2 Medium specifications

### U.2.1 Cable

The bus medium is a shielded twisted-pair cable. The shield helps to improve the electromagnetic compatibility (EMC). In Type 24-3, 6-conductor cables and 8-conductor cables are used. Also, a standard type and a flexible type are available for each. The structure and specification of the two types of cables are as shown in Figure U.5, Table U.1, Figure U.6, and Table U.2.

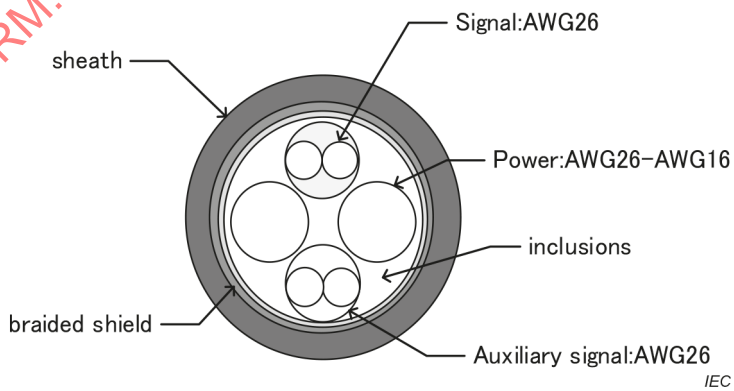


**Figure U.5 – Type 24-3 6-conductor cable structure**

**Table U.1 – Type 24-3 6-conductor cable specification**

| Characteristic | | Constraints |
|---|---|---|
| Overall diameter | | 7,2 ± 0,3 mm |
| Conductor | | Tin plated annealed copper |
| Conductor size | Power | AWG26 to AWG16 range |
| | Signal | AWG26 |
| | Auxiliary signal | AWG26 |
| Electrical resistance of conductor | Power | depends on conductor size |
| | Signal | < 145,6 Ω/km |
| | Auxiliary signal | < 145,6 Ω/km |
| Withstand voltage | | >AC 500 V, 1 min |
| Insulation resistance | | >10 MΩ/km |
| Characteristic impedance | Signal | (120 ± 12) Ω (Differential) |
| Attenuation | Signal | 1,16 dB / 50 m (at 1 MHz)<br>2,55 dB / 50 m (at 4 MHz)<br>4,05 dB / 50 m (at 8 MHz)<br>4,68 dB / 50 m (at 10 MHz)<br>6,17 dB / 50 m (at 16 MHz)<br>6,97 dB / 50 m (at 20 MHz)<br>7,85 dB / 50 m (at 25 MHz)<br>8,84 dB / 50 m (at 31,25 MHz)<br>12,97 dB / 50 m (at 62,5 MHz)<br>17,17 dB / 50 m (at 100 MHz) |
| Color code | Power | Orange / Black |
| | Signal | Red / Blue |
| | Auxiliary signal | Brown / Gray |

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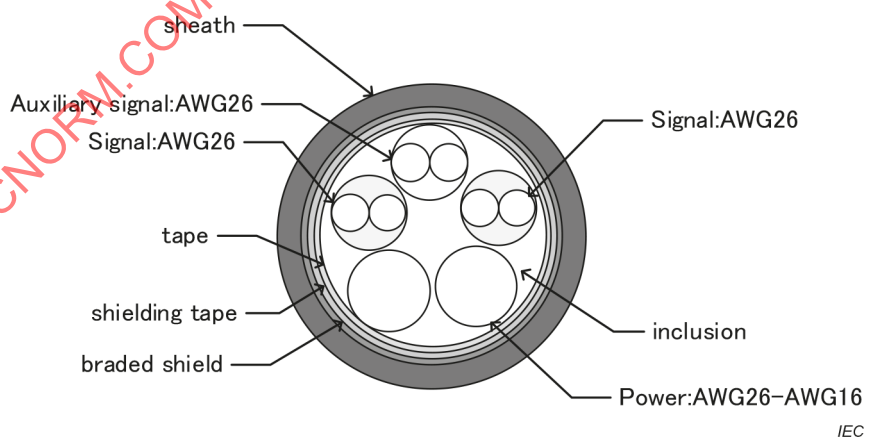


**Figure U.6 – Type 24-3 8-conductor cable structure**

**Table U.2 – Type 24-3 8-conductor cable specification**

| Characteristic | | Constraints |
|---|---|---|
| Overall diameter | | (7,2 ± 0,3) mm |
| Conductor | | Tin plated annealed copper |
| Conductor size | Power | AWG26 to AWG16 range |
| | Signal | AWG26 |
| | Auxiliary signal | AWG26 |
| Electrical resistance of conductor | Power | depends on conductor size |
| | Signal | < 145,6 Ω/km |
| | Auxiliary signal | < 145,6 Ω/km |
| Withstand voltage | | > AC 500 V, 1 min |
| Insulation resistance | | > 100 MΩ/km |
| Characteristic impedance | Signal | (120 ± 12) Ω (Differential) |
| Attenuation | Signal | 1,16 dB / 50 m (at 1 MHz)<br>2,55 dB / 50 m (at 4 MHz)<br>4,05 dB / 50 m (at 8 MHz)<br>4,68 dB / 50 m (at 10 MHz)<br>6,17 dB / 50 m (at 16 MHz)<br>6,97 dB / 50 m (at 20 MHz)<br>7,85 dB / 50 m (at 25 MHz)<br>8,84 dB / 50 m (at 31,25 MHz)<br>12,97 dB / 50 m (at 62,5 MHz)<br>17,17 dB / 50 m (at 100 MHz) |
| Color code | Power | Orange / Black |
| | Signal | Red / Blue, Yellow / White |
| | Auxiliary signal | Brown / Gray |

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The wiring between two devices is shown in Figure U.7.

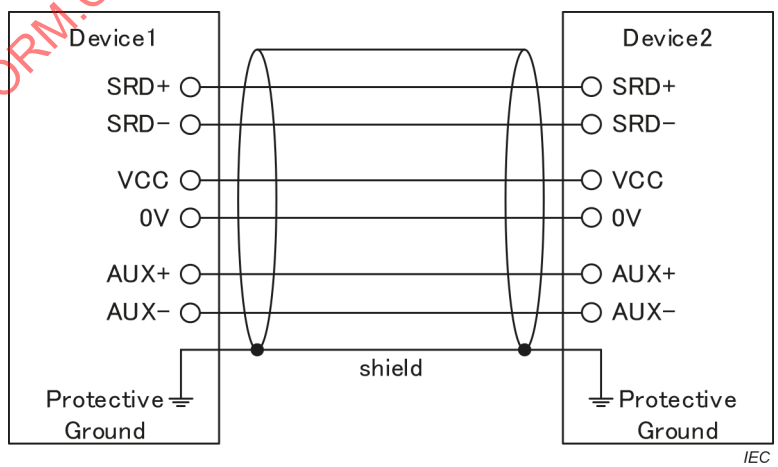


**Figure U.7 – Type 24-3 Interconnecting wiring**

The wiring shown in Figure U.7 allows a common mode voltage between both devices (that is, the voltage difference between the protective grounds) of at most 7 V. If higher common mode voltage is expected, a compensation conductor between the grounding points shall be installed.

### U.2.2 Tap

For the T-branch connection of Type 24-3, taps shall be installed for cable branching. The taps are available with multiple connectors for connecting spur lines as shown in Figure U.8. Use the spur line from the Uplink side of the trunk line.

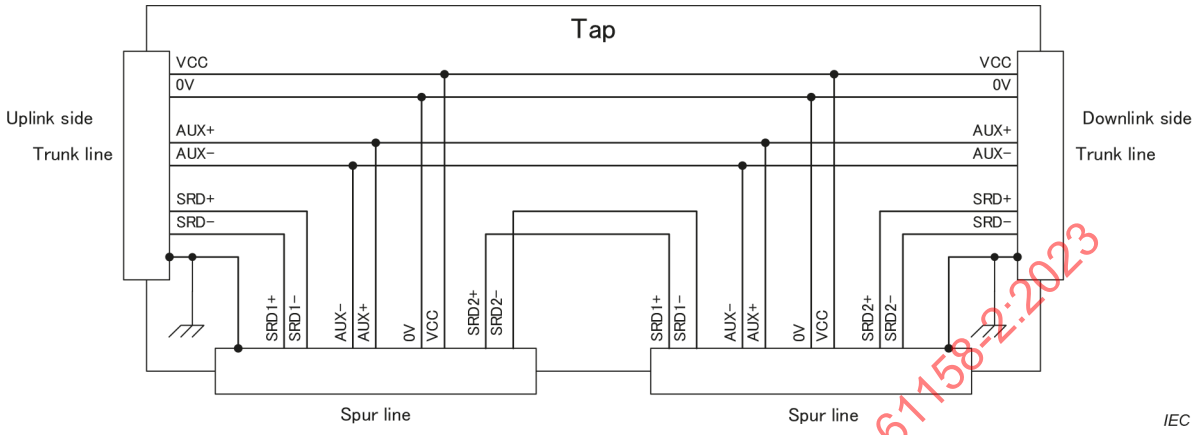


**Figure U.8 – Tap for two branches**

## U.3 Power source wiring

### U.3.1 Overview

In Type 24-3, a communication cable can supply power to the C2 master or the slave. Power to be supplied to the C2 master or the slave shall be supplied from the C1 master or the power adaptor. The power adaptor is installed on the cables on the way to the C1 master, the C2 master or the slave. Figure U.9 shows the power supply from the C1 master to the C2 master or the slave. Figure U.10 shows the power supply from the power adaptor to the C2 master or the slave. Also, Figure U.11 shows the connection of the C2 master or the slave operates with external power supply.

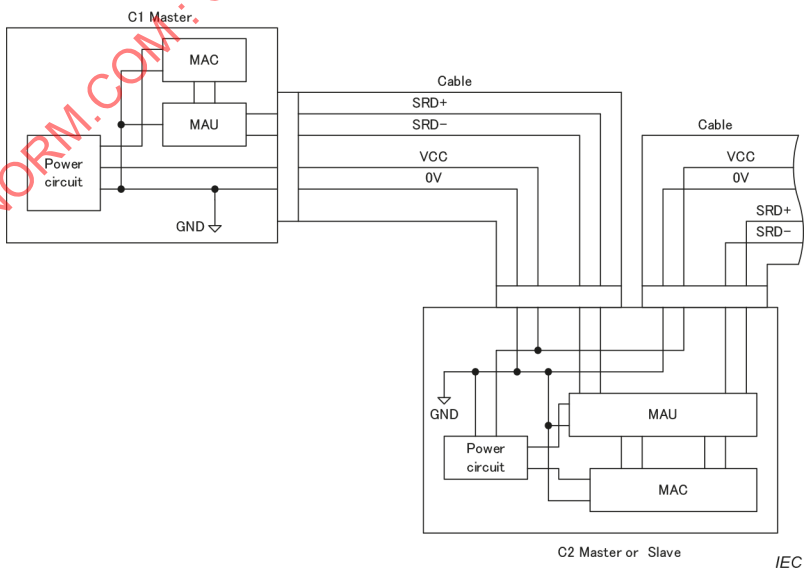


**Figure U.9 – Power supply from C1 master**

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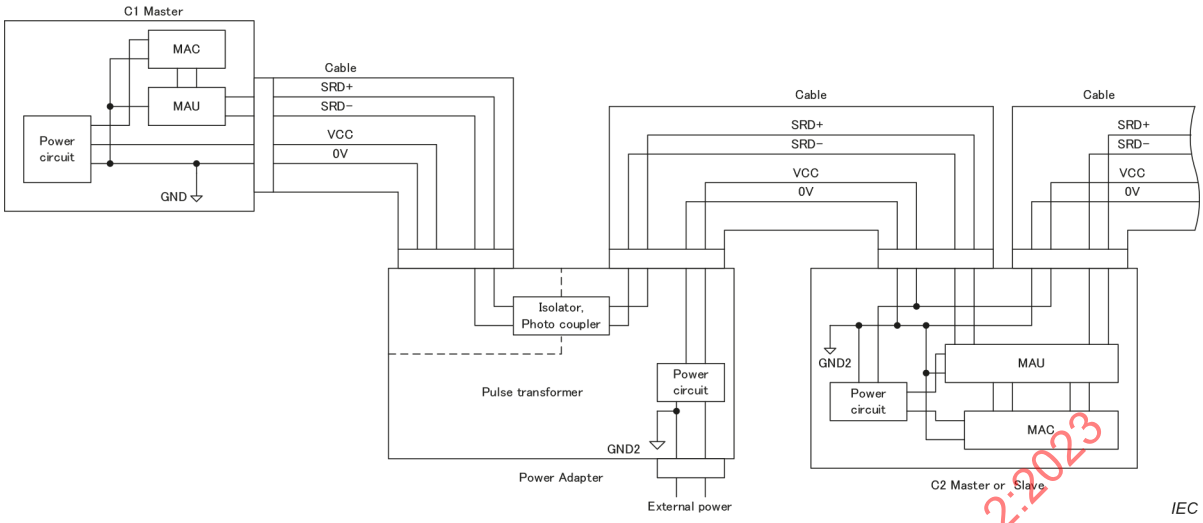


**Figure U.10 – Power supply from power adaptor**

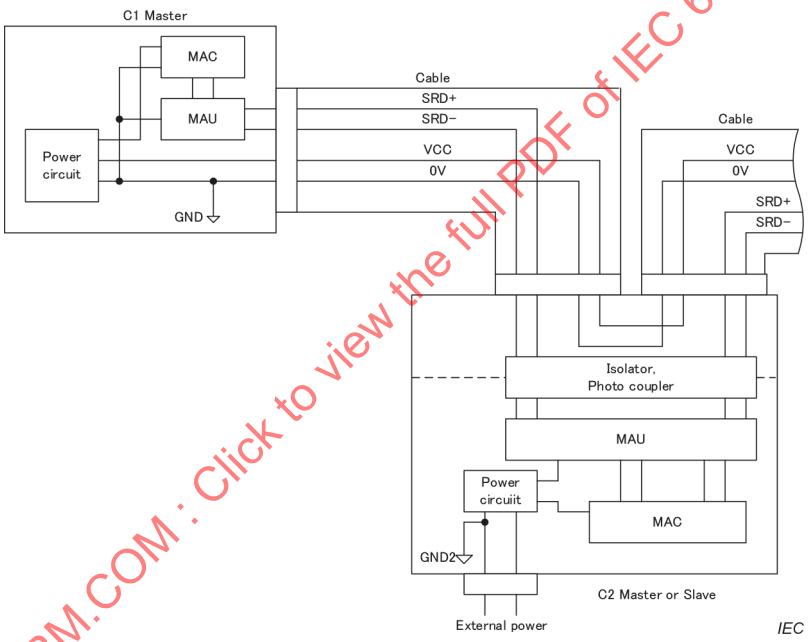


**Figure U.11 – Connection of external power to devices**

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### U.3.2 Power adaptor

In Type 24-3, the power adaptor shall be installed as shown in Figure U.12 when supplying power from a power source other than the C1 master.

The power adaptor shall mount a power circuit to supply power to a downstream device to be connected. Also, parts for galvanic isolation like isolator or photo coupler for signal line (SRD+, SRD-) isolation and an isolation circuit for auxiliary signal line (AUX+, AUX-) shall be mounted.

The power adaptor shall prevent misconnection of the upstream port and the downstream port. Accordingly, a male connector shall be used as a connector for the upstream port connection and a female connector shall be used as a connector for the downstream port connection.

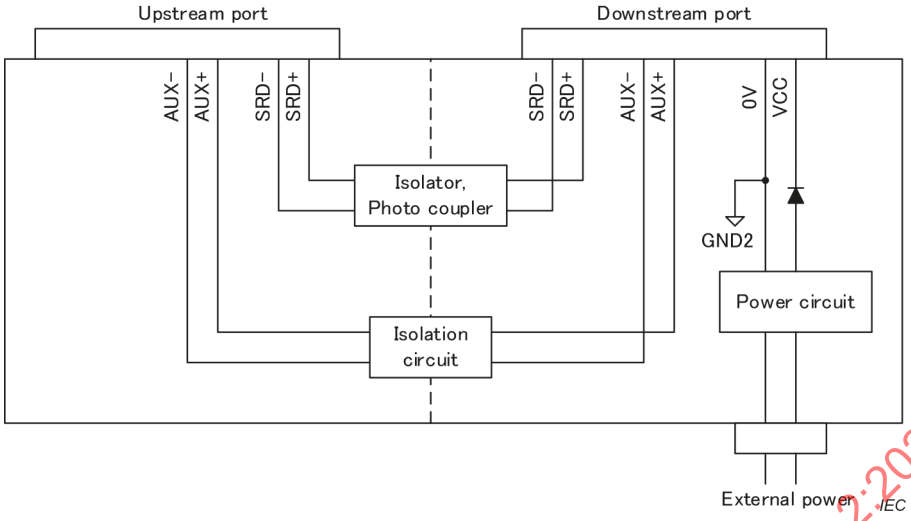


**Figure U.12 – Power adaptor block diagram**

### U.3.3 Power supply

The specification of power for the Type 24-3 power supply shall conform to the contents of Table U.3.

**Table U.3 – Specification of supply power**

| Item | Value | | |
|---|---|---|---|
| | min | typ | max |
| voltage | 5,0 V | – | 26,4 V |
| current | – | – | 1,5 A |

### U.3.4 Power load

In Type 24-3, the maximum power consumption for the C2 master and the slave shall be classified into the four classes as shown in Table U.4. This power load means the load of power supplied from the cable.

**Table U.4 – Classification of power load**

| Class | Maximum power consumption |
|---|---|
| A | 1 W |
| B | 1,5 W |
| C | 2,5 W |
| D | 5 W |

In Type 24-3, the specification of power load for the C2 master and the slave shall conform to the contents of Table U.5.

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**Table U.5 – Specification of power load**

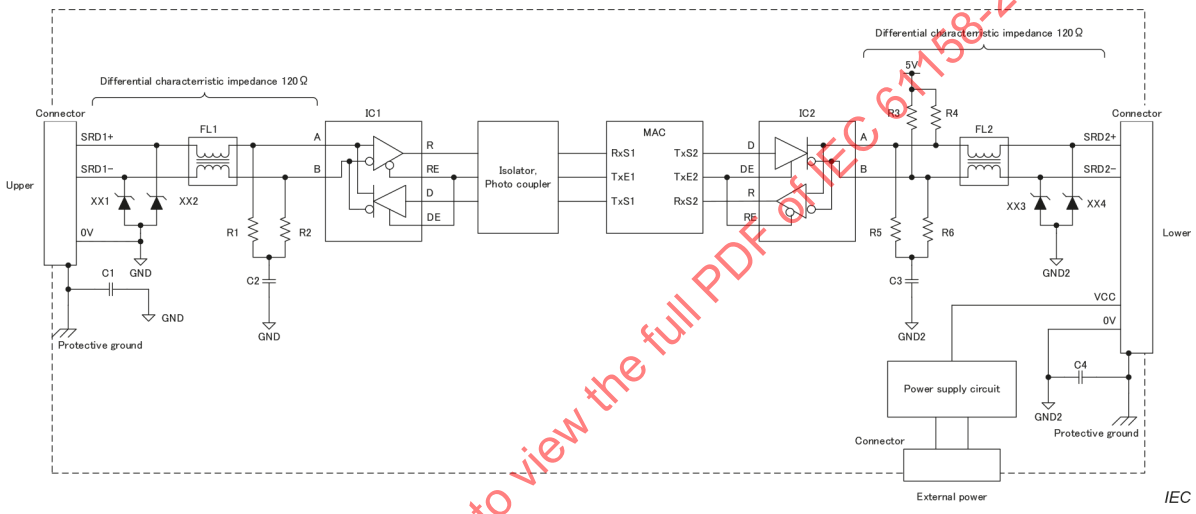
| Item | Value | | |
|---|---|---|---|
| | min | typ | max |
| voltage | 4,0 V | – | 26,4 V |
| current | – | – | depends on class |

### U.3.5 MAU circuit supporting the Type 24-3 power supply

a) MAU circuit for the power adaptor

Figure U.13 shows the MAU circuit for the power adaptor.

The power adaptor shall use the isolator or photo coupler and MAC which repeats the transmission signal to isolate between the upstream port and the downstream port.




**Key**

IC1,IC2: Transceiver IC

FL1,FL2: Common mode filter

R1,R2,R5,R6: (62 ± 3,1) Ω, 1/4 W

R3,R4: (680 ± 6,8) Ω, 1/8 W

C2,C3: 0,1 µF, 50 V

C1,C4: To be selected according to the noise environment

XX1,XX2,XX3,XX4: ESD protection device

**Figure U.13 – MAU circuit for the power adaptor**

b) MAU circuit for the external power device

Figure U.14 and Figure U.15 show the MAU circuit for the C2 master and the slave which operates with the external power supply.

The C2 master and the slave to be supplied the power from the external power supply shall use the to isolate the transmission line and the internal circuit.

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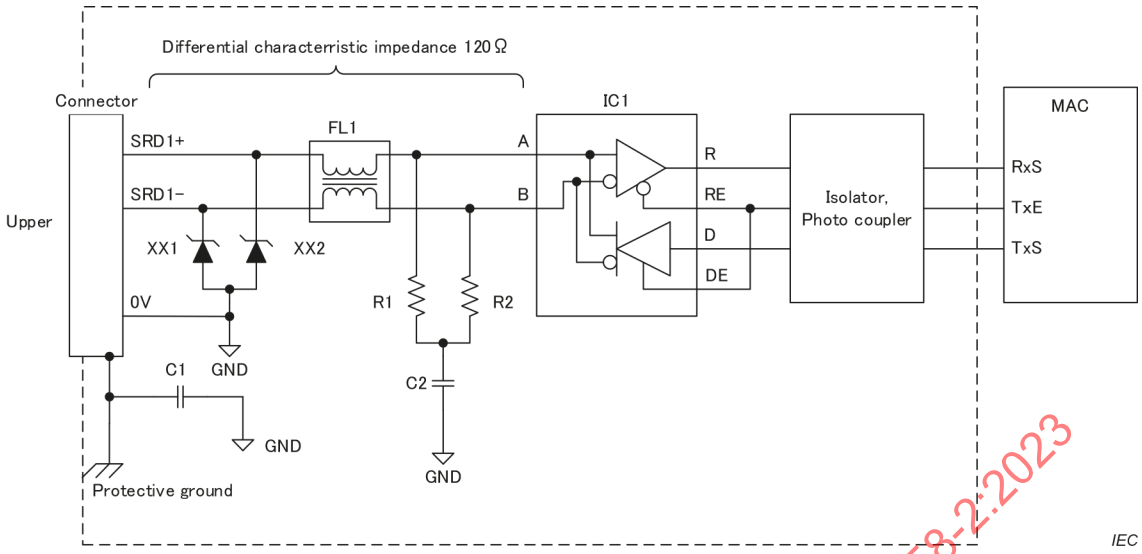


**Key**

IC1: Transceiver IC

FL1: Common mode filter

R1,R2: (62 ± 3,1) Ω, 1/4W

C2: 0,1 μF, 50 V

C1: To be selected according to the noise environment

XX1,XX2: ESD protection device

**Figure U.14 – MAU circuit for the external power device for upstream port**

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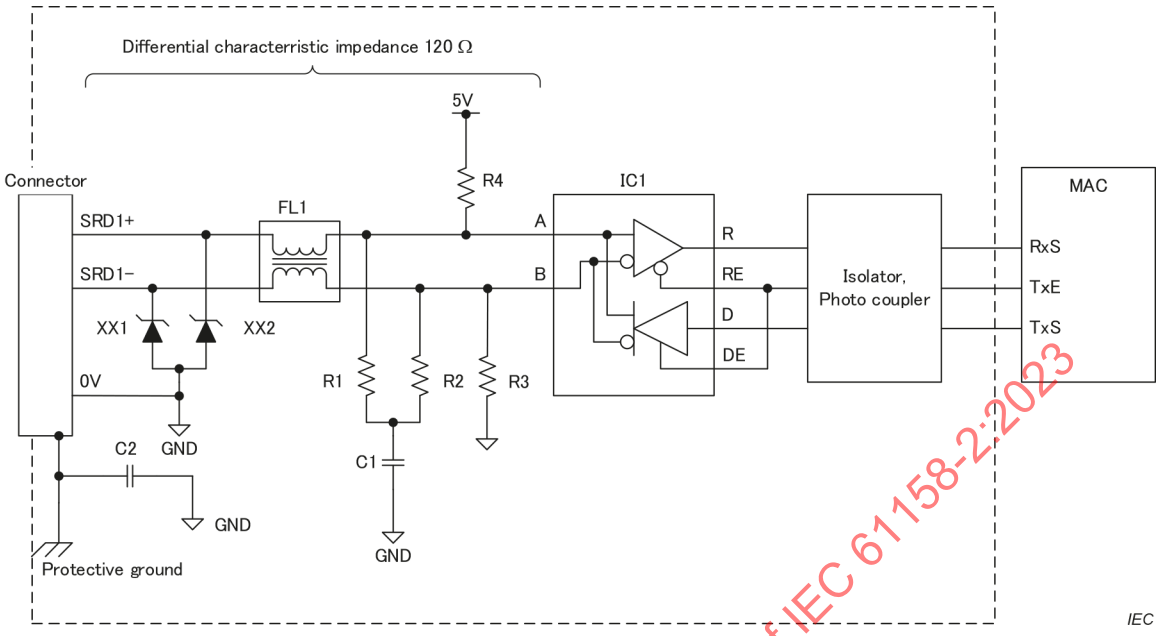


**Key**

| | |
|---|---|
| IC1 | Transceiver IC |
| FL1 | Common mode filter |
| R1,R2 | (62 ± 3,1) Ω, 1/4 W |
| R3,R4 | (680 ± 6,8) Ω, 1/8 W |
| C1 | 0,1 µF, 50 V |
| C2 | To be selected according to the noise environment |
| XX1,XX2 | ESD protection device |

**Figure U.15 – MAU circuit for the external power device for downstream port**

### U.3.6 Power voltage drop

The voltage drop occurs due to power current of power line, cable resistance, etc. on the cable. The cable length shall be set to exceed the power specification voltage on the load side. The maximum value of acceptable voltage drop, Vd_max (V), is calculated by the formula as described below. Vsrc (V) is the supplied voltage as power from the C1 master or the power adaptor. Vl_min (V) is the minimum operation voltage of the C2 master or the slave.

Vd_max = Vsrc - Vl_min

a) Linear connection

The relation between the cable length and the power voltage drop for the linear connection as shown in Figure U.16 is as described below.

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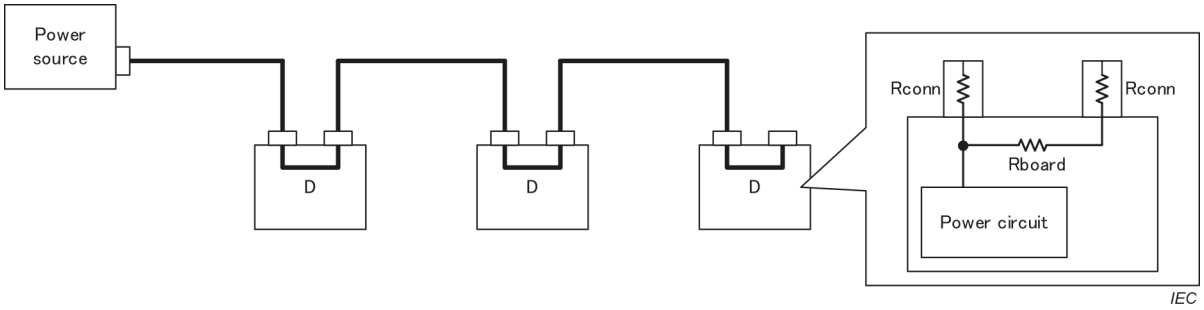


**Key**

D Device

**Figure U.16 – Voltage drop calculation model for a linear connection**

The resistance for total wiring, R (Ω), with the number of nodes, n, for the linear connection can be given by the formula as described below. Rc (Ω) is the resistance of cable. Rconn is the contact resistance. Rboard (Ω) is the resistance between connectors of the node.

$$R = Rc + (Rconn \times 2 + Rboard) \times (n - 1)$$

The value of cable resistance, Rc (Ω), shall be calculated with the cable length, Length (m), and the value of conductor resistance, Rdc (Ω/m), by using the formula as described below.

$$Rc = Rdc \times Length$$

The total resistance value, R (Ω), and the cable length, Length (m), are calculated as follows.

$$R = Rdc \times Length + (Rconn \times 2 + Rboard) \times (n - 1)$$

$$Length = (R - (Rconn \times 2 + Rboard) \times (n - 1)) / Rdc$$

For the wiring with the value of voltage drop, Vd_max (V), when the current value is Icc (A), the resistance value, R (Ω), and the cable length, Length (m), can be given by the formula as described below.

$$R = Vd_max / Icc / 2$$

$$Length = (Vd_max / Icc / 2 - (Rconn \times 2 + Rboard) \times (n - 1)) / Rdc$$

b) T-branch connection

The relation between the power voltage drop and the cable length for the T-branch connection as shown in Figure U.17 is as described below.

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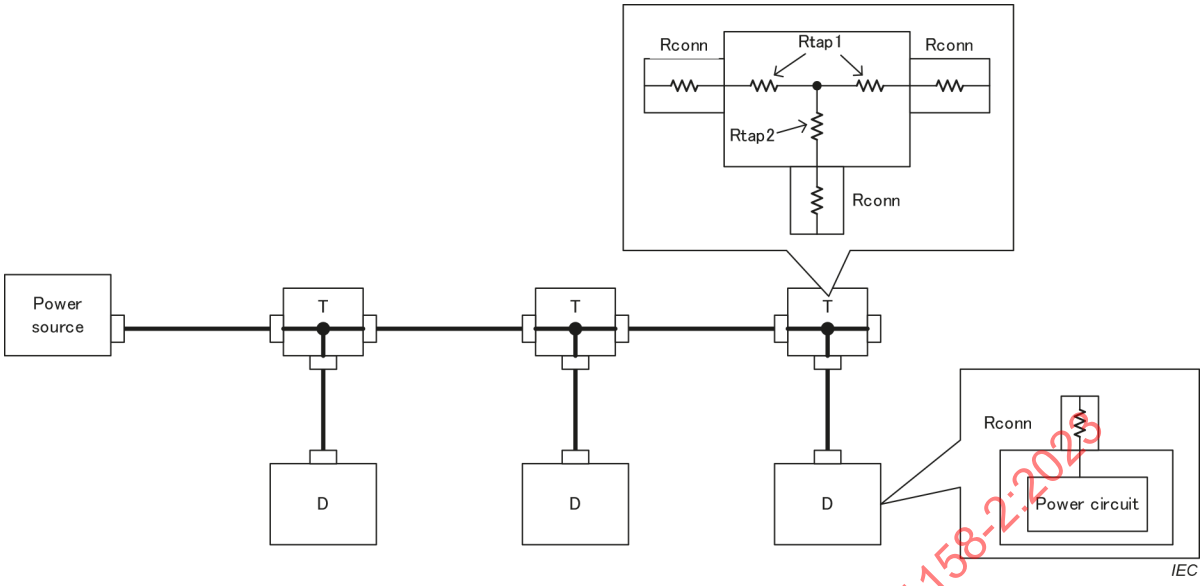


**Key**

D Device

T Tap

**Figure U.17 – Power voltage drop model for a T-branch connection**

The trunk line resistance, Rm (Ω), the spur resistance, Rb (Ω), and the resistance of total wiring, R (Ω), with the number of nodes, n, for the T-branch connection can be given respectively by the formula as described below. Rcm (Ω) is the resistance of trunk line cable and Rcb (Ω) is the resistance of spur line cable. Rconn (Ω) is the contact resistance of the connector, Rtap1 (Ω) and Rtap2 (Ω) are the resistance between the connectors of the tap.

$$Rm = Rcm + (Rconn \times 2 + Rtap1 \times 2) \times (n - 1)$$

$$Rb = Rcb + Rtap1 + Rtap2 + Rconn \times 2$$

$$R = Rm + Rb$$

The cable resistance values, Rcm (Ω) and Rcb (Ω), shall be calculated by the formula as described below. Lm (m) is the trunk line cable length, and Lb (m) is the spur line cable length. Rdcm (Ω/m) is the conductor resistance value of the trunk line cable, and Rdcb (Ω/m) is the conductor resistance value of the spur line cable.

$$Rcm = Rdcm \times Lm$$

$$Rcb = Rdcb \times Lb$$

The total resistance value, R (Ω), as described below, shall be set to ensure that the voltage drop value for the current value, Icc (A), equals to or smaller than Vd_max (V).

$$R = Rm + Rb$$

$$= Rdcm \times Lm + (Rconn \times 2 + Rtap1) \times (n - 1) + Rdcb \times Lb + Rtap2 + Rconn \times 2$$

$$< Vd_max / Icc / 2$$

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# Annex V
(informative)

## Type 28: Example of data subframe allocation

### V.1 Example A

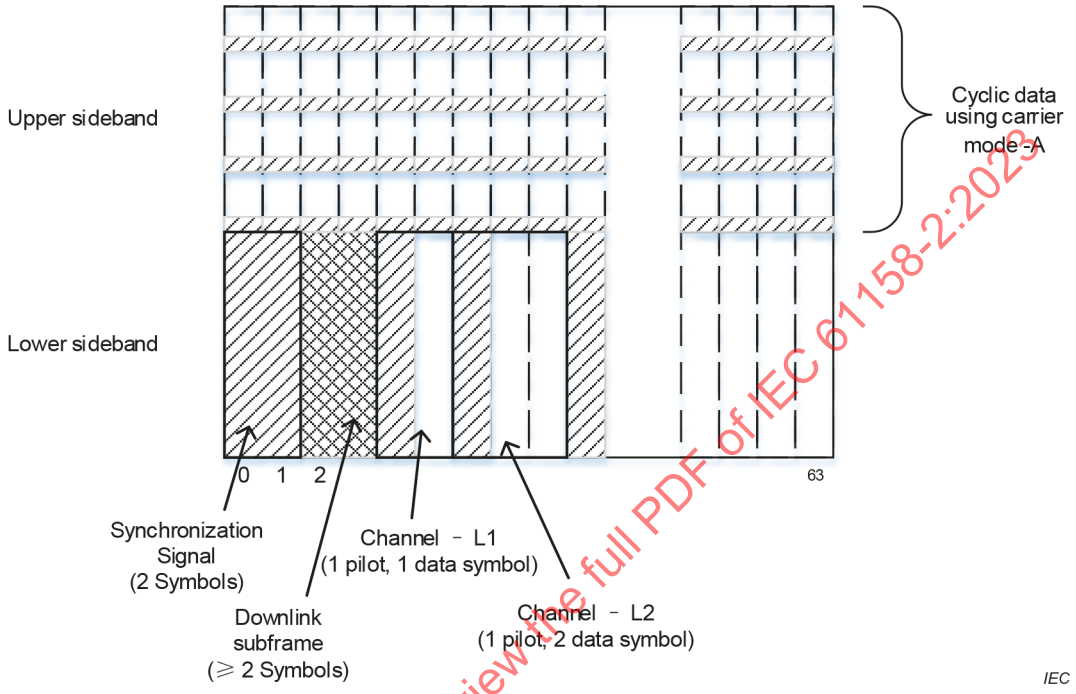


**Figure V.1 – Resource allocation example A**

As shown in Figure V.1, the lower sideband uses carrier mode B to allocate the resource, and the upper sideband uses the use carrier mode A to allocate the resource.

– All resources in the upper sideband are allocated to the same user;
– The data subframe in lower sideband allocated for the first channel uses one half sideband OFDM symbol for pilot and 1 half sideband OFDM symbol for data transfer;
– The data subframe in lower sideband allocated for the second channel uses one half sideband OFDM symbol for pilot and 2 half sideband OFDM symbols for data transfer.

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## V.2 Example B

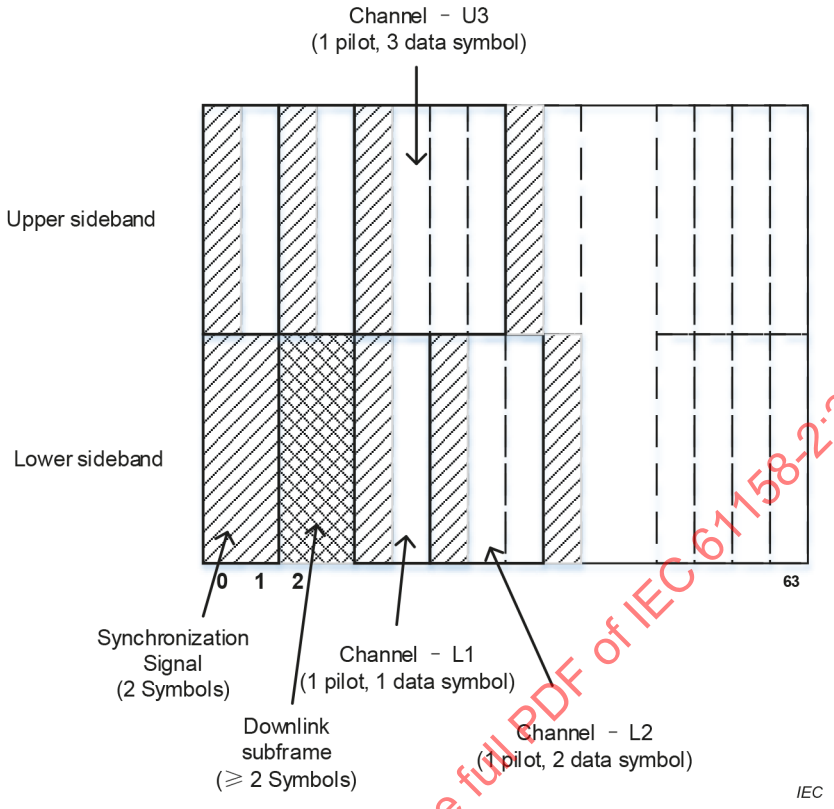


**Figure V.2 – Resource allocation example B**

As shown in Figure V.2, both the upper and lower side band both use carrier mode B for resource allocation. The carrier mode B of each allocable resource is different in number of resource elements except that the pilot takes up a half sideband of OFDM symbols.

– The data subframe in lower sideband allocated for the first channel uses one half sideband OFDM symbol for pilot and 1 half sideband OFDM symbol for data transfer;

– The data subframe in lower sideband allocated for the second channel uses one half sideband OFDM symbol for the pilot and two half sideband OFDM symbols for data transfer;

– The data subframe in upper sideband allocated to the first and second channel uses one half sideband OFDM symbol for pilot and 1 half sideband OFDM symbol for data transfer;

– The data subframe in upper sideband allocated for the third channel uses one half sideband OFDM symbol for pilot and three half sideband OFDM symbols for data transfer.

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## V.3 Example C

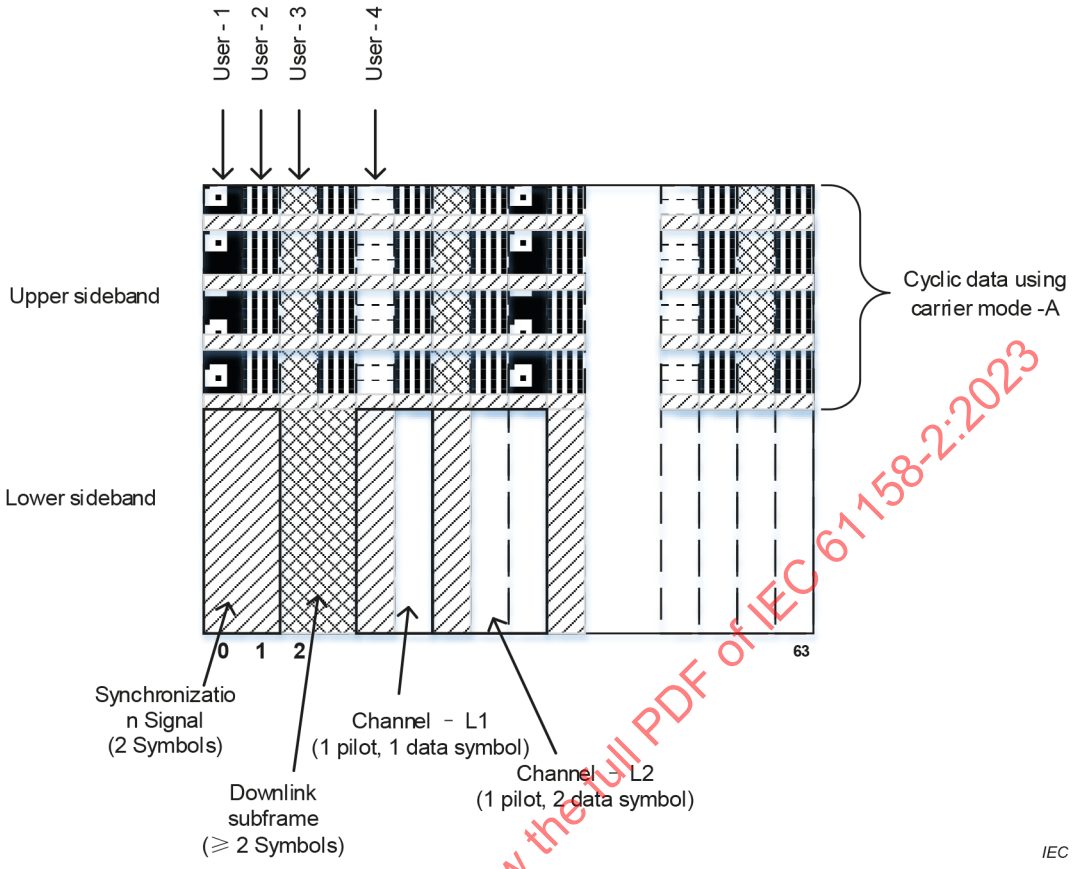


**Figure V.3 – Resource allocation example C**

As shown in Figure V.3, the lower sideband uses carrier mode B to allocate resources, and the upper sideband uses carrier mode A to allocate resources.

– The data subframe in the upper sideband are allocated to four users. User 1 (User-1) and user 4 (User-4) are allocated to resources with 8 OFDM symbols in a cycle; User 2 (User-2) is allocable data subframe with two OFDM symbols in a cycle, and user 3 (User-3) is allocable data subframe with four OFDM symbols in a cycle.

– The data subframe in the lower sideband allocated for the first channel uses one half sideband OFDM symbol for pilot and 1 half sideband OFDM symbol for data transfer;

– The data subframe in the lower- side band allocated for the second channel uses one half sideband OFDM symbol for pilot and two half sideband OFDM symbols for data transfer.

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# Annex W
(normative)

## Type 28: RS code generating polynomial

The RS code generating polynomial coefficients are shown in Table W.1, Table W.2 and Table W.3 respectively corresponding to the system code RS (255, 247), RS (255, 239) and RS (255, 223). The values of the coefficient $g_i$ in polynomial g(x) are shown in the table when corresponding to different coefficients i.

**Table W.1 – RS code (255, 247) generating polynomial**

| i | $g_i$ |
|---|---|
| 0 | 37 |
| 1 | 224 |
| 2 | 8 |
| 3 | 172 |
| 4 | 71 |
| 5 | 178 |
| 6 | 44 |
| 7 | 227 |
| 8 | 1 |

**Table W.2 – RS code (255, 239) generating polynomial**

| i | $g_i$ |
|---|---|
| 0 | 79 |
| 1 | 44 |
| 2 | 81 |
| 3 | 100 |
| 4 | 49 |
| 5 | 183 |
| 6 | 56 |
| 7 | 17 |
| 8 | 232 |
| 9 | 187 |
| 10 | 126 |
| 11 | 104 |
| 12 | 31 |
| 13 | 103 |
| 14 | 52 |
| 15 | 118 |
| 16 | 1 |

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**Table W.3 – RS code (255, 223) generating polynomial**

| i | $g_i$ |
|---|---|
| 0 | 45 |
| 1 | 216 |
| 2 | 239 |
| 3 | 24 |
| 4 | 253 |
| 5 | 104 |
| 6 | 27 |
| 7 | 40 |
| 8 | 107 |
| 9 | 50 |
| 10 | 163 |
| 11 | 210 |
| 12 | 227 |
| 13 | 134 |
| 14 | 224 |
| 15 | 158 |
| 16 | 119 |
| 17 | 13 |
| 18 | 158 |
| 19 | 1 |
| 20 | 238 |
| 21 | 164 |
| 22 | 82 |
| 23 | 43 |
| 24 | 15 |
| 25 | 232 |
| 26 | 246 |
| 27 | 142 |
| 28 | 50 |
| 29 | 189 |
| 30 | 29 |
| 31 | 232 |
| 32 | 1 |

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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# RÉSEAUX DE COMMUNICATION INDUSTRIELS – SPÉCIFICATIONS DES BUS DE TERRAIN –

## Partie 2: Spécification et définition des services de la couche physique

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NOTE 1 Les combinaisons de types de protocoles sont spécifiées dans la série IEC 61784-1 et la série IEC 61784-2.

L'IEC 61158-2 a été établie par le sous-comité 65C: Réseaux industriels, du comité d'études 65 de l'IEC: Mesure, commande et automation dans les processus industriels. Il s'agit d'une Norme internationale.

Cette septième édition annule et remplace la sixième édition parue en 2014. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) option de puissance Type 12 ajoutée à 100BASE-TX dans l'Article 29;
b) spécification Type 24 améliorée dans l'Article 33, l'Annexe S et l'Annexe U;
c) nouvelle spécification Type 28;
d) support câblé LVDS jusqu'à 100 Mbit/s du type 12 supprimé.

Le texte de cette Norme internationale est issu des documents suivants:

| Projet | Rapport de vote |
|---|---|
| 65C/1200/FDIS | 65C/1241/RVD |

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La version française de la norme n'a pas été soumise au vote.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

NOTE 2 De légères variations par rapport aux directives ont été autorisées par le Bureau Central de l'IEC pour assurer la continuité de la numérotation des paragraphes dans les éditions précédentes.

Une liste de toutes les parties de la série IEC 61158, publiées sous le titre général *Réseaux de communication industriels – Spécifications des bus de terrain*, se trouve sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

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# 0 Introduction

## 0.1 Généralités

La présente partie de l'IEC 61158 constitue une partie d'une série produite pour faciliter l'interconnexion de composants d'un système d'automation. Elle est liée à d'autres normes de la série telle qu'elle est définie par le modèle de référence des bus de terrain "à trois couches" décrit dans le rapport IEC 61158-1.

## 0.2 Vue d'ensemble de la couche physique

Le principal objectif du présent document est de fournir un ensemble de règles de communication exprimées en matière de procédures à appliquer par les entités Ph homologues au cours de la communication.

La couche physique reçoit des unités de données de la couche liaison de données, les code au besoin par l'ajout d'informations de trame de communication et transmet les signaux physiques résultants au support de transmission à un nœud donné. Les signaux sont ensuite reçus à un ou plusieurs autres nœuds, décodés au besoin par la suppression des informations de trame de communication avant que les unités de données ne soient transférées à la couche liaison de données de l'appareil de réception.

## 0.3 Vue d'ensemble des documents

Le présent document est constitué de spécifications de couche physique qui correspondent à de nombreux types de protocoles de couche physique spécifiés dans la série IEC 61158.

NOTE 1 La numérotation des types de protocoles utilisés est homogène dans l'ensemble de la série IEC 61158.

NOTE 2 Les spécifications des Types 1, 2, 3, 4, 8, 12, 16, 18, 20, 24 et 28 sont incluses. Le Type 7 utilise des spécifications de Type 1. Les autres Types n'utilisent aucune des spécifications objet du présent document.

NOTE 3 Pour faciliter le renvoi aux textes correspondants, les numéros de Type sont indiqués dans le titre des articles. En d'autres termes, la spécification donnée dans ledit article/paragraphe s'applique à ce type, ce qui n'exclut pas son utilisation pour d'autres Types.

NOTE 4 Le choix des ensembles de dispositions d'interfonctionnement relève de l'utilisateur du présent document. Pour les profils de communication normalisés fondés sur la série IEC 61158, se reporter à la série IEC 61784-1 ou à la série IEC 61784-2.

Un modèle général de la couche physique est représenté à la Figure 1.

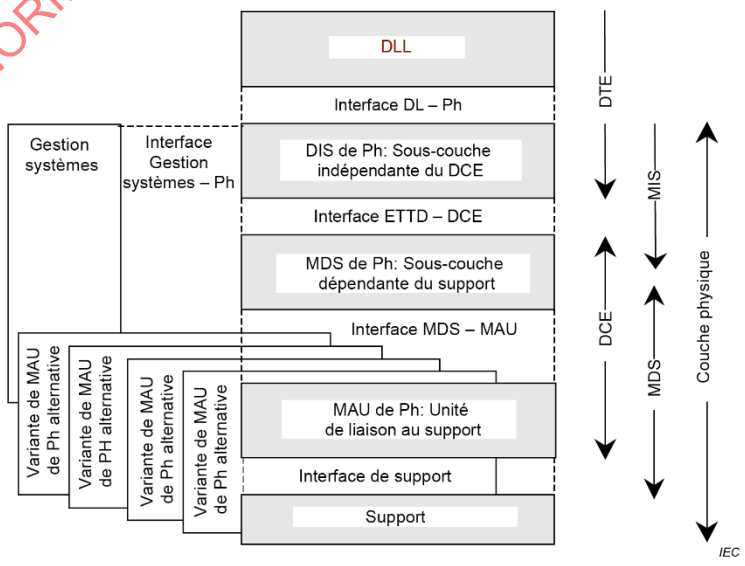


**Figure 1 – Modèle général de couche physique**

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NOTE 5 Les types de protocoles utilisent un sous-ensemble des éléments de structure.

NOTE 6 Étant donné que le Type 8 utilise un DIS plus complexe que celui des autres types, le terme MIS est employé pour le différencier.

Les caractéristiques communes de tous les types et variantes sont les suivantes:

– émission numérique de données;
– pas de transmission d'horloge séparée;
– communication soit en semi-duplex (bidirectionnelle, mais uniquement dans un sens à la fois) soit en transmission bidirectionnelle simultanée.

## 0.4 Principales variantes de couche physique spécifiées dans le présent document

### 0.4.1 Support de Type 1

#### 0.4.1.1 Type 1: Support câblé

Pour les supports câblés à paire torsadée, le Type 1 spécifie deux modes de couplage et différentes vitesses de signalisation comme suit:

a) mode tension (couplage parallèle), 150 Ω, débits binaires de 31,25 kbit/s à 25 Mbit/s;
b) mode tension (couplage parallèle), 100 Ω, 31,25 kbit/s;
c) mode courant (couplage série), 1,0 Mbit/s comprenant deux options de courant.

Les variantes en mode tension peuvent être mises en œuvre avec un couplage inductif en utilisant des transformateurs. Cela n'est pas obligatoire si les exigences d'isolation du présent document sont satisfaites par d'autres moyens.

La couche physique à support câblé de Type 1 (paire torsadée ou non) comporte les options suivantes:

– pas d'alimentation par l'intermédiaire des conducteurs de bus; pas de sécurité intrinsèque;
– alimentation par l'intermédiaire des conducteurs de bus; pas de sécurité intrinsèque;
– pas d'alimentation par l'intermédiaire des conducteurs de bus; sécurité intrinsèque;
– alimentation par l'intermédiaire des conducteurs de bus; sécurité intrinsèque.

#### 0.4.1.2 Type 1: Supports optiques

Les principales variantes du support en fibre optique de Type 1 sont les suivantes:

– fibre optique double, débits binaires de 31,25 kbit/s à 25 Mbit/s;
– mode monofibre, 31,25 kbit/s.

### 0.4.2 Type 2: Supports à câble coaxial et optique

Le Type 2 spécifie les variantes suivantes:

– support à câble cuivre coaxial, 5 Mbit/s;
– support à fibre optique, 5 Mbit/s;
– port d'accès au réseau (NAP), un mécanisme de liaison temporaire point à point qui peut être utilisé pour la programmation, la configuration, le diagnostic ou à d'autres fins;
– sous-couches machine répéteur (RM, RRM) et couches physiques redondantes.

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### 0.4.3 Type 3: Supports câblés et optiques à paire torsadée

Le Type 3 spécifie la transmission synchrone suivante:

a) support câblé à paire torsadée, 31,25 kbit/s, mode tension (couplage parallèle) avec les options suivantes:
   – alimentation par l'intermédiaire des conducteurs de bus; pas de sécurité intrinsèque;
   – alimentation par l'intermédiaire des conducteurs de bus: sécurité intrinsèque;

ainsi que les variantes de transmission asynchrone suivantes:

b) support câblé à paire torsadée, jusqu'à 12 Mbit/s;

c) support à fibre optique, jusqu'à 12 Mbit/s, avec type A4a de l'IEC 60793-2-40 et type A3c de l'IEC 60793-2-30.

### 0.4.4 Type 4: Support câblé

Le Type 4 spécifie des supports câblés ayant les caractéristiques suivantes:

– support câblé RS-485, jusqu'à 76,8 kbit/s.

### 0.4.5 Type 8: Supports câblés et optiques à paire torsadée

La couche physique permet également l'émission d'unités de données reçues par l'intermédiaire d'un accès au support par le support de transmission directement à travers un autre accès au support et son protocole de transmission vers un autre appareil.

Le Type 8 spécifie les variantes suivantes:

– support câblé à paire torsadée, jusqu'à 16 Mbit/s;
– support à fibre optique, jusqu'à 16 Mbit/s.

Les caractéristiques générales de ces supports de transmission sont les suivantes:

– transmission bidirectionnelle simultanée;
– Codage NRZ (non-return-to-ZERO – non retour à zéro).

Les types de supports câblés comportent les options suivantes:

– pas d'alimentation par l'intermédiaire du câble de bus, pas de sécurité intrinsèque;
– alimentation par l'intermédiaire du câble de bus et sur des conducteurs supplémentaires, pas de sécurité intrinsèque.

### 0.4.6 Type 12: Support câblé

Le Type 12 spécifie des supports câblés ayant les caractéristiques suivantes:

– deux paires de câbles qui acheminent deux canaux d'alimentation distincts combinés à une transmission de signal.

### 0.4.7 Type 16: Supports optiques

Le Type 16 spécifie une transmission synchrone utilisant un support à fibre optique, à 2 Mbit/s, 4 Mbit/s, 8 Mbit/s et 16 Mbit/s.

### 0.4.8 Type 18: Supports

#### 0.4.8.1 Type 18: Supports basiques

Le Type 18-PhL-B spécifie un signal de transmission équilibrée sur un câble torsadé blindé à 3 conducteurs. Il est spécifié des débits binaires pouvant atteindre 10 Mbit/s et des distances de transmission allant jusqu'à 1,2 km.

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#### 0.4.8.2 Type 18: Supports alimentés

Le Type 18-PhL-P spécifie un signal de transmission équilibrée sur un câble non blindé à 4 conducteurs, à profil plat ou rond dont les conducteurs sont conçus pour le signal de communications et la distribution d'une alimentation intégrée au réseau. Il est spécifié des débits binaires pouvant atteindre 2,5 Mbit/s et des distances de transmission allant jusqu'à 500 m.

### 0.4.9 Type 20: Supports

Le Type 20 utilise la modulation par déplacement de fréquence (FSK – *Frequency Shift Keying*) continue de phase binaire. Un courant à fréquence relativement élevée est superposé à un courant analogique à basse fréquence, qui se situe habituellement dans une plage comprise entre 4 mA et 20 mA. Les signaux numérique et analogique partagent le même support, mais diffèrent en matière de contenu fréquentiel. Les appareils de communication envoient un signal soit avec le courant, soit avec la tension, et toutes les signalisations apparaissent en tant que tension lorsqu'elles sont détectées à basse impédance. Par conséquent, la signalisation numérique est une extension de la signalisation analogique conventionnelle.

La couche physique utilise généralement un câble en cuivre à paire torsadée en tant que support et fournit uniquement une communication numérique ou une communication numérique et analogique simultanée à des distances d'au moins 1 500 m (environ 5 000 pieds). Les distances de communication maximales varient en fonction de la construction du réseau et des conditions environnementales.

### 0.4.10 Type 24: Supports

#### 0.4.10.1 Type 24: Supports basiques

Le Type 24 spécifie un support câblé à paire torsadée. Les caractéristiques générales de ce support de transmission sont les suivantes:

– L'interface de bus TIA-485-A avec isolation galvanique utilisant un transformateur;
– jusqu’à 10 Mbit/s;
– transmission semi-duplex;
– codage de Manchester.

#### 0.4.10.2 Type 24: Supports alimentés

Les types de supports alimentés comportent les options suivantes:

– L'interface de bus TIA-485-A sans isolation galvanique utilisant un transformateur;
– jusqu’à 32 Mbit/s;
– transmission semi-duplex;
– codage de Manchester ou codage NRZI;
– alimentation par l'intermédiaire des conducteurs de bus.

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### 0.4.11 Type 28: Supports

Le Type 28 utilise la technologie OFDM (Orthogonal Frequency Division Multiplexing – *multiplexage par répartition orthogonale de fréquence*). Les plages de sous-porteuses de fréquence sont comprises entre 1,536 MHz et 32,256 MHz. Les distances de transmission atteignent 500 m sur un seul bus. Le signal analogique doit être délivré sur le support connecté à chaque dispositif du réseau.

Le Type 28 spécifie la transmission synchrone suivante:

a) support câblé à paire torsadée, jusqu'à 100 Mbit/s;

b) support câblé coaxial jusqu'à A 100 Mbit/s.

Les caractéristiques générales de ces supports de transmission sont les suivantes:

a) transmission bidirectionnelle simultanée;

b) codage OFDM

## 0.5 Déclaration de droits de propriété

La Commission Électrotechnique Internationale (IEC) attire l'attention sur le fait qu'il est déclaré que la conformité aux dispositions du présent document peut impliquer l'utilisation d'un brevet. L'IEC ne prend pas position quant à la preuve, à la validité et à la portée de ces droits de propriété.

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# RÉSEAUX DE COMMUNICATION INDUSTRIELS – SPÉCIFICATIONS DES BUS DE TERRAIN –

## Partie 2: Spécification et définition des services de la couche physique

## 1 Domaine d'application

La présente partie de l'IEC 61158 spécifie les exigences applicables aux composants de bus de terrain. Elle spécifie également les exigences de configuration des supports et des réseaux nécessaires pour assurer des niveaux convenus

a) d'intégrité des données avant toute vérification d'erreur de la couche liaison de données;

b) d'interopérabilité entre appareils au niveau de la couche physique.

La couche physique des bus de terrain est conforme à la couche 1 du modèle OSI à 7 couches, telle qu'elle est définie dans l'ISO/IEC 7498, à l'exception du fait que, pour certains types, les délimiteurs de trame se situent dans la couche physique, tandis que pour d'autres types, ils se situent dans la couche liaison de données.

## 2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

NOTE Toutes les parties de la série IEC 61158, ainsi que la série IEC 61784-1 et la série IEC 61784-2 font l'objet d'une maintenance simultanée. Les références croisées à ces documents dans le texte se rapportent par conséquent aux éditions datées dans la présente liste de références normatives.

IEC 60050 (toutes les parties), *Vocabulaire Électrotechnique International* (disponible à l'adresse <http://www.electropedia.org>)

IEC 60079-11, *Atmosphères explosives – Partie 11: Protection de l'équipement par sécurité intrinsèque "i"*

IEC 60079-14:2007 [1], Atmosphères explosives – Partie 14: *Conception, sélection et construction des installations électriques*

IEC 60079-25, *Atmosphères explosives – Partie 25: Systèmes électriques de sécurité intrinsèque*

IEC 60169-17, Connecteurs pour fréquences radioélectriques − Dix-septième partie: *Connecteurs coaxiaux pour fréquences radioélectriques avec diamètre intérieur du conducteur extérieur de 6,5 mm (0,256 in) à verrouillage à vis − Impédance caractéristique 50 ohms (type TNC)*

IEC 60189-1:2018, *Low-frequency cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods* (disponible en anglais seulement)

[1] Il existe une édition 2013, mais l'édition citée s'applique.

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IEC 60255-22-1:1988 [2], *Relais électriques – Partie 22-1: Essais d'influence électrique concernant les relais de mesure et appareils de protection – Section 1: Essais à l'onde oscillatoire amortie à 1 Mhz*

IEC 60364-4-41, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*

IEC 60364-5-54, *Installations électriques à basse tension – Partie 5-54: Choix et mise en œuvre des matériels électriques – Installations de mise à la terre et conducteurs de protection*

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 60603-7-4, *Connecteurs pour équipements électroniques – Partie 7-4: Spécification particulière pour les fiches et les embases non blindées à 8 voies pour la transmission de données à des fréquences jusqu'à 250 MHz*

IEC 60754-2, *Essai sur les gaz émis lors de la combustion des matériaux prélevés sur câbles – Partie 2: Détermination de la conductivité et de l'acidité (par mesure du pH)*

IEC 60793 (toutes les parties), *Fibres optiques*

IEC 60793-2:2019, *Fibres optiques – Partie 2: Spécifications de produits – Généralités*

IEC 60793-2-30:2015, *Fibres optiques – Partie 2-30: Spécifications de produits – Spécification intermédiaire pour les fibres multimodales de catégorie A3*

IEC 60793-2-40:2021, *Fibres optiques – Partie 2-40: Spécifications de produits – Spécification intermédiaire pour les fibres multimodales de catégorie A4*

IEC 60794-1-2:200[3], *Câbles à fibres optiques – Part 1-2: Spécification générique – Procédures de base applicables aux essais des câbles optiques*

IEC 60807-3, *Connecteurs rectangulaires utilisés aux fréquences inférieures à 3 MHz – Partie 3: Spécification particulière pour une gamme de connecteurs ayant les boîtiers métalliques de forme trapézoïdale et les contacts ronds – Types de contacts à sertir démontables avec fûts fermés, à insérer et à extraire par l'arrière de l'isolant*

IEC 60811-403, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 403: Essais divers – Essai de résistance à l'ozone sur les mélanges réticulés*

IEC 60811-404:2012, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 404: Essais divers – Essais de résistance à l'huile minérale pour les gaines*

IEC 61000-4-2, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3, *Compatibilité électromagnétique (CEM) − Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*

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2 Cette publication a été supprimée.

3 Il existe une nouvelle édition de l'IEC 60794-1-2 (2021). Les références croisées à la version de 2003 sont décrites à l'Annexe informative A.

IEC 61000-4-4, *Compatibilité électromagnétique (CEM) – Partie 4-4*: *Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61076-2-114:2020, *Connecteurs pour équipements électriques et électroniques − Exigences de produit − Partie 2-114: Connecteurs circulaires − Spécification particulière pour les connecteurs avec verrouillage à vis M8 avec contacts de puissance et contact de signaux pour transmission de données jusqu'à 100 MHz*

IEC 61131-2:2017, *Mesurage et contrôle des processus industriels* − Automates programmables – Partie 2: *Exigences et essais des équipements*

IEC 61156-1:2007, *Câbles multiconducteurs à paires symétriques et quartes pour transmissions numériques – Partie 1: Spécification générique*

IEC 61158-3-20:2023, *Réseaux de communication industriels − Spécifications de bus de terrain − Partie 3-20: Définition des services de la couche liaison de données – Éléments de type 20*

IEC 61158-4-2:2023, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 4-2: Spécification du protocole de la couche liaison de données – Éléments de type 2*

IEC 61158-4-3:2019, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 4-3: Spécification du protocole de la couche liaison de données – Éléments de type 3*

IEC 61169-8:2007, *Connecteurs pour fréquences radioélectriques – Partie 8*: *Spécification intermédiaire – Connecteurs coaxiaux pour fréquences radioélectriques avec diamètre intérieur du conducteur extérieur de 6,5 mm (0,256 in) à verrouillage à baïonnette – Impédance caractéristique 50 Ω (type BNC)*

IEC 61210:2010, *Dispositifs de connexion – Bornes plates à connexion rapide pour conducteurs électriques en cuivre – Exigences de sécurité*

IEC 61754-2, *Interfaces de connecteurs pour fibres optiques – Partie 2: Famille de connecteurs de type BFOC/2,5*

IEC 61754-13, *Interfaces de connecteurs pour fibres optiques – Partie 13: Connecteurs de type FC-PC*

IEC 61754-22, *Interfaces de connecteurs pour fibres optiques – Partie 22: Famille de connecteurs de type F-SMA*

IEC 63171, *Connecteurs pour équipements électriques et électroniques – Fiches et embases écrantées ou non écrantées pour transmission de données sur une seule paire symétrique avec courant admissible – Exigences générales et essais.*

ISO/IEC 7498 (toutes les parties), T*echnologies de l'information – Interconnexion de systèmes ouverts (OSI) – Modèle de référence de base*

ISO/IEC 7498-1:1994, *Technologies de l'information – Interconnexion de systèmes ouverts (OSI) − Modèle de référence de base*: *Le modèle de base*

ISO/IEC 8482, *Information technology – Telecommunications and information exchange between systems – Twisted pair multipoint interconnections* (disponible en anglais seulement)

ISO/IEC/IEEE 8802-3:2021, *Telecommunications and information exchange between systems – Requirements for local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet* (disponible en anglais seulement)

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ISO 9314-1, *Systèmes de traitement de l'information − Interface de données distribuées sur fibre (FDDI) − Partie 1: Protocole de la couche physique de l'anneau à jeton*

ISO/IEC 10731:1994, *Technologies de l'information – Interconnexion de systèmes ouverts (OSI) – Modèle de Référence de Base – Conventions pour la définition des services OSI*

ISO 4892-1, *Plastiques – Méthodes d'exposition à des sources lumineuses de laboratoire – Partie 1*: *Lignes directrices générales*

TIA-422-B:1994, *Electrical Characteristics of Balanced Voltage Digital Interface Circuits*

TIA-485-A:1998, *Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems*

## 3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de la série ISO/IEC 7498 ainsi que les définitions suivantes s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

### 3.1 Termes et définitions communs

NOTE De nombreuses définitions sont communes à plusieurs types de protocoles; elles ne sont pas nécessairement utilisées par tous les types de protocoles.

**3.1.1**
**activité**
présence d'un signal ou d'un bruit aux bornes d'entrée d'un appareil de bus de terrain qui est d'un niveau supérieur au seuil de niveau du signal du récepteur de cet appareil

**3.1.2**
**barrière**
entité physique qui limite le courant et la tension dans une zone dangereuse afin de satisfaire aux exigences de sécurité intrinsèque

**3.1.3**
**bit**
unité de données constituée d'un 1 ou d'un 0

Note 1 à l'article: Un bit est la plus petite unité de données qui peut être transmise.

**3.1.4**
**bus**
ligne principale ainsi que tous les appareils qui y sont connectés

**3.1.5**
**connecteur d'interface de canalisation de câbles**
**CPIC**
point auquel les essais et mesurages de conformité sont effectués et qui assurent l'interface entre l'appareil de réseau et la canalisation du câble

Note 1 à l'article: L'abréviation "CPIC" est dérivée du terme anglais développé correspondant "cable plant interface connector".

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**3.1.6**
**élément de communication**
partie d'un appareil de bus de terrain qui communique avec d'autres éléments par le bus

**3.1.7**
**connecteur**
appareil de couplage utilisé pour connecter le support d'un circuit ou d'un élément de communication avec celui d'un autre circuit ou élément de communication

**3.1.8**
**coupleur**
interface physique entre la ligne principale et une dérivation ou entre la ligne principale et l'appareil

**3.1.9**
**équipement de transmission de données**
**DCE**
mode de réalisation des supports, partie dépendante de la modulation et du codage d'un appareil connecté au bus de terrain, incluant les parties inférieures de la couche physique au sein de l'appareil

Note 1 à l'article: L'abréviation "DCE" est dérivée du terme anglais développé correspondant "Data Communications Equipment".

**3.1.10**
**équipement terminal de traitement de données**
**ETTD**
mode de réalisation des supports, partie indépendante de la modulation et du codage d'un appareil connecté au bus de terrain, incluant la partie la plus haute de la couche physique ainsi que toutes les couches supérieures dans l'appareil

**3.1.11**
**décibel(milliwatt)**
**dB(mW)**
unité logarithmique de puissance référencée à 1 mW

$$P_{dBm} = 10 \log (P_{mW})$$

Note 1 à l'article: db(mW) est également exprimé dBm.

Note 2 à l'article: Si $P_{mW}$ est la puissance mesurée en mW, alors $P_{dBm}$ est la puissance logarithmique exprimée en dB(mW), ou de manière équivalente, en dBm.

**3.1.12**
**délimiteur**
drapeau (indicateur) qui sépare et organise des éléments de données

**3.1.13**
**appareil**
entité physique connectée au bus de terrain, constituée d'au moins un élément de communication (l'élément réseau) et qui peut comporter un élément de commande et/ou un élément final (transducteur, actionneur, etc.)

Note 1 à l'article: Un appareil peut contenir plusieurs nœuds.

**3.1.14**
**puissance d'injection effective**
puissance effective couplée dans le cœur d'un guide d'onde à fibre optique par l'émetteur

Note 1 à l'article: La puissance d'injection effective est mesurée au moyen d'une fibre d'essai normalisée connectée au CPIC.

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**3.1.15**
**puissance effective**
différence, exprimée en dBm, entre la puissance optique absolue, mesurée en milliwatts au point médian dans le temps du niveau (Hi) et la puissance optique absolue mesurée en milliwatts au point médian dans le temps du l(Lo)

Note 1 à l'article: La puissance effective donne un mesurage plus exact des conditions qui affectent les récepteurs que des mesurages conventionnels tels que la puissance crête et la puissance moyenne. Des méthodes de mesure de la puissance effective feront l'objet d'études ultérieures.

**3.1.16**
**erreur**
écart ou discordance entre une valeur ou une condition calculée, observée ou mesurée et la valeur ou la condition prescrite ou théoriquement correcte

**3.1.17**
**rapport d'extinction**
rapport de la puissance optique absolue, mesurée en milliwatts au point médian dans le temps du niveau haut (Hi) à la puissance optique absolue mesurée en milliwatts au point médian dans le temps du niveau bas (Lo)

Note 1 à l'article: Un exemple de calcul de la puissance efficace et du rapport d'extinction est fourni ci-après. Si le point médian du niveau (Hi) est mesuré à 105 µW, et si le point médian du niveau (Lo) est mesuré à 5 µW, alors la différence est de 100 µW. Par conséquent, la puissance effective est de 10 log ((100 µW) / 1 mW)), ce qui est égal à –10,0 dBm. Le rapport d'extinction est (105/5), ce qui équivaut à 21:1.

**3.1.18**
**câble à fibre optique**
câble contenant un ou plusieurs guides d'onde à fibre optique, couvert de matériau d'enrobage destiné à faciliter le traitement et à protéger la fibre

**3.1.19**
**récepteur à fibre optique**
appareil de communication combinant l'optique et l'électronique qui accepte le signal optique reçu par l'intermédiaire du CPIC

**3.1.20**
**domaine de fonctionnement d'un récepteur à fibre optique**
plage de puissance optique qui doit être présente au niveau du CPIC pour assurer la conformité aux spécifications relatives au taux d'erreur sur les bits

**3.1.21**
**émetteur à fibre optique**
appareil qui émet des signaux optiques qui se propagent dans un guide d'onde à fibre optique à travers le CPIC

**3.1.22**
**guide d'onde à fibre optique**
brin souple, transparent du point de vue optique, utilisé pour transporter des signaux optiques d'un point géographique à un autre

**3.1.23**
**trame**
ensemble de créneaux temporels numériques consécutifs dans lesquels la position de chaque créneau temporel numérique peut être identifiée par référence à un signal de verrouillage de trame

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**3.1.24**
**sécurité intrinsèque**
méthodologie de conception d'un circuit ou d'un ensemble de circuits dans lequel toute étincelle ou tout effet thermique produit dans des conditions normales de fonctionnement et des conditions de défaut spécifiées, est incapable, dans des conditions d'essai prescrites, de provoquer l'inflammation d'une atmosphère explosive donnée

**3.1.25**
**isolation**
disposition physique et électrique des parties d'un système de transmission de signaux destinée à prévenir les courants de perturbations électriques dans ou entre ces composants

**3.1.26**
**bavardage**
transmission continue sur le support due à un appareil défectueux

**3.1.27**
**instabilité (gigue)**
décalage des points de transition à 50 % des fronts d'impulsion par rapport à leur position théorique, résultant de causes diverses

**3.1.28**
**codage Manchester**
méthode au moyen de laquelle des signaux de données et d'horloge séparés peuvent être combinés en un seul flux de données à synchronisation automatique, transmissible sur un canal série

**3.1.29**
**support**
câble, fibre optique ou autre moyen permettant de transmettre des signaux de communication entre deux ou plusieurs points

Note 1 à l'article: Dans la version anglaise de la présente partie de l'IEC 61158, le terme "media" est utilisé comme pluriel du terme medium.

**3.1.30**
**réseau**
tous les supports, connecteurs, répéteurs, routeurs, passerelles et éléments de communication du nœud associés permettant d'interconnecter un ensemble donné d'appareils de communication

**3.1.31**
**nœud**
point d'extrémité d'une dérivation de réseau ou point auquel se rencontrent une ou plusieurs dérivations

**3.1.32**
**étoile active optique**
appareil actif dans lequel un signal provenant d'une fibre d'entrée est reçu, amplifié et retransmis à un plus grand nombre de fibres optiques de sortie

Note 1 à l'article: La resynchronisation du signal reçu est facultative.

**3.1.33**
**temps de décroissance optique**
durée nécessaire pour qu'une impulsion passe d'une puissance efficace de 90 % à une puissance efficace de 10 %, spécifiée en pourcentage du temps binaire nominal

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**3.1.34**
**étoile passive optique**
appareil passif dans lequel des signaux provenant de fibres d'entrée sont combinés puis distribués entre des fibres optiques de sortie

**3.1.35**
**temps de croissance optique**
durée nécessaire pour qu'une impulsion passe d'une puissance efficace de 10 % à une puissance efficace de 90 %, spécifiée en pourcentage du temps binaire nominal

**3.1.36**
**longueur d'onde de transmission crête**
**λp**
longueur d'onde à laquelle l'intensité énergétique est maximale

**3.1.37**
**récepteur**
ensemble des circuits de réception d'un élément de communication

**3.1.38**
**répéteur**
appareil de couche physique actif à deux accès qui reçoit et réémet tous les signaux pour accroître la distance et le nombre d'appareils auxquels les signaux peuvent être correctement transférés pour un support donné

**3.1.39**
**segment**
section de câble d'une ligne principale de bus de terrain dont la terminaison a une impédance caractéristique

Note 1 à l'article: Les segments sont reliés par des répéteurs au sein d'une liaison logique et par des ponts, de manière à constituer un réseau de bus de terrain.

**3.1.40**
**appareil à alimentation séparée**
appareil qui ne reçoit pas son alimentation de fonctionnement par l'intermédiaire des conducteurs de signal de bus de terrain

**3.1.41**
**blindage**
revêtement métallique mis à la terre enveloppant utilisé pour confiner le champ électrique dans le câble et pour protéger le câble contre les influences électriques externes

Note 1 à l'article: Les gaines et armatures métalliques ainsi que les conducteurs concentriques mis à la terre peuvent également servir de blindage.

**3.1.42**
**ligne secondaire**
dérivation (c'est-à-dire une connexion à une ligne plus importante en un point donné sur son itinéraire) qui constitue un circuit terminal

Note 1 à l'article: Le terme "câble de dérivation" est également utilisé dans le présent document.

**3.1.43**
**terminateur**
résistance reliant des paires de conducteurs aux deux extrémités d'un segment de support câblé afin d'éviter les réflexions aux extrémités des câbles

Note 1 à l'article: Pour le Type 2, le terminateur est monté dans un connecteur BNC ou TNC.

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**3.1.44**
**émetteur-récepteur**
appareil constitué d'équipements de réception et de transmission dans un même boîtier utilisant des composants de circuit communs pour la transmission et la réception

Note 1 à l'article: Une unité de liaison support peut être l'émetteur-récepteur ou peut contenir l'émetteur-récepteur, en fonction du type et de la mise en œuvre.

[SOURCE: IEEE Std 100-1996, définition modifiée pour l'usage non radioélectrique]

**3.1.45**
**émetteur**
ensemble des circuits de transmission d'un élément de communication

**3.1.46**
**ligne principale**
principal bus de communication agissant comme source d'alimentation principale pour un certain nombre d'autres lignes (secondaires)

**3.1.47**
**longueur d'onde type de demi-intensité**
$\Delta\lambda$
plage de longueurs d'onde de répartition spectrale dans laquelle l'intensité énergétique est au moins égale à la moitié de l'intensité maximale

## 3.2 Type 1: Termes et définitions

**3.2.1**
**activité**
[VOIR: 3.1.1]

**3.2.2**
**barrière**
[VOIR: 3.1.2]

**3.2.3**
**bus**
[VOIR: 3.1.4]

**3.2.4**
**connecteur d'interface de canalisation de câbles**
**CPIC**
[VOIR: 3.1.5]

**3.2.5**
**élément de communication**
[VOIR: 3.1.6]

**3.2.6**
**connecteur**
[VOIR: 3.1.7]

**3.2.7**
**coupleur**
[VOIR: 3.1.8]

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**3.2.8**
**équipement de transmission de données**
**DCE**
[VOIR: 3.1.9]

**3.2.9**
**équipement terminal de traitement de données**
**ETTD**
[VOIR: 3.1.10]

**3.2.10**
**dBm**
[VOIR: 3.1.11]

**3.2.11**
**délimiteur**
[VOIR: 3.1.12]

**3.2.12**
**appareil**
[VOIR: 3.1.13]

**3.2.13**
**puissance d'injection effective**
[VOIR: 3.1.14]

**3.2.14**
**puissance effective**
[VOIR: 3.1.15]

**3.2.15**
**câble à fibre optique**
[VOIR: 3.1.18]

**3.2.16**
**récepteur à fibre optique**
[VOIR: 3.1.19]

**3.2.17**
**domaine de fonctionnement d'un récepteur à fibre optique**
[VOIR: 3.1.20]

**3.2.18**
**émetteur à fibre optique**
[VOIR: 3.1.21]

**3.2.19**
**guide d'onde à fibre optique**
[VOIR: 3.1.22]

**3.2.20**
**trame**
[VOIR: 3.1.23]

**3.2.21**
**sécurité intrinsèque**
[VOIR: 3.1.24]

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**3.2.22**
**isolation**
[VOIR: 3.1.25]

**3.2.23**
**bavardage**
[VOIR: 3.1.26]

**3.2.24**
**codage Manchester**
[VOIR: 3.1.28]

**3.2.25**
**support**
[VOIR: 3.1.29]

**3.2.26**
**réseau**
[VOIR: 3.1.30]

**3.2.27**
**nœud**
[VOIR: 3.1.31]

**3.2.28**
**temps de décroissance optique**
[VOIR: 3.1.33]

**3.2.29**
**temps de croissance optique**
[VOIR: 3.1.35]

**3.2.30**
**longueur d'onde de transmission crête**
**λp**
[VOIR: 3.1.36]

**3.2.31**
**répéteur**
[VOIR: 3.1.38]

**3.2.32**
**segment**
[VOIR: 3.1.39]

**3.2.33**
**appareil à alimentation séparée**
[VOIR: 3.1.40]

**3.2.34**
**blindage**
[VOIR: 3.1.41]

**3.2.35**
**ligne secondaire**
[VOIR: 3.1.42]

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**3.2.36**
**terminateur**
[VOIR: 3.1.43]

**3.2.37**
**émetteur-récepteur**
[VOIR: 3.1.44]

**3.2.38**
**émetteur**
[VOIR: 3.1.45]

**3.2.39**
**ligne principale**
[VOIR: 3.1.46]

### 3.3 Type 2: Termes et définitions

**3.3.1**
**activité**
[VOIR: 3.1.1]

**3.3.2**
**bit**
[VOIR: 3.1.3]

**3.3.3**
**suppression ou temps de suppression**
intervalle de temps exigé après émission avant qu'un nœud ne puisse recevoir

**3.3.4**
**bus**
[VOIR: 3.1.4]

**3.3.5**
**élément de communication**
[VOIR: 3.1.6]

**3.3.6**
**connecteur**
[VOIR: 3.1.7]

**3.3.7**
**équipement de transmission de données**
**DCE**
[VOIR: 3.1.9]

**3.3.8**
**dBm**
[VOIR: 3.1.11]

**3.3.9**
**délimiteur**
[VOIR: 3.1.12]

**3.3.10**
**appareil**
[VOIR: 3.1.13]

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**3.3.11**
**délimiteur de fin**
séquence unique de symboles qui identifie la fin d'une trame

**3.3.12**
**nœud d'extrémité**
nœud producteur ou consommateur

**3.3.13**
**erreur**
[VOIR: 3.1.16]

**3.3.14**
**trame**
[VOIR: 3.1.23]

**3.3.15**
**isolation**
[VOIR: 3.1.25]

**3.3.16**
**bavardage**
[VOIR: 3.1.26]

**3.3.17**
**codage Manchester**
[VOIR: 3.1.28]

**3.3.18**
**support**
[VOIR: 3.1.29]

**3.3.19**
**M_symbol**
représentation des bits de données MAC à coder et à émettre par la couche physique

**3.3.20**
**trame MAC**
ensemble de M-symbols émis sur le support et contenant un préambule, un délimiteur de début, des données, un CRC et un délimiteur de fin

**3.3.21**
**réseau**
[VOIR: 3.1.30]

**3.3.22**
**port d'accès au réseau**
variante de couche physique qui permet la connexion d'un nœud temporaire à la liaison par connexion au NAP d'un nœud permanent

**3.3.23**
**nœud**
[VOIR: 3.1.31]

Note 1 à l'article: En outre, un nœud est une connexion à une liaison qui exige un M_ID (identifiant de Support) unique.

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**3.3.24**
**symbole non données**
signal de couche physique codé Manchester utilisé pour des délimiteurs et ne transportant aucune donnée

**3.3.25**
**isolateurs optiques**
composants placés dans l'émetteur-récepteur de couche physique d'un nœud, qui convertit le courant en lumière et de nouveau en signal électrique

**3.3.26**
**nœud permanent**
nœud dont la connexion au réseau n'utilise pas la variante de couche physique de port d'accès au réseau (NAP)

Note 1 à l'article: Ce nœud peut, facultativement, prendre en charge une variante de couche physique NAP pour permettre à des nœuds temporaires de se connecter au réseau.

Note 2 à l'article: L'abréviation ''NAP'' est dérivée du terme anglais développé correspondant ''network access port''.

**3.3.27**
**supports redondants**
plusieurs supports utilisés pour réduire le plus possible les échecs de communication

**3.3.28**
**répéteur**
[VOIR: 3.1.38]

**3.3.29**
**segment**
[VOIR: 3.1.39]

**3.3.30**
**blindage**
[VOIR: 3.1.41]

**3.3.31**
**durée de créneau**
temps maximal exigé pour détecter une émission prévue

Note 1 à l'article: Chaque nœud attend pendant une durée de créneau chaque nœud manquant pendant le passage de jeton implicite.

**3.3.32**
**ligne secondaire**
[VOIR: 3.1.42]

Note 1 à l'article: Elle fait partie intégrante des prises réseau.

**3.3.33**
**délimiteur de début**
séquence unique de symboles qui identifie le début d'une trame

**3.3.34**
**prise**
point de liaison d'un nœud ou d'une ligne secondaire au câble de ligne principale

Note 1 à l'article: Une prise permet de retirer facilement un nœud sans interrompre la liaison.

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**3.3.35**
**terminateur**
[VOIR: 3.1.43]

**3.3.36**
**outil**
programme logiciel exécutable qui interagit avec l'utilisateur pour réaliser certaines fonctions

**3.3.37**
**émetteur-récepteur**
[VOIR: 3.1.44]

**3.3.38**
**nœud transitoire**
nœud uniquement destiné à être connecté au réseau de manière temporaire, en utilisant le support de couche physique NAP connecté au NAP d'un nœud permanent

**3.3.39**
**émetteur**
[VOIR: 3.1.45]

**3.3.40**
**ligne principale**
[VOIR: 3.1.46]

**3.3.41**
**câble de ligne principale**
bus ou partie centrale d'un système de câble

**3.3.42**
**section de câble de ligne principale**
longueur de câble de ligne principale entre deux prises quelconques

### 3.4 Type 3: Termes et définitions

**3.4.1**
**activité**
[VOIR: 3.1.1]

**3.4.2**
**barrière**
[VOIR: 3.1.2]

**3.4.3**
**temps binaire**
temps nécessaire pour transmettre un bit

**3.4.4**
**bus**
[VOIR: 3.1.4]

**3.4.5**
**élément de communication**
[VOIR: 3.1.6]

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**3.4.6**
**confirmation (primitive de)**

[SOURCE: ISO/IEC 10731:1994]

**3.4.7**
**connecteur**
[VOIR: 3.1.7]

**3.4.8**
**coupleur**
[VOIR: 3.1.8]

**3.4.9**
**équipement de transmission de données**
**DCE**
[VOIR: 3.1.9]

**3.4.10**
**équipement terminal de traitement de données**
**ETTD**
[VOIR: 3.1.10]

**3.4.11**
**dBm**
[VOIR: 3.1.11]

**3.4.12**
**appareil**
[VOIR: 3.1.13]

**3.4.13**
**entité-DL**
élément actif dans un sous-système DL comportant un ensemble de capacités définies pour la couche DL et correspondant à un type donné d'entité DL (sans que soient utilisées d'autres capacités)

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.11, modifié – (N) remplacée par DL pour la couche liaison de données]

**3.4.14**
**câble à fibre optique**
**FOC**
Note 1 à l'article: L'abréviation "FOC" est dérivée du terme anglais développé correspondant "fiber optic cable".

[VOIR: 3.1.18]

**3.4.15**
**trame**
[VOIR: 3.1.23]

**3.4.16**
**indication (primitive d')**

[SOURCE: ISO/IEC 10731:1994]

**3.4.17**
**sécurité intrinsèque**
[VOIR: 3.1.24]

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**3.4.18**
**isolation**
[VOIR: 3.1.25]

**3.4.19**
**bavardage**
[VOIR: 3.1.26]

**3.4.20**
**support**
[VOIR: 3.1.29]

**3.4.21**
**entité (N)**
élément actif dans un sous-système (N) comportant un ensemble de capacités définies pour la couche (N) et correspondant à un type donné d'entité (N) (sans que soient utilisées d'autres capacités)

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.11]

**3.4.22**
**service (N)**

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.5]

**3.4.23**
**réseau**
[VOIR: 3.1.30]

**3.4.24**
**nœud**
[VOIR: 3.1.31]

**3.4.25**
**entité Ph**
élément actif dans un sous-système DL comportant un ensemble de capacités définies pour la couche DL et correspondant à un type donné d'entité DL (sans que soient utilisées d'autres capacités)

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.11, modifié – (N) remplacée par Ph pour la couche physique.]

**3.4.26**
**service Ph**
capacité de la couche Ph et des couches inférieures à celle-ci, offerte aux entités DL à la frontière entre la couche Ph et la couche DL

[SOURCE: ISO/IEC 7498-1:1994, 5.2.1.5, modifié – (N) remplacée par Ph pour la couche physique]

**3.4.27**
**répéteur**
[VOIR: 3.1.38]

**3.4.28**
**demande (primitive de)**

[SOURCE: ISO/IEC 10731:1994]

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**3.4.29**
**réinitialisation**

[SOURCE: ISO/IEC 7498-1:1994, 5.8.1.17]

**3.4.30**
**segment**
[VOIR: 3.1.39]

**3.4.31**
**appareil à alimentation séparée**
[VOIR: 3.1.40]

**3.4.32**
**blindage**
[VOIR: 3.1.41]

**3.4.33**
**ligne secondaire**
[VOIR: 3.1.42]

**3.4.34**
**station**
nœud

**3.4.35**
**terminateur**
[VOIR: 3.1.43]

**3.4.36**
**émetteur-récepteur**
[VOIR: 3.1.44]

**3.4.37**
**émetteur**
[VOIR: 3.1.45]

**3.4.38**
**ligne principale**
[VOIR: 3.1.46]

### 3.5 Type 4: Termes et définitions

**3.5.1**
**activité**
[VOIR: 3.1.1]

**3.5.2**
**bus**
[VOIR: 3.1.4]

**3.5.3**
**connecteur**
[VOIR: 3.1.7]

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**3.5.4**
**équipement de transmission de données**
**DCE**
[VOIR: 3.1.9]

**3.5.5**
**équipement terminal de traitement de données**
**ETTD**
[VOIR: 3.1.10]

**3.5.6**
**appareil**
[VOIR: 3.1.13]

**3.5.7**
**compteur de repos**
compteur mesurant le nombre de périodes binaires pendant lesquelles le niveau du signal sur la liaison physique a été élevé pour des appareils de classe normale ou de classe simple en mode semi-duplex

**3.5.8**
**isolation**
[VOIR: 3.1.25]

**3.5.9**
**support**
[VOIR: 3.1.29]

**3.5.10**
**réseau**
[VOIR: 3.1.30]

**3.5.11**
**appareil de classe normale**
appareil qui lance l'émission et répond aux demandes et qui peut agir comme serveur (répondeur) et en tant que client (demandeur) (également appelé "homologue")

**3.5.12**
**blindage**
[VOIR: 3.1.41]

**3.5.13**
**appareil de classe simple**
appareil qui répond aux demandes d'appareils de classe normale et agit comme serveur ou répondeur uniquement

**3.5.14**
**émetteur**
[VOIR: 3.1.45]

### 3.6 Vide

NOTE Dans la présente édition, le 3.6 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

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## 3.7 Type 8: Termes et définitions

**3.7.1**
**activité**
[VOIR: 3.1.1]

**3.7.2**
**coupleur de bus**
appareil qui divise l'anneau en segments, en ouvrant l'anneau et en intégrant un autre anneau à cet endroit

**3.7.3**
**connecteur d'interface de canalisation de câbles**
**CPIC**
[VOIR: 3.1.5]

**3.7.4**
**élément de communication**
[VOIR: 3.1.6]

**3.7.5**
**connecteur**
[VOIR: 3.1.7]

**3.7.6**
**dBm**
[VOIR: 3.1.11]

**3.7.7**
**puissance d'injection effective**
[VOIR: 3.1.14]

**3.7.8**
**puissance effective**
[VOIR: 3.1.15]

**3.7.9**
**câble à fibre optique**
[VOIR: 3.1.18]

**3.7.10**
**récepteur à fibre optique**
[VOIR: 3.1.19]

**3.7.11**
**domaine de fonctionnement d'un récepteur à fibre optique**
[VOIR: 3.1.20]

**3.7.12**
**émetteur à fibre optique**
[VOIR: 3.1.21]

**3.7.13**
**guide d'onde à fibre optique**
[VOIR: 3.1.22]

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**3.7.14**
**trame**
[VOIR: 3.1.23]

**3.7.15**
**interface d'arrivée**
interface qui reçoit des données de l'appareil précédent et qui envoie des données, reçues par l'intermédiaire d'une interface de départ, à l'appareil précédent

**3.7.16**
**isolation**
[VOIR: 3.1.25]

**3.7.17**
**bus local**
segment d'anneau d'un réseau ayant différentes spécifications de supports et couplé à un bus distant par l'intermédiaire du coupleur de bus

**3.7.18**
**appareil de bus local**
appareil fonctionnant comme un esclave sur un bus local

**3.7.19**
**maître**
appareil qui commande le transfert de données sur le réseau et lance l'accès aux supports (au support) des esclaves en envoyant des messages et qui constitue l'interface avec le système de commande

**3.7.20**
**support**
[VOIR: 3.1.29]

**3.7.21**
**sensibilité minimale du récepteur optique**
puissance optique minimale à l'entrée du récepteur optique exigée pour obtenir un taux d'erreur binaire inférieur à $10^{-9}$ pour le système de transmission optique

**3.7.22**
**réseau**
[VOIR: 3.1.30]

**3.7.23**
**temps de décroissance optique**
[VOIR: 3.1.33]

**3.7.24**
**temps de croissance optique**
[VOIR: 3.1.35]

**3.7.25**
**interface de départ**
interface qui envoie des données à l'esclave suivant de sorte que les données qui sont reçues par l'intermédiaire de cette interface soient envoyées, par l'intermédiaire d'une autre interface de départ, à l'esclave suivant ou, par l'intermédiaire d'une interface d'arrivée, à l'esclave précédent et renvoyées au maître

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**3.7.26**
**longueur d'onde de transmission crête**
**λp**
[VOIR: 3.1.36]

**3.7.27**
**fibre optique polymère**
**POF**
guide d'onde à fibre optique en matière plastique dont les caractéristiques nominales sont compatibles avec l'IEC 60793 [type de fibre: A4a (980/1000)]

Note 1 à l'article: L'abréviation "POF" est dérivée du terme anglais développé correspondant "polymer optical fiber".

**3.7.28**
**fibre de silice gainée de plastique**
**PCS**
guide d'onde à fibre optique dont le cœur est en verre (silice) et la gaine en matière plastique et dont les caractéristiques nominales sont compatibles avec l'IEC 60793-2-30 [type de fibre: A3c (200/230 µm)]

Note 1 à l'article: L'abréviation "PCS" est dérivée du terme anglais développé correspondant "plastic clad silica fiber".

**3.7.29**
**bus distant**
segment d'anneau d'un réseau

**3.7.30**
**appareil de bus distant**
appareil fonctionnant comme esclave sur un bus distant

**3.7.31**
**liaison de bus distant**
connexion de deux appareils de bus distant

**3.7.32**
**segment d'anneau**
section de réseau

Note 1 à l'article: Le maître constitue le premier segment d'anneau et d'autres segments d'anneau peuvent être reliés par des coupleurs de bus.

**3.7.33**
**blindage**
[VOIR: 3.1.41]

**3.7.34**
**esclave**
appareil qui n'accède au support qu'après avoir été lancé par l'esclave précédent ou le maître

**3.7.35**
**largeur spectrale à mi-crête**
**Δλ**
plage de longueurs d'onde de répartition spectrale dans laquelle l'intensité énergétique est au moins égale à la moitié de l'intensité maximale

**3.7.36**
**terminateur**
[VOIR: 3.1.43]

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## 3.8 Type 12: Termes et définitions

**3.8.1**
**alimentation à 2 paires**
**2PP**
concept d'alimentation fournissant 2 canaux indépendants pour la source d'alimentation en combinaison avec Ethernet 100BASE-TX

Note 1 à l'article: Une paire est utilisée pour alimenter le dispositif lui-même, y compris les composants Ethernet et d'autres consommateurs de puissance fiables, l'autre paire étant utilisée pour alimenter les composants ou éléments externes dans le PD ayant des besoins de puissance spécifiques.

Note 2 à l'article: L'abréviation "2PP" est dérivée du terme anglais développé correspondant "2 Pair Powering".

**3.8.2**
**appareil alimenté**
**PD**
partie d'un dispositif qui extrait la puissance et connecte éventuellement au moins deux PI

Note 1 à l'article: Il s'agit d'une abstraction des éléments qui consomme de la puissance et ne contient aucun comportement fonctionnel des composants.

Note 2 à l'article: L'abréviation "PD" est dérivée du terme anglais développé correspondant "powered device".

**3.8.3**
**interface de puissance**
**PI**
connexion mécanique et électrique entre le PSE ou le PD et le support de transmission

Note 1 à l'article: Dans un PSE de point d'extrémité et un PD, la PI est englobée dans la MDI d'une liaison 100BASE-TX d'Ethernet.

Note 2 à l'article: L'abréviation "PI" est dérivée du terme anglais développé correspondant "power interface".

**3.8.4**
**équipement source d'alimentation**
**PSE**
partie de l'équipement de station d'extrémité qui alimente un PD

Note 1 à l'article: Il s'agit d'une abstraction des éléments qui fournit de la puissance et ne contient aucun comportement fonctionnel des composants. L'alimentation ETTD est destinée à fournir aux dispositifs 100BASE-TX des interfaces pour la réception et la transmission des données, ainsi que deux sources d'alimentation pour fonctionner. Un PSE est spécifié électriquement au point de connexion physique avec le câblage.

Note 2 à l'article: L'abréviation "PSE" est dérivée du terme anglais développé correspondant "power sourcing equipment".

## 3.9 Type 16: Termes et définitions

**3.9.1**
**affaiblissement**
phénomène tel que la puissance optique au récepteur est inférieure à celle à l'émetteur

**3.9.2**
**barrière**
[VOIR: 3.1.2]

**3.9.3**
**bit**
[VOIR: 3.1.3]

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**3.9.4**
**insertion binaire**
procédure par laquelle, après cinq "1" logiques, l'émetteur insère automatiquement un zéro qui est ensuite supprimé par le récepteur

Note 1 à l'article: Ce zéro entraîne une modification des fronts de signaux qui permet au récepteur de récupérer une horloge de réception.

**3.9.5**
**connecteur**
[VOIR: 3.1.7]

**3.9.6**
**équipement de transmission de données**
**DCE**
[VOIR: 3.1.9]

**3.9.7**
**équipement terminal de traitement de données**
**ETTD**
[VOIR: 3.1.10]

**3.9.8**
**dBm**
[VOIR: 3.1.11]

**3.9.9**
**délimiteur**
[VOIR: 3.1.12]

**3.9.10**
**appareil**
[VOIR: 3.1.13]

**3.9.11**
**erreur**
[VOIR: 3.1.16]

**3.9.12**
**câble à fibre optique**
[VOIR: 3.1.18]

**3.9.13**
**trame**
[VOIR: 3.1.23]

**3.9.14**
**connecteur F-SMA**
connecteur F-SMA conforme à l'IEC 61754-22

**3.9.15**
**signal de remplissage**
séquence de sept "1" suivie d'un "0"

**3.9.16**
**instabilité (gigue)**
[VOIR: 3.1.27]

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**3.9.17**
**support**
[VOIR: 3.1.29]

**3.9.18**
**réseau**
[VOIR: 3.1.30]

**3.9.19**
**nœud**
[VOIR: 3.1.31]

**3.9.20**
**non retour à zéro inversé**
**NRZI**
échange de signaux ayant lieu uniquement à des intervalles fixes et réguliers en synchronisation avec l'impulsion de l'horloge de transmission en débit binaire

Note 1 à l'article: Une modification du front de signal n'est affectée qu'à un niveau logique "0".

Note 2 à l'article: L'abréviation ''NRZI'' est dérivée du terme anglais développé correspondant ''non-return-to-ZÉRO-inverted''.

**3.9.21**
**temps de décroissance optique**
[VOIR: 3.1.33]

**3.9.22**
**temps de croissance optique**
[VOIR: 3.1.35]

**3.9.23**
**remplissage (octet de)**
séquence d'octets ajoutée pour assurer que le télégramme est suffisamment long pour un fonctionnement approprié

**3.9.24**
**longueur d'onde de transmission crête**
**λp**
[VOIR: 3.1.36]

**3.9.25**
**récepteur**
[VOIR: 3.1.37]

**3.9.26**
**répéteur**
[VOIR: 3.1.38]

**3.9.27**
**fonction répéteur**
fonction par laquelle un télégramme est reçu par un nœud et passé et resynchronisé sur le nœud suivant du réseau, tout en restant logiquement non modifié

**3.9.28**
**émetteur**
[VOIR: 3.1.45]

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**3.9.29**
**longueur d'onde type de demi-intensité**
**$\Delta\lambda$**
[VOIR: 3.1.47]

**3.9.30**
**flux zéro bit**
séquence de zéros logiques qui, en codage NRZI, entraîne une modification périodique du front de signal sur la ligne de transmission (utilisée uniquement en mode d'essai)

### 3.10 Type 18: Termes et définitions

**3.10.1**
**activité**
[VOIR: 3.1.1]

**3.10.2**
**bit**
[VOIR: 3.1.3]

**3.10.3**
**bus**
[VOIR: 3.1.4]

**3.10.4**
**élément de communication**
[VOIR: 3.1.6]

**3.10.5**
**connecteur**
[VOIR: 3.1.7]

**3.10.6**
**équipement de transmission de données**
**DCE**
[VOIR: 3.1.9]

**3.10.7**
**équipement terminal de traitement de données**
**ETTD**
[VOIR: 3.1.10]

**3.10.8**
**appareil**
[VOIR: 3.1.13]

**3.10.9**
**erreur**
[VOIR: 3.1.16]

**3.10.10**
**isolation**
[VOIR: 3.1.25]

**3.10.11**
**support**
[VOIR: 3.1.29]

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**3.10.12**
**réseau**
[VOIR: 3.1.30]

**3.10.13**
**nœud**
[VOIR: 3.1.31]

**3.10.14**
**récepteur**
[VOIR: 3.1.37]

**3.10.15**
**segment**
[VOIR: 3.1.39]

**3.10.16**
**blindage**
[VOIR: 3.1.41]

**3.10.17**
**ligne secondaire**
[VOIR: 3.1.42]

**3.10.18**
**station**
appareil de réseau matérialisant un nœud

**3.10.19**
**terminateur**
[VOIR: 3.1.43]

**3.10.20**
**émetteur-récepteur**
[VOIR: 3.1.44]

**3.10.21**
**émetteur**
[VOIR: 3.1.45]

**3.10.22**
**ligne principale**
[VOIR: 3.1.46]

### 3.11 Type 24: Termes et définitions

**3.11.1**
**bit**
[VOIR: 3.1.3]

**3.11.2**
**bus**
[VOIR: 3.1.4]

**3.11.3**
**élément de communication**
[VOIR: 3.1.6]

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**3.11.4**
**connecteur**
[VOIR: 3.1.7]

**3.11.5**
**équipement de transmission de données**
**DCE**
[VOIR: 3.1.9]

**3.11.6**
**délimiteur**
[VOIR: 3.1.12]

**3.11.7**
**appareil**
[VOIR: 3.1.13]

**3.11.8**
**erreur**
[VOIR: 3.1.16]

**3.11.9**
**trame**
[VOIR: 3.1.23]

**3.11.10**
**isolation**
[VOIR: 3.1.25]

**3.11.11**
**isolateur**
parties pour l'isolation du signal par des éléments inductifs ou capacitifs

**3.11.12**
**codage Manchester**
[VOIR: 3.1.28]

**3.11.13**
**support**
[VOIR: 3.1.29]

**3.11.14**
**réseau**
[VOIR: 3.1.30]

**3.11.15**
**nœud**
[VOIR: 3.1.31]

**3.11.16**
**photocoupleur**
parties pour l'isolation du signal par des éléments optiques

**3.11.17**
**répéteur**
[VOIR: 3.1.38]

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**3.11.18**
**blindage**
[VOIR: 3.1.41]

**3.11.19**
**terminateur**
[VOIR: 3.1.43]

**3.11.20**
**émetteur-récepteur**
[VOIR: 3.1.44]

**3.11.21**
**émetteur**
[VOIR: 3.1.45]

### 3.12 Type 20: Termes et définitions

**3.12.1**
**signal analogique**
courant basse fréquence, avec signal prédominant de 4 mA à 20 mA envoyé ou provenant d'un appareil de terrain

**3.12.2**
**spectre de signal analogique**
fréquences de 0 Hz à 25 Hz à amplitude unitaire et décroissant à 40 dB par décade au-dessus de 25 Hz

**3.12.3**
**filtre d'essai analogique**
filtre passe-bas bipolaire de Butterworth avec fréquence de coupure de 25 Hz

**3.12.4**
**barrière**
entité physique qui limite le courant et la tension dans une zone dangereuse afin de satisfaire aux exigences de sécurité intrinsèque

**3.12.5**
**capacité linéique du câble**
capacité linéique du câble, mesurée à 1 kHz à partir d'un conducteur autre que le blindage jusqu'à tous les autres conducteurs y compris le blindage

Note 1 à l'article: Pour les réseaux comprenant plus d'un type ou d'un calibre de câble, la plus grande valeur de capacité de tout type ou tout calibre de câble est utilisée pour déterminer cette valeur.

**3.12.6**
**caractère**
8 bits de données et bits supplémentaires qui sont transmis en tant qu'unité continue par le PhE

**3.12.7**
**délai de caractère**
durée exigée pour la transmission d'un caractère

**3.12.8**
**résistance de détection du courant**
résistance utilisée pour convertir un signal de courant analogique en signal de tension

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**3.12.9**
**distorsion de temps de propagation**
écart entre le temps de retard de propagation d'ondes sinusoïdales de différentes fréquences en cas d'observation du retard dans un réseau ou circuit

**3.12.10**
**appareil**
toute entité contenant une mise en application du présent document

**3.12.11**
**signal numérique**
communication des informations à l'aide du signal de modulation par déplacement de fréquence de 1 200 bits par seconde

**3.12.12**
**bande de fréquences numérique**
plage de fréquences comprise entre 950 Hz et 2 500 Hz qui est utilisée pour le signal numérique

**3.12.13**
**spectre de signal numérique**
fréquences de 500 Hz à 10 kHz à amplitude unitaire, décroissant à 40 dB par décade en dessous de 500 Hz et décroissant à 20 dB par décade au-dessus de 10 kHz

**3.12.14**
**bande de fréquences étendue**
plage de fréquences de 500 Hz à 10 kHz

Note 1 à l'article: Cette bande de fréquences est composée d'une bande de fréquences numérique et d'une bande de garde.

**3.12.15**
**appareil de terrain**
entité physique qui est connectée au matériel de processus ou de production et qui a au moins un élément de signalisation qui communique avec l'autre ou les autres éléments de signalisation par un câble

Note 1 à l'article: L'appareil de terrain relie directement le détecteur ou l'actionneur ou exécute la fonction de commande de processus, et il est directement connecté à la couche physique spécifiée dans le présent document. Il peut générer ou recevoir un signal analogique en plus d'un signal numérique.

**3.12.16**
**masse**
surface de la terre ou des conduits ou canalisations qui sont connectés, ou le bus de raccordement de sécurité ou le rail de zéro volt sur lequel les barrières sont connectées

Note 1 à l'article: La masse peut être ou peut ne pas être la même en tant qu'alimentation commune réseau.

**3.12.17**
**sécurité intrinsèque**
méthodologie de conception d'un circuit ou d'un ensemble de circuits dans lequel toute étincelle ou tout effet thermique produit dans des conditions normales de fonctionnement et des conditions de défaut spécifiées, est incapable, dans des conditions d'essai prescrites, de provoquer l'inflammation d'une atmosphère explosive donnée

**3.12.18**
**jonction**
toute jonction de fil de deux câbles ou tout point de contact d'un autre câble ou d'un appareil de terrain vers un câble existant

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**3.12.19**
**réseau multipoints**
réseau avec plus d'un appareil esclave connecté à un réseau

**3.12.20**
**alimentation réseau**
source fournissant une puissance de fonctionnement directement à un réseau

**3.12.21**
**résistance du réseau**
résistance ou partie réelle de l'impédance d'un réseau

Note 1 à l'article: Elle est calculée comme impédance équivalente de tous les appareils connectés en parallèle sur le réseau. Par conséquent, elle est généralement dominée par un appareil à faible impédance.

**3.12.22**
**élément sans signalisation**
entité physique ou élément n'utilisant pas ou ne produisant pas de signaux analogique ou numérique

Note 1 à l'article: Une alimentation réseau constitue un exemple d'élément sans signalisation.

**3.12.23**
**réseau point à point**
réseau équipé d'un appareil esclave uniquement et d'un ou aucun appareil maître

Note 1 à l'article: Il n'est pas nécessaire que le réseau point à point soit équipé d'un appareil maître. Cette situation peut se produire, par exemple, dans le cas où seul un contrôleur analogique est utilisé, le seul appareil de terrain ayant été programmé par un maître secondaire qui a ensuite été déconnecté.

**3.12.24**
**élément de signalisation**
entité physique ou élément utilisant ou produisant un signal numérique

Note 1 à l'article: L'entité qui produit ou utilise uniquement un signal analogique n'entre pas dans le cadre de cette définition; l'entité qui utilise/produit uniquement un signal numérique et non pas un signal analogique entre dans le cadre de cette définition.

**3.12.25**
**silence**
état du réseau en cas d'absence de signal numérique

**3.12.26**
**début de message**
préambule de l'unité de données de protocole de la couche physique suivi par le délimiteur de l'unité de données de protocole de couche liaison de données sans aucune erreur de réception et distance entre les caractères

### 3.13 Type 28: Termes et définitions

**3.13.1**
**mode de porteuse**
mode de transfert de données sur des ressources disponibles composées de symboles OFDM

**3.13.2**
**synchronisation d'horloge**
étalonnage d'horloge de l'appareil de nœud terminal

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**3.13.3**
**bloc de code**
séquence d'octets d'interaction de données entre l'entité de couche physique de Type 28 et l'entité de couche de liaison de données de Type 28

**3.13.4**
**dispositif de commande**
appareil qui commande tous les appareils de terrain pour les opérations logiques, la synchronisation, les calculs, etc.

**3.13.5**
**trame cyclique**
trames de signal traitées d'une manière répétitive régulière

**3.13.6**
**symbole cyclique**
symboles OFDM dans les trames de signal, traités d'une manière répétitive régulière

**3.13.7**
**mi-bande latérale**
bande latérale supérieure ou bande latérale inférieure d'un symbole OFDM

**3.13.8**
**bande latérale inférieure**
sous-porteuses dont la plage de fréquences est comprise entre 1,536 MHz et 16,896 MHz d'un symbole OFDM

**3.13.9**
**nœud de gestion**
appareil qui attribue et gère les ressources de communication physique de réseau de Type 28

**3.13.10**
**symbole de multiplexage par répartition orthogonale des fréquences (OFDM)**
unité minimale de transmission de données dans le domaine temporel qui contient toutes les sous-porteuses de la fréquence en fonction de la technologie OFDM

Note 1 à l'article: L'abréviation ''OFDM'' est dérivée du terme anglais développé correspondant ''orthogonal frequency division multiplexing''.

**3.13.11**
**nœud terminal**
appareil du réseau de Type 28 qui communique en fonction des ressources de communication physiques allouées

**3.13.12**
**à deux fils non ponté**
appareils reliés par des supports physiques avec deux fils, sans être reliés par l'intermédiaire d'un appareil de pontage

**3.13.13**
**bande latérale supérieure**
sous-porteuses dont la plage de fréquences est comprise entre 16,896 MHz et 32,256 MHz d'un symbole OFDM

**3.13.14**
**mode de fonctionnement**
fonctionnement OFDM dans un mode de transmission, code RS, code de convolution et mode de modulation spécifiques

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# 4 Symboles et abréviations

## 4.1 Symboles

### 4.1.1 Type 1: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| $A_{max}$ | Affaiblissement maximal entre appareils | dB |
| $AD_{max}$ | Distorsion d'affaiblissement maximal entre appareils | dB |
| BR | Débit binaire nominal | Mbit/s |
| $\Delta$BR | Écart maximal par rapport à BR | - |
| $CS_{max}$ | Espacement maximal des coupleurs pour former une grappe | m |
| $Din_{min}$ | Impédance d'entrée minimale d'un appareil | kΩ |
| dBm | Unité logarithmique de puissance référencée à 1 mW | dB(mW) |
| $F_c$ | Fréquence centrale de porteuse utilisée en modulation par déplacement de fréquence | kHz |
| $F_{c+f}$ | Fréquence qui correspond au niveau logique 1 en modulation par déplacement de fréquence | kHz |
| $F_{c-f}$ | Fréquence qui correspond au niveau logique 0 en modulation par déplacement de fréquence | kHz |
| $f_r$ | Fréquence correspondant au débit binaire nominal | MHz |
| $f_{min}$ | Fréquence nominale minimale pour le débit binaire nominal | MHz |
| $f_{max}$ | Fréquence nominale maximale pour le débit binaire nominal | MHz |
| $fQTO_{max}$ | Fréquence maximale pour le mesurage de QTOmax | MHz |
| $L_{max}$ | Distance maximale entre appareils | m |
| $MD_{max}$ | Distorsion de désadaptation maximale entre appareils | dB |
| N+ | Symbole non données – positif; Signal codé Manchester à niveau haut pour un temps binaire, utilisé pour des délimiteurs et ne transportant aucune donnée | - |
| N- | Symbole non données – négatif; Signal codé Manchester à niveau bas pour un temps binaire, utilisé pour des délimiteurs et ne transportant aucune donnée | - |
| $N_{max}$ | Nombre maximal d'appareils | - |
| P | Période nominale de transmission d'octets | s |
| PICS | Déclaration de conformité d'une instance de protocole | - |
| $QTO_{max}$ | Sortie maximale d'émetteur passif | mV |
| Tbit | Durée binaire nominale | µs |
| $\Delta T_{bit}$ | Écart maximal par rapport à Tbit | - |
| $T_{rf}$ | Temps de croissance ou de décroissance de signal maximal | ns |
| $V_{DD}$ | Le niveau d'alimentation le plus positif (ou le moins négatif) | V |
| $V_{IH}$ | Tension d'entrée de niveau haut minimale | V |
| $V_{IL}$ | Tension d'entrée de niveau bas maximale | V |
| $V_{OH}$ | Tension de sortie de niveau haut minimale | V |
| $V_{OL}$ | Tension de sortie de niveau bas maximale | V |

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| Symbole | Définition | Unité |
|---|---|---|
| Z | Impédance; somme vectorielle de la résistance et de réactance (inductive ou capacitive) | Ω |
| $Zf_r$ | Impédance caractéristique; impédance d'un câble, et de ses terminateurs, à la fréquence fr | Ω |
| $Z_o$ | Impédance caractéristique, impédance d'un câble, et de ses terminateurs, sur la plage de fréquences définie | Ω |

### 4.1.2 Type 2: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| dBm | Unité logarithmique de puissance référencée à 1 mW | dB (mW) |
| $f_r$ | Fréquence correspondant au débit binaire | Hz |
| GND | Niveau masse de référence de l'alimentation | V |
| H | Symbole physique – niveau haut | - |
| L | Symbole physique – niveau bas | - |
| M_0 | Contrôle d'accès au support – symbole de données – "zéro";<br>Symbole à l'interface DL-Ph, représentant le signal codé Manchester émis et reçu, à niveau haut pendant un demi temps binaire et à un niveau bas pendant un demi temps binaire, transportant des données "zéro" | - |
| M_1 | Contrôle d'accès au support – symbole de données – "un";<br>Symbole à l'interface DL-Ph, représentant le signal codé Manchester émis et reçu, à un niveau bas pendant un demi temps binaire et à un niveau haut pendant un demi temps binaire, transportant des données "un" | - |
| M_ND+ | Contrôle d'accès au support – symbole non données – positif;<br>Symbole à l'interface DL-Ph, représentant le signal codé Manchester émis et reçu, à un niveau haut pendant un temps binaire complet, utilisé pour des délimiteurs et ne transportant aucune donnée | - |
| M_ND- | Contrôle d'accès au support – symbole non données – négatif;<br>Symbole à l'interface DL-Ph, représentant le signal codé Manchester émis et reçu, à un niveau bas pendant un temps binaire complet, utilisé pour des délimiteurs et ne transportant aucune donnée | - |
| Rx_H | Réception – niveau haut (interface NAP) | V |
| Rx_L | Réception – niveau bas (interface NAP) | V |
| Tx_H | Émission – niveau haut (interface NAP) | V |
| Tx_L | Émission – niveau bas (interface NAP) | V |
| $V_{in}$ | Tension sur le conducteur central du câble coaxial ($V_{in}$+ ou $V_{in}$–) référencée au blindage coaxial | V |
| $V_{sense}$+ | Limite positive de sensibilité des données | V |
| $V_{sense}$- | Limite négative de sensibilité des données | V |
| $V_{sense}$H | Limite haute de sensibilité de la porteuse | V |
| $V_{sense}$L | Limite basse de sensibilité de la porteuse | V |

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### 4.1.3 Type 3: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| dBm | Unité logarithmique de puissance référencée à 1 mW | dB (mW) |
| fr | Fréquence correspondant au débit binaire | Hz, kHz, MHz |
| N- | Symbole non données – négatif; Signal codé Manchester à niveau bas pour un temps binaire, utilisé pour des délimiteurs et ne transportant aucune donnée | - |
| N+ | Symbole non données – positif; Signal codé Manchester à niveau haut pour un temps binaire, utilisé pour des délimiteurs et ne transportant aucune donnée | - |
| P | Période nominale de transmission d'octets | s |
| $R_d$ | Résistance de polarisation à la masse | Ω |
| $R_t$ | Terminateur de bus | Ω |
| $R_u$ | Résistance de polarisation à l'alimentation | Ω |
| SYN | Bits de synchronisation d'une trame (période de repos) | s |
| $t_{BIT}$ | Le temps binaire tBIT est la durée qui s'écoule pendant l'émission d'un bit. | s |
| $T_{SBIT}$ | Tolérance élargie (uniquement pour le bit d'arrêt) | s |
| $T_{SYN}$ | Temps de synchronisation | s |
| $T_{SYNI}$ | Temps d'intervalle de synchronisation | s |
| $V_{DD}$ | Le niveau d'alimentation le plus positif (ou le moins négatif) | V |
| $V_{IH}$ | Tension d'entrée de niveau haut minimale | V |
| Vil | Tension d'entrée de niveau bas maximale | V |
| Voh | Tension de sortie de niveau haut minimale | V |
| Vol | Tension de sortie de niveau bas maximale | V |
| VP | Plus de la Tension | V |
| Z | Impédance; somme vectorielle de la résistance et de réactance (inductive ou capacitive) | Ω |
| $Z_O$ | Impédance caractéristique, impédance d'un câble, et de ses terminateurs, sur la plage de fréquences définie | Ω |

### 4.1.4 Type 4: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| $V_{CC}$ | Le niveau d'alimentation le plus positif (ou le moins négatif) | V |
| GND | Niveau masse de référence de l'alimentation | V |

### 4.1.5 Vide

NOTE Dans la présente édition, le 4.1.5 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

### 4.1.6 Type 8: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| dBm | Unité logarithmique de puissance référencée à 1 mW | dB (mW) |
| fr | Fréquence correspondant au débit binaire | Hz |
| $V_{DD}$ | Le niveau d'alimentation le plus positif (ou le moins négatif) | V |
| GND | Niveau masse de référence de l'alimentation | V |

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### 4.1.7 Type 12: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| dB | Décibel, unité logarithmique (base 10) utilisée pour exprimer le rapport de puissance entre un signal d'envoi et un signal de réception | - |

### 4.1.8 Type 16: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| j | Instabilité (gigue) | µs |
| $J_{noise}$ | Instabilité du signal optique | µs |
| $J_{t2}$ | Instabilité de $t_2$ | µs |
| $J_{tscyc}$ | Instabilité de $t_{Scyc}$ | µs |
| $P$ | Puissance | dBm ou µW |
| $P_{RmaxH}$ | Puissance maximale reçue à un niveau haut optique | dBm ou µW |
| $P_{RmaxL}$ | Puissance maximale reçue à un niveau bas optique | dBm ou µW |
| $P_{RminH}$ | Puissance minimale reçue à un niveau haut optique | dBm ou µW |
| $P_{TmaxH}$ | Puissance de transmission maximale à un niveau haut optique | dBm ou µW |
| $P_{TmaxL}$ | Puissance de transmission maximale à un niveau bas optique | dBm ou µW |
| $P_{TminH}$ | Puissance de transmission minimale à un niveau haut optique | dBm ou µW |
| $P_X$ | Seuil de puissance | dBm ou µW |
| $t_{cable}$ | Durée de retard du signal transmis, dû au câble, pour chaque unité de longueur (environ 5 ns/m) | ns |
| $t_{fri}$ | Temps pour le niveau optique faible à l'entrée d'un esclave | ns |
| $t_{fro}$ | Temps pour le niveau optique faible à la sortie d'un esclave | ns |
| $t_{rep}$ | Temps de retard du signal reçu, dû à un esclave d'acheminement (entrée-sortie) | ns |
| $t_{ring}$ | Temps nécessaire à un télégramme du maître pour passer à travers tout le réseau et revenir de nouveau au maître | µs |
| $t_{RPAT}$ | Temps de transition maximal dans un esclave pour passer de la fonction répéteur à la fonction émetteur de l'AT | µs |
| $t_{RPAT.2}$ | Temps de transition maximal dans l'esclave 2 pour passer de la fonction répéteur à la fonction émetteur de l'AT | µs |

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### 4.1.9 Type 18: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| $V_{DD}$ | Tension fournie aux composantes logiques numériques de puissance | V |
| $V_{OL}$ | Tension de sortie, niveau bas | V |
| $V_{OH}$ | Tension de sortie, niveau haut | V |
| $V_{IL}$ | Tension d'entrée, niveau bas | V |
| $V_{IH}$ | Tension d'entrée, niveau haut | V |

### 4.1.10 Type 24: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| GND | Niveau masse de référence de l'alimentation | V |
| H | Symbole physique – niveau haut | - |
| L | Symbole physique – niveau bas | - |
| DL_Symbols | représentation des bits de données DL à coder et à émettre par la couche physique | - |
| Ph_Symbols | représentation des bits de données qui doivent être codés par le contrôle d'accès au support (MAC – *Medium Access Control*) et qui doivent être émis par la couche physique | - |
| $V_{DD}$ | Le niveau d'alimentation le plus positif | V |

### 4.1.11 Type 20: Symboles

| Symbole | Définition |
|---|---|
| $C_{cbl}$ | Capacité linéique du câble |
| $C_{dev}$ | Capacité d'appareil équivalent |
| $C_{tg}$ | Capacité de borne à terre |
| $C_{tt}$ | Capacité de borne à borne |
| HOLD | Temps de maintien |
| $R_{cbl}$ | Capacité linéique de résistance de câble |
| $R_{dev}$ | Capacité d'appareil équivalent |
| Rp | Résistance parallèle du réseau |
| RT1 | Temps de silence de liaison |
| RT2 | Temps d'autorisation de liaison |
| $R_{tg}$ | Résistance borne à terre |
| $R_{tt}$ | Résistance borne à borne |
| STO | Expiration de délai esclave |
| $Z_{tt}$ | Impédance borne à borne |

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### 4.1.12 Type 28: Symboles

| Symbole | Définition | Unité |
|---|---|---|
| $T_S$ | Intervalle d'échantillonnage | ns |
| $N_{CBIB}$ | Longueur de bloc d'entrelacement de bits | - |
| $N_{COL}$ | Numéro de colonne d'entrelacement de bits | - |
| $N_{BPS}$ | Nombre de bits de symbole d'entrelacement de bits | - |
| $N_{SD}$ | Nombre de sous-porteuses d'un symbole OFDM | - |
| $N_{SYM}$ | Nombre de symboles OFDM d'une trame de signal | - |

## 4.2 Abréviations

### 4.2.1 Type 1: Abréviations

CTS (Clear-to-send signal) signal "Prêt à émettre" (du DCE)

DCE Data Communication Equipment) équipement de transmission de données

DIS (DCE Independent Sublayer) sous-couche indépendante du DCE

DL (Data-link) Liaison de données (utilisée comme préfixe) [ISO/IEC 7498-1]

DLE (Data-Link Entity) entité de liaison de données

DLL (Data-Link Layer) couche liaison de données [ISO/IEC 7498-1]

ETTD équipement terminal de traitement de données

EMI (Electro-magnetic Interference) brouillage électromagnétique

IDU (Interface Data Unit) unité de données d'interface [ISO/IEC 7498-1]

IS (Intrinsic Safety) sécurité intrinsèque

LbE (Loopback-Enable Signal) signal d'activation du rebouclage (vers MAU)

MAU (Medium attachment unit) unité de liaison au support (pour les supports câblés, MAU = émetteur-récepteur)

MDS (Medium Dependent Sublayer) sous-couche dépendante du support

min o/p (Minimum output voltage peak-to-peak) tension minimale de sortie crête à crête

MIS (Media Independent Sublayer) sous-couche indépendante des supports

NRZ (Non-Return-to-ZÉRO code) code de non retour à zéro

NOTE Niveau haut = 1 logique, niveau bas = 0 logique.

Ph Physique (utilisée comme préfixe)[ISO/IEC 7498-1]

PhE (Physical layer entity) entité de couche physique [ISO/IEC 7498-1]

PhL (Physical layer) couche physique [ISO/IEC 7498-1]

PhICI (Physical layer interface control information) informations de commande d'interface de couche physique [ISO/IEC 7498-1]

PhID (Physical layer interface data) données d'interface de couche physique [ISO/IEC 7498-1]

PhIDU (Physical layer interface data unit) unité de données d'interface de couche physique [ISO/IEC 7498-1]

PhPCI (Physical layer protocol control information) informations de commande de protocole de couche physique [ISO/IEC 7498-1]

PhPDU (Physical layer protocol data unit) unité (ensemble) de données de protocole de couche physique [ISO/IEC 7498-1]

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PhS (Physical layer service) service de couche physique [ISO/IEC 7498-1]

PhSAP (Physical layer service access point) point d'accès de service de couche physique [ISO/IEC 7498-1]

PhSDU (Physical layer service data unit) unité (ensemble) de données de service de couche physique [ISO/IEC 7498-1]

Pk (Peak) crête

pk-pk (Peak-to-peak) crête à crête

RDF (Receive-Data-and-Framing signal) signal de réception de données et de verrouillage de trame (du DCE)

RFI (Radio Frequency Interference) brouillage radioélectrique

RTS (Request-To-Send signal) signal "Demande pour émettre" (vers le DCE)

RxA Signal d'activité de réception (du DCE)

RxC Signal d'horloge de réception (du DCE)

RxS Signal de réception (de la MAU)

SDU (Service data unit) unité (ensemble) de données de service [ISO/IEC 7498-1]

TxC Signal d'horloge de transmission (du DCE)

TxD Signal de données de transmission (vers DCE)

TxE (Transmit -enable signal) signal d'activation de la transmission (vers MAU)

TxS Signal de transmission (vers MAU)

### 4.2.2 Type 2: Abréviations

BNC (Bayonet Neill Concelman) Connecteur pour câble coaxial ayant une enveloppe de type à baïonnette avec deux petits boutons sur le clip qui s'enclenchent dans les rainures spiralées du connecteur mâle lorsqu'il est tourné [IEC 61169–8]

DCE (Data Communication Equipment) équipement de transmission de données

DL (Data-link) Liaison de données (utilisée comme préfixe) [ISO/IEC 7498-1]

DLL (Data-Link Layer) couche liaison de données [ISO/IEC 7498-1]

MAC (Medium access control) contrôle d'accès au support (section de niveau inférieur de la couche liaison de données en interface avec la couche physique)

MAC ID (Medium access control identification) identification du contrôle d'accès au support – adresse d'un nœud

MAU (Medium attachment unit) unité de liaison au support (pour les supports câblés, MAU = émetteur-récepteur)

MDS (Medium Dependent Sublayer) sous-couche dépendante du support

MIS (Media Independent Sublayer) sous-couche indépendante des supports

NAP (Network Access Port) port d'accès au réseau (accès local à un appareil, c'est-à-dire non par l'intermédiaire du bus)

NetEnable Signal d'activation de transmission

NUT (Network Update Time) temps de mise à jour du réseau [IEC 61158-4-2]

Ph Physique (utilisée comme préfixe)[ISO/IEC 7498-1]

PhL (Physical layer) couche physique [ISO/IEC 7498-1]

Pk (Peak) crête

Rcv Récepteur

Rx Récepteur

RxCarrier Signal de porteuse de réception

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| | |
|---|---|
| RxData | Signal de données de réception |
| RxPTC | Signal de données de réception (interface NAP) |
| RM | (Repeater Machine) machine répéteur (mécanisme d'extension de la longueur du bus, fournissant de multiples interfaces de supports, et permettant la redondance des supports) |
| RRM | (Ring Repeater Machine) machine répéteur d'anneau (mécanisme fournissant une topologie annulaire sur support optique) |
| SMAX | (Scheduled maximum address) adresse maximale planifiée [IEC 61158-4-2] |
| TNC | Threaded Neill Concelman (version filetée du connecteur BNC) [IEC 60169–17] |
| Tx | Transmettre |
| TxDataBar | Signal de données de transmission (inversé) |
| TxDataOut | Signal de données de transmission |
| TxPTC | Signal de données de transmission (interface NAP) |
| Xmit | Transmettre |

#### 4.2.3 Type 3: Abréviations

| | |
|---|---|
| ASC | (Active star coupler) coupleur en étoile actif |
| BER | (Bit error rate) taux d'erreurs sur les bits |
| CO | Convertisseur |
| CTS | (Clear-to-send signal) signal "Prêt à émettre" (du DCE) |
| DCE | (Data Communication Equipment) équipement de transmission de données |
| DGND | (Data ground) masse de référence des données |
| DIS | (DCE Independent Sublayer) sous-couche indépendante du DCE |
| DL | (Data-link) liaison de données (utilisée comme préfixe) |
| DLE | (Data-Link Entity) entité de liaison de données |
| DLL | (Data-Link Layer) couche liaison de données [ISO/IEC 7498-1] |
| DLPDU | (Data-link protocol data unit) ensemble (unité) de données de protocole de liaison de données [ISO/IEC 7498-1] |
| ETTD | équipement terminal de traitement de données |
| DUT | (Device under test) appareil en essai |
| CEM | Compatibilité électromagnétique |
| EMI | (Electro-magnetic Interference) brouillage électromagnétique |
| FEC | (Forward error correction) correction d'erreurs sans voie de retour |
| FISCO | (Fieldbus intrinsically safe concept) concept de bus de terrain de sécurité intrinsèque |
| FO | Fibre optique |
| FOC | (Fiber optic cable) câble à fibre optique |
| IS | (Intrinsic Safety) sécurité intrinsèque |
| LbE | (Loopback Enable Signal) signal d'activation du rebouclage (vers MAU) |
| LSS | (Line selector switch) sélecteur de ligne |
| M/S | (Master / slave station) station maître / esclave |
| MAU | (Medium attachment unit) unité de liaison au support (pour les supports câblés, MAU = émetteur-récepteur) |
| MDS | (Medium Dependent Sublayer) sous-couche dépendante du support |

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| | |
|---|---|
| MIS | (Media Independent Sublayer) sous-couche indépendante des supports |
| N | Numéro d'une station |
| NRZ | (Non-Return-to-ZÉRO code) code de non retour à zéro |

NOTE Niveau haut = 1 logique, niveau bas = 0 logique.

| | |
|---|---|
| OST | (Overshot of transition) dépassement de transition |
| PC | (Physical contact) contact physique |
| Ph | Physique (utilisée comme préfixe) |
| Ph-ASYN-DATA | Service de données physique pour transmission asynchrone |
| PhE | (Physical layer entity) entité de couche physique [ISO/IEC 7498-1] |
| PhICI | (Physical layer interface control information) informations de commande d'interface de couche physique [ISO/IEC 7498-1] |
| PhID | (Physical layer interface data) données d'interface de couche physique [ISO/IEC 7498-1] |
| PhIDU | (Physical layer interface data unit) unité de données d'interface de couche physique [ISO/IEC 7498-1] |
| PhL | (Physical layer) couche physique [ISO/IEC 7498-1] |
| PhM | (Ph-Management) gestion Ph |
| PhMS | (Ph-management service) service de gestion Ph |
| PhPCI | (Physical layer protocol control information) informations de commande de protocole de couche physique [ISO/IEC 7498-1] |
| PhPDU | (Physical layer protocol data unit) unité (ensemble) de données de protocole de couche physique [ISO/IEC 7498-1] |
| PhS | (Physical layer service) service de couche physique [ISO/IEC 7498-1] |
| PhSAP | (Physical layer service access point) point d'accès de service de couche physique [ISO/IEC 7498-1] |
| PhSDU | (Physical layer service data unit) unité (ensemble) de données de service de couche physique [ISO/IEC 7498-1] |
| pk-pk | (Peak-to-peak) crête à crête |
| RDF | (Receive-Data-and-Framing signal) signal de réception de données et de verrouillage de trame (du DCE) |
| REP | Répéteur |
| RFI | (Radio Frequency Interference) brouillage radioélectrique |
| RS 485 | TIA-RS485-A:1998 |
| RTS | (Request-To-Send signal) signal "Demande pour émettre" (vers le DCE) |
| RxA | Signal d'activité de réception (du DCE) |
| RxC | Signal d'horloge de réception (du DCE) |
| RxS | Signal de réception (de la MAU) |
| Stn | Stations (maître ou esclave) |
| TPC | (Twisted-pair cable) câble à paire torsadée |
| TxC | Signal d'horloge de transmission (du DCE) |
| TxD | Signal de données de transmission (vers DCE) |
| TxE | (Transmit -enable signal) signal d'activation de la transmission (vers MAU) |
| TxS | Signal de transmission (vers MAU) |
| UART | (Universal asynchronous receiver/transmitter) émetteur-récepteur asynchrone universel |

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### 4.2.4 Type 4: Abréviations

CTS (Clear-to-send signal) signal "Prêt à émettre" (du DCE)

DCE (Data Communication Equipment) équipement de transmission de données

DL (Data-link) Liaison de données (utilisée comme préfixe) [ISO/IEC 7498-1]

DLE (Data-Link Entity) entité de liaison de données

DLL (Data-Link Layer) couche liaison de données [ISO/IEC 7498-1]

ETTD équipement terminal de traitement de données

MAU (Medium attachment unit) unité de liaison au support (pour les supports câblés, MAU = émetteur-récepteur)

MDS (Medium Dependent Sublayer) sous-couche dépendante du support

MIS (Media Independent Sublayer) sous-couche indépendante des supports

NRZ (Non-Return-to-ZÉRO code) code de non retour à zéro

NOTE Niveau haut = 1 logique, niveau bas = 0 logique.

Ph Physique (utilisée comme préfixe)[ISO/IEC 7498-1]

PhE (Physical layer entity) entité de couche physique [ISO/IEC 7498-1]

PhL (Physical layer) couche physique [ISO/IEC 7498-1]

PhID (Physical layer interface data) données d'interface de couche physique [ISO/IEC 7498-1]

PhPDU (Physical layer protocol data unit) unité (ensemble) de données de protocole de couche physique [ISO/IEC 7498-1]

RS-485 TIA-RS485-A:1998

RTS (Request-To-Send signal) signal "Demande pour émettre" (vers le DCE)

RxS Signal de réception (de la MAU)

TxE (Transmit -enable signal) signal d'activation de la transmission (vers MAU)

TxS Signal de transmission (vers MAU)

### 4.2.5 Vide

NOTE Dans la présente édition, le 4.2.5 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

### 4.2.6 Type 8: Abréviations

BC (Bus connector) connecteur de bus

BLL (Basic link layer) couche de liaison basique

BSY (Busy) occupé

CPIC (Cable plant interface connector) Connecteur d'interface de canalisation de câbles

CRC (Cyclic redundancy check) contrôle de redondance cyclique

CTS (Clear-to-send) prêt à émettre

DL (Data-link) Liaison de données (utilisée comme préfixe) [ISO/IEC 7498-1]

DLL (Data-Link Layer) couche liaison de données [ISO/IEC 7498-1]

DI (Data In) données entrantes

DLPDU (Data-link process data unit) unité (ensemble) de données de processus de liaison de données

DO (Data out) données sortantes

DS (Data select) sélection de données

GND (Ground) Masse

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ICI (Interface control information) informations de commande d'interface

| | |
|---|---|
| ID | Identifiant |
| LbE | (Loopback enable) activation du rebouclage |
| LSB | (Least significant byte) octet de poids faible |
| MA | (Medium activity) activité du support |
| MAC | (Medium access control) contrôle d'accès au support |
| MAU | (Medium attachment unit) unité de liaison au support |
| MDS | (Medium Dependent Sublayer) sous-couche dépendante du support |
| MIS | (Media Independent Sublayer) sous-couche indépendante des supports |
| MSB | (Most significant bit) bit de poids fort |
| NRZ | (Non-Return-to-ZÉRO) non retour à zéro |
| PCS | (Plastic-clad silica fiber) fibre de silice gainée de plastique |
| Ph | Physique (utilisée comme préfixe)[ISO/IEC 7498-1] |
| PhE | (Physical layer entity) entité de couche physique [ISO/IEC 7498-1] |
| PhICI | (Physical interface control information) informations de commande d'interface de couche physique |
| PhIDU | (Physical interface data unit) unité de données d'interface de couche physique |
| PhL | (Physical layer) couche physique [ISO/IEC 7498-1] |
| PhPDU | (Physical protocol data unit) unité (ensemble) de données de protocole de couche physique |
| PhSDU | (Physical service data unit) unité (ensemble) de données de service de couche physique |
| PNM1 | (Peripherals network management of layer 1) gestion de réseau de périphériques de couche 1 |
| POF | (Polymer optical fiber) Fibre optique polymère |
| RI | (Reset-in) réinitialisation-entrée |
| RO | (Reset-out) réinitialisation-sortie |
| RqDly | (Request delay 1) délai de demande 1 |
| RqDly2 | (Request delay 2) délai de demande 1 |
| RTS | (Request-to-send) demande pour émettre |
| RxA | Activité de réception |
| RxC | Horloge de réception |
| RxCR | Ligne de commande de réception |
| RxD | Données de réception |
| RxS | Séquence de réception |
| RxSL | Ligne de sélection de réception |
| SL | (Select line) ligne de sélection |
| TRst | Codage et décodage (du PhPDU de réinitialisation) |
| TxC | Horloge de transmission |
| TxCR | Ligne de commande de transmission |
| TxD | Données de transmission |
| TxS | Séquence de transmission |
| TxSL | Ligne de sélection de transmission |

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### 4.2.7 Type 12: Abréviations

2PP Puissance deux paires

AWG (American Wire Gauge) calibre AWG

DCE (Data Circuit-terminating Equipment) équipement de terminaison de circuit de données

ETTD Équipement terminal de traitement de données

M8P Connecteur selon l'IEC 61076-2-114, codage P

MDI (Medium Dependant Interface) interface dépendante du support [ISO/IEC/IEEE 8802-3]

PD (Powered device) appareil alimenté

PHY (Physical Layer Service) service de couche physique [ISO/IEC/IEEE 8802-3]

PI (Power Interface) interface de puissance

PSE (Power Sourcing Equipment) équipement source d'alimentation

### 4.2.8 Type 16: Abréviations

DPLL (digital phase locked loop) boucle numérique à verrouillage de phase

HCS (hard clad silica) silice gainée en dur (fibre de verre)

IC (Integrated Circuit) circuit intégré

LED (light emitting diode) diode électroluminescente

LSB (least significant bit) bit de poids faible

MSB (most significant bit) bit de poids fort

NRZI (non-return to ZÉRO inverted) non retour à zéro inversé

POF (polymer optical fiber) fibre optique polymère (fibre plastique)

RxCLK horloge de réception

RxD données reçues

TxCLK horloge de transmission

TxD données émises

### 4.2.9 Type 18: Abréviations

AWG (American Wire Gauge) calibre AWG

CMOS (Complementary Metal Oxide Silicon) semi-conducteur à oxyde métallique complémentaire – une classe de spécification d'interface logique numérique

DA / DB Données A et données B – paire de signaux de télécommunication

DG (Data Ground) masse de référence des données – référence des signaux de télécommunication dont le potentiel est égal à zéro

FG (Field Ground) masse de référence du bus de terrain – référence des appareils dont le potentiel est égal à zéro

NRZI (Non-Return to ZÉRO Inverted) non retour à zéro inversé

PhL-B (Physical layer – Basic type) couche physique – de type basique

PhL-P (Physical layer – Powered type) couche physique – de type alimenté

RxS Signal de réception

SLD Blindage – cage de Faraday linéaire

TTL (Transistor-Transistor Logic) logique transistor-transistor – une classe de spécification d'interface logique numérique

TxE Activation de transmission

TxS Signal de transmission

UL (Unit Load) charge unitaire

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### 4.2.10 Type 24: Abréviations

| | |
|---|---|
| AUX | Signal auxiliaire |
| AWG | (American Wire Gauge) calibre AWG |
| DL | (Data-link) Liaison de données (utilisée comme préfixe) [ISO/IEC 7498-1] |
| DLL | (Data-Link Layer) couche liaison de données [ISO/IEC 7498-1] |
| NC | (No connection) aucune connexion |
| Ph | Physique (utilisée comme préfixe)[ISO/IEC 7498-1] |
| PhL | (Physical layer) couche physique [ISO/IEC 7498-1] |
| pk | (Peak) crête |
| pk-pk | (Peak-to-peak) crête à crête |
| SRD | (Send data Receive data) (données de transmission données de réception) |
| RxS | Signal de réception |
| TxE | Signal d'activation de transmission |
| TxS | Signal de transmission |

### 4.2.11 Type 20: Abréviations

| | |
|---|---|
| AWG | (American Wire Gauge) calibre AWG |
| bit/s | Bits par seconde |
| DUT | (Device under test) appareil en essai |
| EMI | (Electro-magnetic Interference) brouillage électromagnétique |
| FSK | (Frequency shift keying) modulation par déplacement de fréquence |
| HCF | HART™ Communication Foundation |
| EFF | valeur efficace |
| SOM | (Start of message) Début de message |
| STX | (Start of transaction) Début de transaction |

### 4.2.12 Type 28: Abréviations

| | |
|---|---|
| AL | (Application layer) Couche Application |
| BPSK | (Binary Phase Shift Keying) modulation par déplacement de phase bivalente |
| DCE | (Data Communication Equipment) équipement de transmission de données |
| DL | (Data-link) Liaison de données (utilisée comme préfixe) [ISO/IEC 7498-1] |
| DLDE | (Data-Link Data Entity) entité de données de liaison de données |
| DLE | (Data-Link Entity) entité de liaison de données |
| DLL | (Data-Link Layer) couche liaison de données [ISO/IEC 7498-1] |
| DLP | (Data-Link Protocol) protocole de liaison de données |
| DLPDU | (Data-Link Process Data Unit) unité (ensemble) de données de processus de liaison de données |
| DIS | (DCE Independent Sublayer) sous-couche indépendante du DCE |
| DTC | (Data transmission channel) canal de transmission de données |
| ETTD | équipement terminal de traitement de données |
| LbE | (Loopback-Enable signal) signal d'activation du rebouclage |
| MAU | (Medium attachment unit) unité de liaison au support |
| MCS | (Modulation coding scheme) schéma de codage de modulation |
| MDS | (Medium Dependent Sublayer) sous-couche dépendante du support |
| MIS | (Media Independent Sublayer) sous-couche indépendante des supports |

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| | |
|---|---|
| MN | (Management node) Nœud de gestion |
| NodeID | (Node Identifier) identifiant de nœud |
| OFDM | (Orthogonal Frequency Division Multiplexing) multiplexage par répartition orthogonale de la fréquence |
| PhE | (Physical layer entity) entité de couche physique [ISO/IEC 7498-1] |
| PhL | (Physical layer) couche physique [ISO/IEC 7498-1] |
| PhL | (Physical layer) couche physique (utilisée comme préfixe) |
| PhLDE | (Physical layer data entity) entité de données de couche physique |
| PhLME | (Physical layer management entity) entité de gestion de couche physique |
| PhICI | (Physical layer interface control information) informations de commande d'interface de couche physique [ISO/IEC 7498-1] |
| PhID | (Physical layer interface data) données d'interface de couche physique [ISO/IEC 7498-1] |
| PhIDU | (Physical layer interface data unit) unité de données d'interface de couche physique [ISO/IEC 7498-1] |
| PhPCI | (Physical layer protocol control information) informations de commande de protocole de couche physique [ISO/IEC 7498-1] |
| PhPDU | (Physical layer protocol data unit) (unité (ensemble) de données de protocole de couche physique [ISO/IEC 7498-1] |
| PhS | (Physical layer service) service de couche physique [ISO/IEC 7498-1] |
| PhSDU | (Physical layer service data unit) unité (ensemble) de données de service de couche physique [ISO/IEC 7498-1] |
| QAM | (Quadrature amplitude modulation) modulation d'amplitude en quadrature |
| RF | (Radio frequency) fréquence radioélectrique |
| EFF | valeur efficace |
| RS | Reed-Solomon |
| RxS | Signal de réception (de la MAU) |
| SF | (Signal frame) trame de signal |
| SyC | (Synchronization confirm) confirmation de synchronisation |
| SynS | (Synchronization signal) signal de synchronisation |
| SyR | (Synchronization request) demande de synchronisation |
| TM | (Transmit mode) mode de transmission |
| TN | (Terminal node) nœud terminal |
| TxD | Données de transmission |
| TxE | (Transmit-enable signal) signal d'activation de la transmission (vers MAU) |
| TxR | (Transmit request) demande de transmission |
| TxS | Signal de transmission (vers MAU) |

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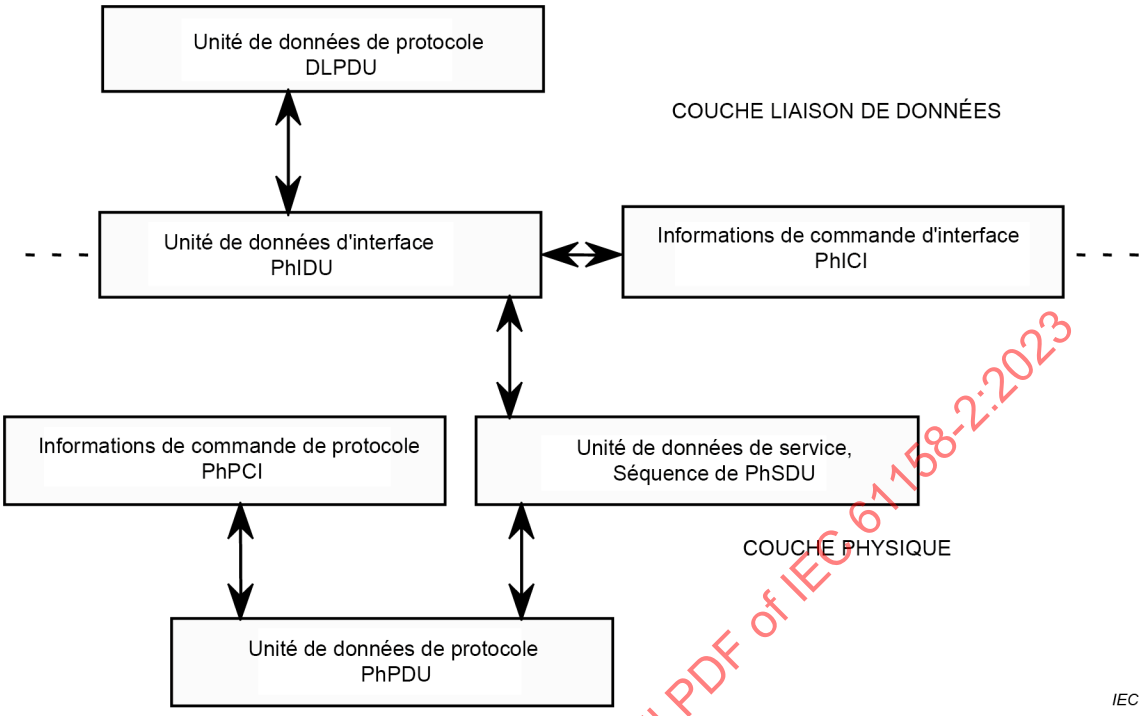
## 5 Interface DLL – PhL

### 5.1 Généralités

L'Article 5 définit les primitives de services physiques (PhS) exigées et les contraintes liées à leur utilisation.

NOTE 1 L'interface physique – liaison de données est une interface de service virtuelle entre machines virtuelles; il n'y a aucune exigence concernant les lignes de signaux physiques car le document n'exige pas que cette interface soit exposée.

Les PhIDU doivent être transférées entre la DLL et la PhL conformément aux exigences de l'ISO/IEC 7498, comme cela est représenté à la Figure 2.




NOTE La prise en charge des PhPCI et PhICI est spécifique au type.

**Figure 2 – Mapping entre unités de données sur l'interface DLL – PhL**

NOTE 2 Ces services assurent l'échange de PhIDU entre une entité DLL et l'entité PhL correspondante. Ce transfert fait partie d'une transaction entre entités DLL coopérantes. Les services énumérés dans cette section constituent les services minimaux; ils peuvent conjointement fournir les moyens par lesquels des entités DLL coopérantes peuvent coordonner leurs émissions et leurs échanges de données sur le support de communication partagé. La synchronisation de l'échange de données et les actions correspondantes sont également prévues au besoin.

NOTE 3 Une structuration en couches appropriée assure qu'une entité de couche (N+1) ne soit pas concernée par les moyens utilisés par une couche (N) pour fournir ses services (N) et qu'une interface de services (N) ne restreigne pas exagérément ces moyens. Ainsi, l'interface de Ph-service ne réclame pas que les DLE soient informées des informations détaillées internes de la PhE (par exemple, préambule (synchroniseur initial), synchroniseur final et configuration des signaux délimiteurs de trames, nombre de bits par baud) et n'empêche pas la PhE d'utiliser des avancées technologiques appropriées.

NOTE 4 Un certain nombre de différentes interfaces DLL – PhL sont spécifiées, sur la base des pratiques industrielles en la matière.

## 5.2 Type 1: Services exigés

### 5.2.1 Primitives du PhS

#### 5.2.1.1 Généralités

La granularité des données utilisateur PhS échangées au niveau de l'interface PhL-DLL est d'un octet.

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#### 5.2.1.2 Indication des Ph-CHARACTERISTICS

Le PhS doit fournir la primitive de service suivante afin de rendre compte des caractéristiques essentielles du PhS (qui peuvent être utilisées dans les activités de transmission, de réception et de planification de la DLL):

Indication des Ph-CHARACTERISTICS (débit binaire minimal, surdébit de trame)

où

débit binaire minimal – doit spécifier le débit minimal d'acheminement des données effectif, en bits/s, y compris d'éventuelles tolérances temporelles

NOTE 1 Une PhE ayant un débit binaire nominal de 1 Mbit/s avec une tolérance de ± 0,01 % indique un débit binaire minimal de 0,999 9 Mbit/s.

le surdébit de trame – doit spécifier le nombre maximal de périodes binaires (la période binaire étant l'inverse du débit binaire) utilisées dans toute émission de PhPDU qui n'acheminent pas directement de données (par exemple, des PhPDU qui acheminent des préambules (synchroniseurs initiaux), des délimiteurs de trames, des synchroniseurs finaux, des "silences" inter-trames, etc.).

NOTE 2 Si le surdébit de trame est F et si deux longueurs de messages DL sont $L_1$ et $L_2$, alors le temps nécessaire à l'envoi d'un message de longueur $L_1$ + F +$L_2$ est au moins égal au temps exigé pour envoyer deux messages immédiatement consécutifs de longueurs $L_1$ et $L_2$.

#### 5.2.1.3 Services PhS de transmission et de réception

Le PhS doit fournir les primitives de service suivantes pour la transmission et la réception:

Demande de PH-DATA (class, data);

Indication de PH-DATA (class, data);

Confirmation de PH-DATA (status)

où

classe – doit spécifier la composante PhICI de la PhIDU.

Pour une demande de PH-DATA, les valeurs possibles doivent être:

START-OF-ACTIVITY – l'émission des PhPDU qui précèdent les Ph user-data doit commencer;

DATA – la valeur d'octet unique du paramètre de données correspondant doit être transmise comme partie d'une émission continue correctement formée; et

END-OF-DATA-AND-ACTIVITY – les PhPDU qui mettent fin aux Ph user-data doivent être émises après le dernier octet précédent des Ph user-data, aboutissant à la cessation de l'émission active.

Pour une indication de PH-DATA, les valeurs possibles doivent être:

START-OF-ACTIVITY – la réception d'une émission apparente d'une ou de plusieurs PhE a commencé;

DATA – le paramètre de données correspondant a été reçu comme partie d'une réception continue correctement formée;

END-OF-DATA – la réception continue correctement formée des Ph-user-data en cours s'est terminée par la réception correcte des PhPDU impliquant la END-OF-DATA;

END-OF-ACTIVITY – la réception en cours (d'une émission apparente provenant d'une ou de plusieurs PhE) s'est achevée avec aucune preuve supplémentaire de transmission PhE; et

END-OF-DATA-AND-ACTIVITY – occurrence simultanée d'END-OF-DATAet d'END-OF-ACTIVITY.

– données – doit spécifier la composante PhID de la PhIDU. Elle est constituée d'un octet de Ph-user-data à émettre (demande de PH-DATA) ou qui a été reçu avec succès (indication de PH-DATA).

– état – doit spécifier soit le succès, soit la raison détectée localement qui a donné lieu à l'échec.

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La primitive de confirmation de PH-DATA doit fournir le retour d'informations critiques de temporisation physique nécessaires pour empêcher la DLE de démarrer une seconde émission avant que la première ne soit terminée. La confirmation de PH-DATA finale d'une émission ne doit pas être initiée avant que la PhE n'ait terminé l'émission.

### 5.2.2 Notification de PhS-characteristics

La PhE a la responsabilité d'informer la DLE des caractéristiques du PhS qui peuvent être importantes pour le fonctionnement de la DLE. La PhE doit fournir ces informations à chaque PhSAP de PhE en émettant une primitive unique d'indication de Ph-CHARACTERISTICS, au démarrage de la PhE.

### 5.2.3 Transmission des Ph user-data

La PhE doit déterminer la temporisation de toutes les émissions. Lorsqu'une DLE émet une séquence de PhSDU, la DLE doit envoyer la séquence de PhSDU en réalisant une séquence bien formée de demandes de PH-DATA, constituée d'une seule demande qui spécifie le START-OF-ACTIVITY, suivie d'une série de 3 à 300 demandes consécutives, y compris, qui spécifient également les DATA, chacune de ces demandes acheminant une PhSDU et se terminant par une demande unique qui spécifie la END-OF-DATA-AND-ACTIVITY.

La PhE doit signaler l'achèvement de chaque demande de PH-DATA et indique qu'elle est prête à accepter une nouvelle demande de PH-DATA, par l'émission d'une primitive de confirmation de PH-DATA; le paramètre d'état de la primitive de confirmation de PH-DATA doit acheminer le résultat, succès ou échec, de la demande de PH-DATA correspondante. Une seconde demande de PH-DATA ne doit être lancée par la DLE qu'après que la PhE a émis la confirmation de PH-DATA correspondant à la première demande.

### 5.2.4 Réception des Ph user-data

La PhE doit rendre compte d'une émission reçue par une séquence bien formée des indications de PH-DATA, qui doit être constituée

a) d'une indication unique qui spécifie le START-OF-ACTIVITY; suivie par des indications consécutives qui spécifient les DATA et acheminant chacune une PhSDU; suivie par une indication unique spécifiant la END-OF-DATA; et terminée par une indication unique qui spécifie la END-OF-ACTIVITY; ou

b) d'une indication unique qui spécifie le START-OF-ACTIVITY; suivie par des indications consécutives qui spécifient les DATA et acheminant chacune une PhSDU; et suivie par une indication unique qui spécifie la END-OF-DATA-AND-ACTIVITY; ou

c) d'une indication unique qui spécifie le START-OF-ACTIVITY; suivie, facultativement, par une ou des indications consécutives qui spécifient des DATA et acheminant chacune une PhSDU; et terminée par une indication unique qui spécifie la END-OF-ACTIVITY.

Cette dernière séquence indique une réception incomplète ou incorrecte. La détection d'une erreur dans la séquence de PhPDU reçues, ou dans le processus de réception des PhE, doit désactiver des indications ultérieures de PH-DATA avec un paramètre de classe qui spécifie DATA, END-OF-DATA, ou END-OF-DATA-AND-ACTIVITY jusqu'à ce que la fin de la période d'activité courante et le début d'une période d'activité suivante aient été consignés par des indications de PH-DATA qui spécifient END-OF-ACTIVITY et START-OF-ACTIVITY, respectivement.

## 5.3 Type 2: Services exigés

### 5.3.1 Généralités

Le Pararaphe 5.3 définit les primitives de services physiques (PhS) requises et les contraintes liées à leur utilisation.

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Il n'est pas nécessaire d'exposer l'interface DLL-PhL lors de la mise en œuvre d'une quelconque variante de PhL. Cette interface peut être interne au nœud et peut être mise en œuvre comme interne à un appareil à semi-conducteur. Cependant, s'il est revendiqué une conformité à l'interface DLL-PhL, celle-ci doit satisfaire aux exigences du 5.3.

### 5.3.2 M_symbols

Les unités de données de l'interface PhL, présentes à l'interface DLL-PhL, doivent être des M_symbols, comme cela est présenté dans le Tableau 1. Les symboles M_ND doivent être utilisés pour créer des modèles de données uniques utilisés pour les délimiteurs de début et de fin.

**Tableau 1 – Règles de codage de données**

| Bits de données (nom commun) | Représentation M_symbol |
|---|---|
| données "zéro" | M_0 ou {0} |
| données "un" | M_1 ou {1} |
| "non_data+" | M_ND+ ou {+} |
| "non_data-" | M_ND- ou {-} |

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### 5.3.3 Indication de PH-LOCK

L'indication de PH-LOCK doit informer s'il y a verrouillage des données ou synchronisation du Ph-symbol par la MDS. Les états valides pour l'indication de PH-LOCK doivent être "vrai" et "faux". L'indication de PH-LOCK doit être "vrai" lorsque des Ph-symbols valides sont présents à l'interface MDS-MAU et lorsque la synchronisation d'interface DLL-PhL des M_symbols est conforme aux exigences d'exactitude de l'horloge. Cette indication doit être "faux" entre trames (lorsqu'aucun Ph-symbols n'est présent sur le support) ou lorsque la synchronisation des données est perdue ou que la temporisation n'est pas conforme aux exigences d'exactitude d'horloge. L'indication de PH-LOCK doit être "vrai" avant le commencement du délimiteur de début.

### 5.3.4 Indication de PH-FRAME

L'indication de PH-FRAME doit fournir une information de trame de données valide en provenance de la MAU. Les états valides pour l'indication de PH-FRAME doivent être "vrai" et "faux". L'indication de PH-FRAME doit être "vrai" sur indication de PH-LOCK = "vrai" et à la réception du premier délimiteur de début valide. L'indication de PH-FRAME doit être "faux" à la réception du symbole M_ND suivant (après le délimiteur de début) ou sur indication de PH-LOCK = "faux".

NOTE Ce signal fournit une synchronisation des octets vers la DLL.

### 5.3.5 Indication de PH-CARRIER

L'indication de PH-CARRIER doit représenter la présence d'une porteuse de signal sur le support. L'indication de PH-CARRIER doit être "vrai" si RXCARRIER (porteuse de réception) à l'interface MDS-MAU était à l'état "vrai" au cours de l'une des 4 dernières durées de M_symbol et elle doit être "faux" dans le cas contraire.

### 5.3.6 Indication de PH-DATA

L'indication de PH-DATA doit représenter les M_symbols définis dans le Tableau 1. Les symboles valides doivent être M_0, M_1, M_ND+ ou M_ND- (ou M_symbols). L'indication de PH-DATA doit représenter les M_symbols tels que décodés à partir de la MAU si l'indication de PH-LOCK est "vrai".

### 5.3.7 Indication de PH-STATUS

L'indication de PH-STATUS doit représenter l'état de la trame qui a été reçue de la MAU, comme cela est présenté dans le Tableau 2. Les symboles valides sont "Normal", "Abandon" et "Invalide". L'indication dePH-STATUS doit être "Normal" après réception d'une trame (Indication de PH-FRAME = "vrai") constituée d'un délimiteur de début, de données codées Manchester valides (pas de symboles M_ND) et d'un délimiteur de fin. L'indication de PH-STATUS doit être "Abandon" après réception d'une trame (Indication de PH-FRAME = "vrai") constituée d'un délimiteur de début, de données codées Manchester valides et d'un second délimiteur de début. L'indication de PH-STATUS doit être "Invalide" après réception d'une trame (Indication de PH-FRAME = "vrai") constituée d'un délimiteur de début et indiquer la détection de tout symbole M_ND qui ne faisait pas partie d'un délimiteur de début ou de fin.

**Tableau 2 – Tableau de vérité de l'indication de -STATUS**

| Indication de Ph-STATUS | Indication de Ph-FRAME | Délimiteurs de début dans une trame unique | Détection de délimiteur de fin | Toute violation de code Manchester non-délimiteur |
|---|---|---|---|---|
| Normale | vrai | 1 | vrai | faux |
| Abandon | vrai | 2 | sans effet | faux |
| Invalide | vrai | 1 | sans effet | vrai |

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### 5.3.8 Demande de PH-DATA

La demande de PH-DATA doit représenter le M_symbols à émettre. Les symboles valides doivent être M_0, M_1, M_ND+ ou M_ND- comme cela est présenté dans le Tableau 1. La demande de PH-DATA doit indiquer M_0 lorsqu'aucune donnée ne doit être émise (et demande de PH-FRAME = "Faux").

### 5.3.9 Demande de PH-FRAME

La demande de PH-FRAME doit être "vrai" lorsque la demande de PH-DATA représente des M_symbols à coder en Ph-symbols appropriés et à transférer à la MAU; elle doit être "faux" lorsqu'aucun M_symbols valide ne doit être transféré à la MAU.

### 5.3.10 Indication de PH-JABBER

L'indication de PH-JABBER doit être "vrai" si l'interface MDS-MAU détecte une trame unique (indication de PH-FRAME = "vrai") supérieure ou égale à 1 024 octets (8 192 M_symbols) et que la demande de PH-JABBER-TYPE est "vrai". L'indication de PH-JABBER doit être "vrai" si l'interface MDS-MAU détecte une trame unique (indication de PH-FRAME = "vrai") supérieure ou égale à 2 048 octets (16 384 M_symbols) et que la demande de PH-JABBER-TYPE est "faux". Dans le cas contraire, l'indication de PH-JABBER doit être "faux". Si l'indication de PH-JABBER devient "vrai", elle doit être verrouillée dans cet état par le MDS jusqu'à ce que la demande de Ph-JABBER-CLEAR soit "vrai" ou que le nœud soit mis hors tension puis de nouveau sous tension ou que le nœud soit initialisé.

### 5.3.11 Demande de Ph-JABBER-CLEAR

La demande de Ph-JABBER-CLEAR (facultative) doit être "faux" dans des conditions normales de fonctionnement et doit être "vrai" pour réinitialiser une indication de PH-JABBER qui a été verrouillée à l'état "vrai".

### 5.3.12 Demande de Ph-JABBER-TYPE

Une demande de PH-JABBER-TYPE doit être "vrai" si le nœud est l'origine des données de transmission ("NODE") et doit être "faux" si le nœud réémet des données reçues d'un autre nœud (lorsqu'il agit par exemple comme "REPEATER" de données provenant d'un autre nœud; voir l'Annexe G).

Les combinaisons d'indication de PH-JABBER et de demande de PH-JABBER-TYPE doivent être telles qu'elles sont présentées dans le Tableau 3.

**Tableau 3 – Indications de Jabber**

| Indication de Ph-JABBER | Demande de Ph-JABBER-TYPE | Longueur de trame |
|---|---|---|
| vrai | vrai = "NODE" | ≥ 1 024 octets |
| vrai | faux = "REPEATER" | ≥ 2 048 octets |
| faux | vrai = "NODE" | < 1 024 octets |
| faux | faux = "REPEATER" | < 2 048 octets |

## 5.4 Type 3: Services exigés

### 5.4.1 Transmission synchrone

Les services définis pour le Type 1 doivent être utilisés (voir 5.2).

### 5.4.2 Transmission asynchrone

#### 5.4.2.1 Services PhS de transmission et de réception

Le service de données pour transmission asynchrone (Ph-ASYN-DATA) comprend deux primitives de service. Une primitive de demande est utilisée pour une demande de service par la DLE; une primitive d'indication est utilisée pour indiquer une réception vers la DLE. Les primitives correspondantes portent les désignations suivantes:

Demande de Ph-ASYN-DATA

Indication de Ph-ASYN-DATA

La relation temporelle entre primitives est représentée à la Figure 3.

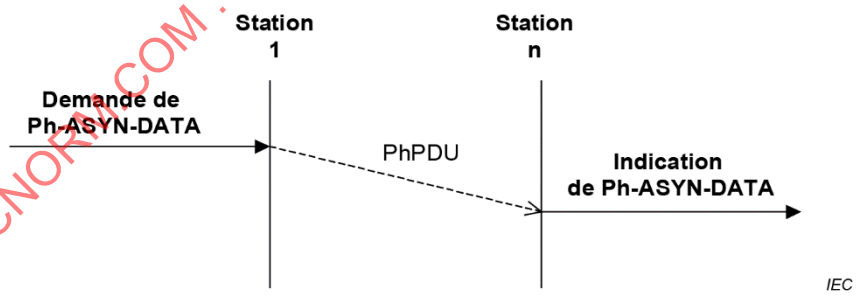


**Figure 3 − Service de données pour transmission asynchrone**

#### 5.4.2.2 Spécification détaillée du service et interaction

Le paragraphe 5.4.2.2 donne une description détaillée des primitives de service et des paramètres correspondants, de manière abstraite. Les paramètres contiennent les données PhS-user échangées au niveau de l'interface PhL-DLL avec une granularité d'un bit.

**Paramètres des primitives:**

Demande de Ph-ASYN-DATA (DL_symbol)

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Le paramètre DL_symbol doit prendre l'une des valeurs suivantes qui spécifient la composante PhID de PhIDU. Ces valeurs doivent être:

a) ZÉRO qui correspond à un "0" binaire;

b) ONE qui correspond à un "1" binaire;

c) SILENCE qui désactive l'émetteur lorsqu'aucun symbole DL ne doit être transmis.

La primitive de demande Ph-ASYN-DATA est transmise de la DLE à la PhE afin de demander que le symbole indiqué soit envoyé au support de bus de terrain.

La réception de cette primitive doit engendrer une tentative de codage et de transmission du symbole DL par la PhE.

La demande Ph-ASYN-DATA est une primitive qui ne doit être générée qu'une fois par période de symbole DL ($t_{BIT}$). La PhE peut confirmer cette primitive au moyen d'une primitive de confirmation définie localement.

Indication de Ph-ASYN-DATA (DL_symbol).

Le paramètre DL_symbol doit prendre l'une des valeurs suivantes:

a) ZÉRO qui correspond à un "0" binaire;

b) ONE qui correspond à un "1" binaire.

La primitive d'indication de Ph-ASYN-DATA est transmise de la PhE à la DLE pour indiquer qu'un DL symbol a été reçu du support de bus de terrain. L'effet de la réception de cette primitive par la DLE n'est pas spécifié.

L'indication de Ph-ASYN-DATA est une primitive qui ne doit être générée qu'une fois par période de symbole DL reçu ($t_{BIT}$).

## 5.5 Type 4: Services exigés

### 5.5.1 Généralités

Les PhIDU doivent être transférées entre la DLL et la PhL conformément aux exigences de la série ISO/IEC 7498.

### 5.5.2 Primitives du PhS

#### 5.5.2.1 Généralités

La granularité de transmission dans le protocole de bus de terrain est d'un octet. Il s'agit de la granularité des données PhS-user échangées au niveau de l'interface PhL-DLL.

#### 5.5.2.2 Services PhS de transmission et de réception

Le PhS doit fournir les primitives de service suivantes pour la transmission et la réception:

Demande de PH-DATA (class, data)

Indication de PH-DATA (class, data, status)

Confirmation de PH-DATA (status)

où

**class** – spécifie la composante Ph-interface-control-information (PhICI) de Ph-interface-data-unit (PhIDU).

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Pour une demande de PH-DATA, les valeurs possibles sont:

START-OF-ACTIVITY**-11** – la PhE doit lancer la transmission par émission du paramètre de données correspondant, comme un "Caractère d'adresse". La PhE doit effectuer cette opération immédiatement, bien qu'il faille attendre que la valeur du compteur de repos des PhE ait atteint 11. Cette classe s'applique uniquement au mode semi-duplex.

START-OF-ACTIVITY**-2** – la PhE doit activer son pilote et lancer la transmission par émission du paramètre de données correspondant, comme un "Caractère d'adresse". La PhE doit effectuer cette opération immédiatement, bien qu'il faille attendre que la valeur du module 10 du compteur de repos des PhE ait atteint 2, en cas de mode semi-duplex.

DATA – la PhE doit émettre le paramètre de données correspondant, comme un "Caractère de données".

END-OF-ACTIVITY – la PhE doit attendre la fin de l'émission de toutes les données précédemment reçues de la DLE puis ensuite mettre fin à l'émission. Le paramètre de données correspondant ne doit pas être émis.

Pour une indication de PH-DATA, les valeurs possibles sont:

START-OF-ACTIVITY – la PhE a reçu un "Caractère d'adresse", dont la valeur est indiquée dans le paramètre de données correspondant. Le paramètre d'état correspondant spécifie le succès ou la raison de l'échec, détectée localement.

DATA – la PhE a reçu un "Caractère de données", dont la valeur est indiquée dans le paramètre de données correspondant. Le paramètre d'état correspondant spécifie le succès ou la raison de l'échec, détectée localement.

LINK-IDLE – la PhE a détecté que le niveau du signal sur la liaison a été "Au repos" pendant 30, 35, 40, 50, 60… périodes binaires. Le paramètre d'état correspondant indique si la liaison a été au repos pendant 30, 35 ou 40 périodes binaires ou plus. Cette classe s'applique uniquement au mode semi-duplex.

**data** – spécifie la composante Ph-interface-data (PhID) de la PhIDU. Elle est constituée d'un octet de Ph-user à émettre (demande de PH-DATA ) ou d'un octet de Ph-user qui a été reçu (indication de PH-DATA).

**status** – spécifie soit le succès soit la raison de l'échec détectée localement ou indique si l'indication LINK-IDLE correspondante est "30", "35", "40 ou plus" périodes binaires de repos après activité de la liaison.

La primitive de confirmation de PH-DATA fournit le retour d'informations nécessaire pour permettre à la DLE de rendre compte des échecs tels qu'un court-circuit de la liaison ou du bruit qui entraîne des erreurs de verrouillage de trame à l'utilisateur DLS; elle fournit également les indications de temps physique critique nécessaires pour éviter que la DLE ne démarre une seconde émission avant que la première ne soit terminée.

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### 5.5.3 Transmission des données Ph-user

#### 5.5.3.1 Généralités

Lorsqu'une DLE a une DLPDU à émettre et que le système d'accès à la liaison donne à cette DLE le droit d'émettre, il convient que la DLE envoie la DLPDU, y compris une FCS concaténée. Le résultat d'une séquence de demande de PH-DATA est le suivant:

a) en mode semi-duplex, il convient que la première demande spécifie le START-OF-ACTIVITY-11 si la DLPDU à émettre est un acquittement ou une DLPDU de réponse immédiate ou si l'émission est une réémission immédiate d'une DLPDU confirmée ou non confirmée. Il convient que la première demande spécifie START-OF-ACTIVITY-2 si l'émission d'une DLPDU confirmée ou non confirmée à partir de la file d'attente a commencé. En mode bidirectionnel simultané, il convient que la première demande spécifie toujours START-OF-ACTIVITY-2;

b) il convient que la première demande soit suivie de demandes consécutives qui spécifient des DATA, et se termine par une simple demande indiquant la END-OF-ACTIVITY.

La PhE signale l'achèvement de chaque demande de PH-DATA et indique qu'elle est prête à accepter une nouvelle demande de PH-DATA au moyen d'une primitive de confirmation de PH-DATA. Le paramètre d'état de la primitive de confirmation de PH-DATA achemine le résultat, succès ou échec, de la demande de PH-DATA correspondante.

#### 5.5.3.2 Réception des données Ph-user

La PhE rend compte d'une émission reçue avec des indications de PH-DATA qui doivent être constituées:

– soit d'une indication unique qui spécifie le START-OF-ACTIVITY, ou

– soit d'une indication unique qui spécifie le START-OF-ACTIVITY; suivie dans ce cas par des indications consécutives qui spécifient les DATA.

Chaque indication dispose d'un paramètre d'état correspondant, spécifiant le succès de la réception des données associées ou la raison de l'échec, détectée localement.

### 5.6 Vide

NOTE Dans la présente édition, le 5.6 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

### 5.7 Type 8: Services exigés

#### 5.7.1 Généralités

Les PhIDU sont échangées entre la DLL (DLL) et la PhL (PhL). Pour le transfert de données, l'interface DL-Ph (interface MAC-MIS) doit mettre à disposition les primitives de service suivantes:

Demande de PH-DATA

Confirmation de PH-DATA

Indication de PH-DATA

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### 5.7.2 Primitives du PhS

#### 5.7.2.1 Demande de PH-DATA (PhICI, PhIDU)

Cette primitive de service est utilisée pour transférer une unité de données de la sous-couche MAC à MIS. Le paramètre **PhICI** détermine les composantes d'interface de la PhIDU à émettre et peut contenir les valeurs suivantes:

**ID_transfer**
Le commencement d'une séquence de données pour la transmission de données d'identification/de commande est demandé.

**data_transfer**
Le commencement d'une séquence de données pour la transmission de données utilisateur est demandé.

**start_ID_cycle**
Le commencement d'un cycle d'identification pour la transmission de données d'identification/commande est demandé par le maître.

**start_data_cycle**
Le commencement d'un cycle de données pour la transmission de données utilisateur est demandé par le maître.

**user_data**
L'émission d'une unité de données utilisateur, définie par le paramètre PhIDU (données d'identification/commande ou données utilisateur) est demandée.

**CRC_data**
L'émission d'une unité de données de la somme de contrôle définie par le paramètre PhIDU est demandée.

**CRC_status**
L'émission d'une unité de données d'état de la somme de contrôle définie par le paramètre PhIDU est demandée.

**user_data_idle**
L'émission des messages user_data_idle est demandée.

**CRC_data_idle**
L'émission des messages CRC_data_idle est demandée.

**CRC_status_idle**
L'émission des messages CRC_status_idle est demandée.

NOTE Les paramètres start_data_cycle et start_ID_cycle sont pris en charge par la sous-couche MAC d'un maître uniquement.

Le paramètre **PhIDU** définit la composante de données de l'unité de données d'interface à émettre. Elle est constituée d'un bit, uniquement si PhICI = user_data, CRC_data ou CRC_status

#### 5.7.2.2 Confirmation de PH-DATA (status)

Cette primitive de service constitue l'acquittement d'une primitive de demande de PH-DATA et elle est utilisée pour la synchronisation. Le paramètre **status** indique le succès ou l'échec de l'exécution de la primitive de demande de PH-DATA correspondante.

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#### 5.7.2.3 Indication de PH-DATA (PhICI, PhIDU)

Cette primitive de service est utilisée pour transférer une unité de données de la MIS à la sous-couche MAC. Le paramètre **PhICI** définit la composante Interface de la PhIDU à émettre et peut prendre pour hypothèse les valeurs suivantes:

**ID_transfer**
Indique le commencement d'une séquence de données pour la transmission de données d'identification/de commande.

**data_transfer**
Indique le commencement d'une séquence de données pour la transmission de données utilisateur.

**user_data**
Indique la réception correcte d'une unité de données pour la transmission des données utilisateur (données d'identification/commande ou données utilisateur) définie par le paramètre PhIDU.

**CRC_data**
Indique la réception correcte d'une unité de données pour émission de la somme de contrôle définie par le paramètre PhIDU.

**CRC_status**
Indique la réception correcte de l'unité de données pour émission de l'état de la somme de contrôle défini par le paramètre PhIDU.

**user_data_idle**
Indique la réception de messages user_data_idle.

**CRC_data_idle**
Indique la réception des messages CRC_data_idle.

**CRC_status_idle**
Indique la réception des messages CRC_status_idle.

Le paramètre **PhIDU** définit les composantes de données de l'unité de données d'interface reçue. Il est constitué d'un bit.

### 5.7.3 Vue d'ensemble des interactions

#### 5.7.3.1 Généralités

NOTE Pour le transfert de données par l'interface DL-Ph, une distinction est faite entre la séquence de données (émission des données utilisateur ou d'identification) et la séquence de contrôle (transmission de données de la somme de contrôle).

Les points ci-après s'appliquent de la Figure 4 à la Figure 7.

– Si une séquence de données d'un cycle de données est suivie par une séquence de données d'un cycle d'identification, les interactions indiquées par (+) sont omises pour un cycle d'identification.
– Si une séquence de données d'un cycle d'identification est suivie par une séquence de données d'un cycle de données, les interactions indiquées par (+) sont omises pour un cycle de données.

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### 5.7.3.2 Séquence de données

#### 5.7.3.2.1 Maître

La Figure 4 et la Figure 5 présentent les interactions pour une séquence de données (cycle d'identification et cycle de données) au niveau de l'interface DL-Ph d'un maître (carte contrôleur).

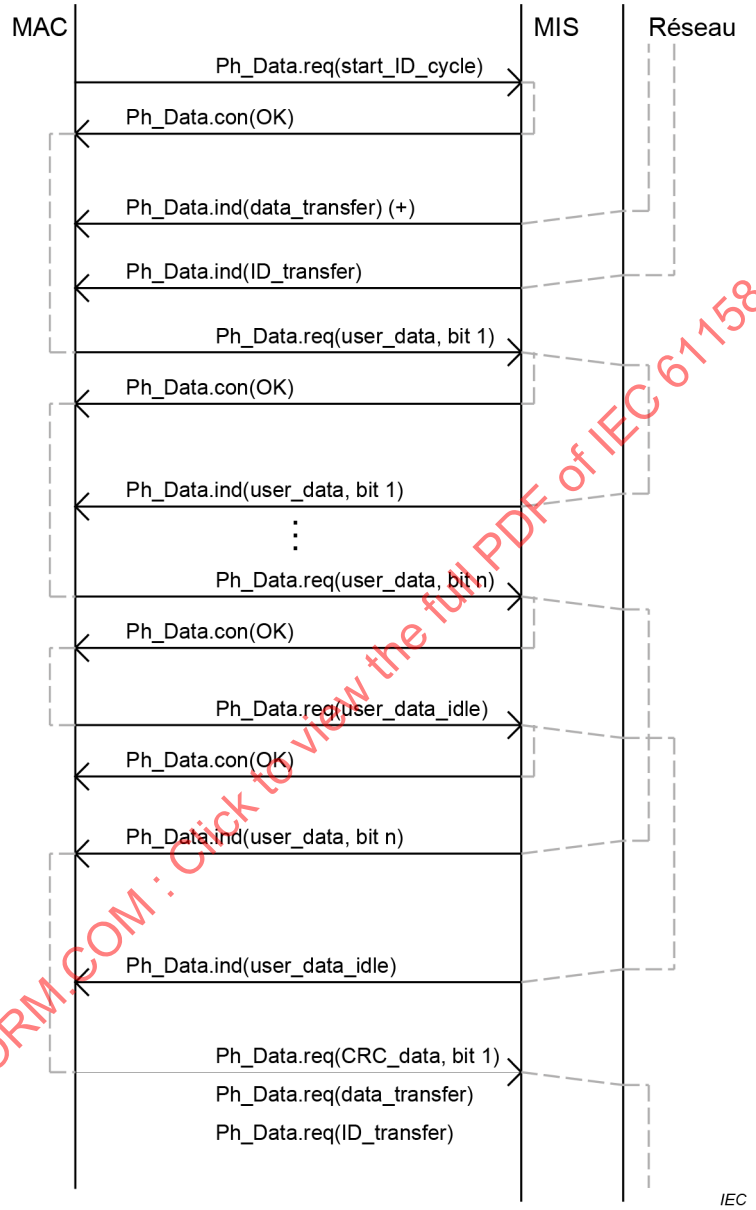


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**Figure 4 – Interactions pour une séquence de données de maître: cycle d'identification**

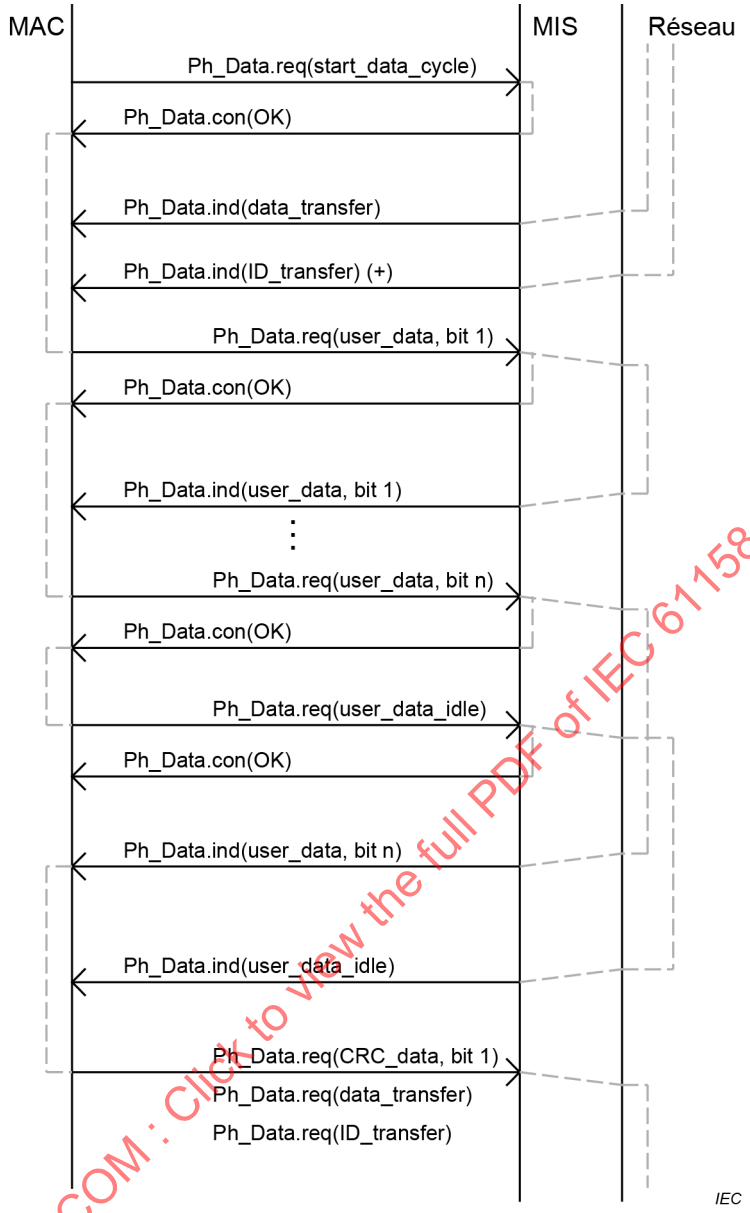


**Figure 5 – Interactions pour une séquence de données de maître: cycle de données**

#### 5.7.3.2.2 Esclave

La Figure 6 et la Figure 7 représentent les interactions pour une séquence de données (cycle d'identification et cycle de données) au niveau de l'interface DL-Ph d'un esclave (appareil de bus distant, appareil de bus local ou coupleur de bus).

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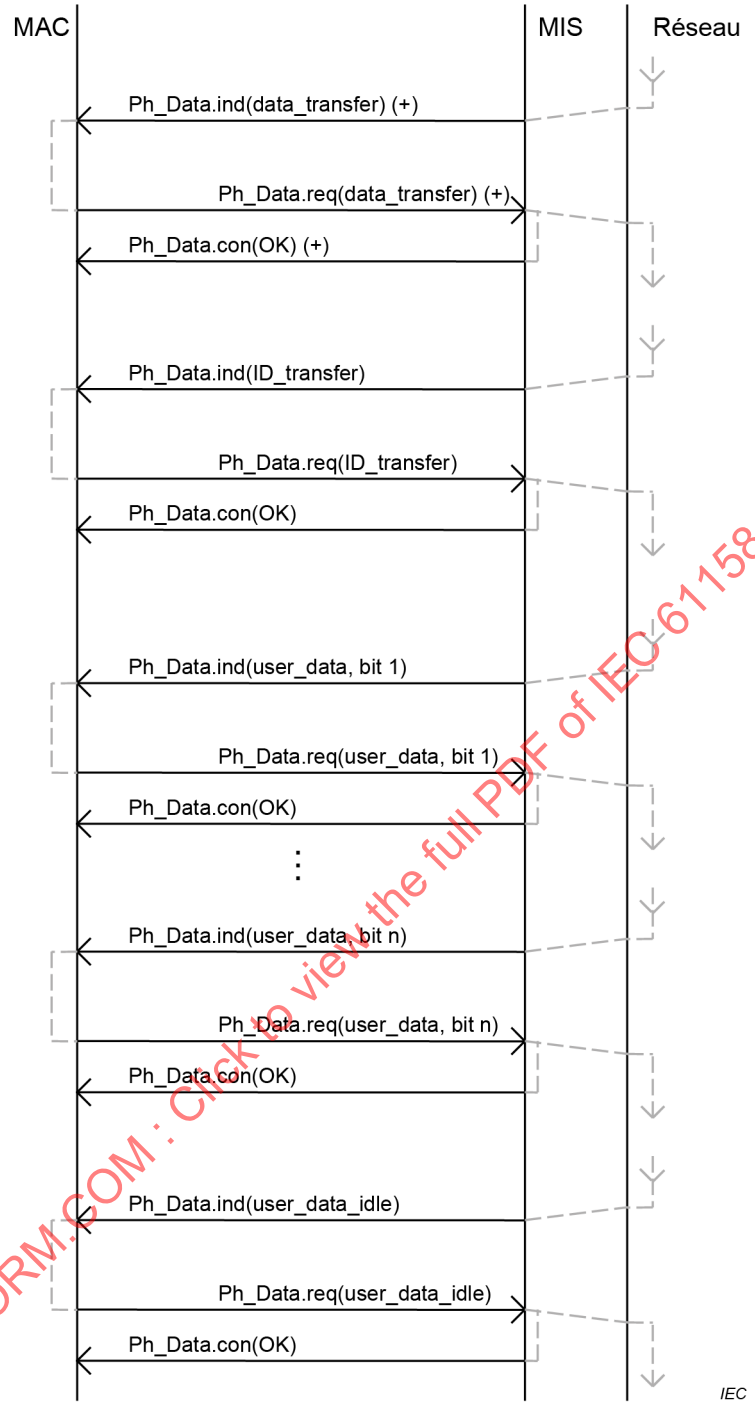


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**Figure 6 – Interactions pour une séquence de données d'esclave: cycle d'identification**

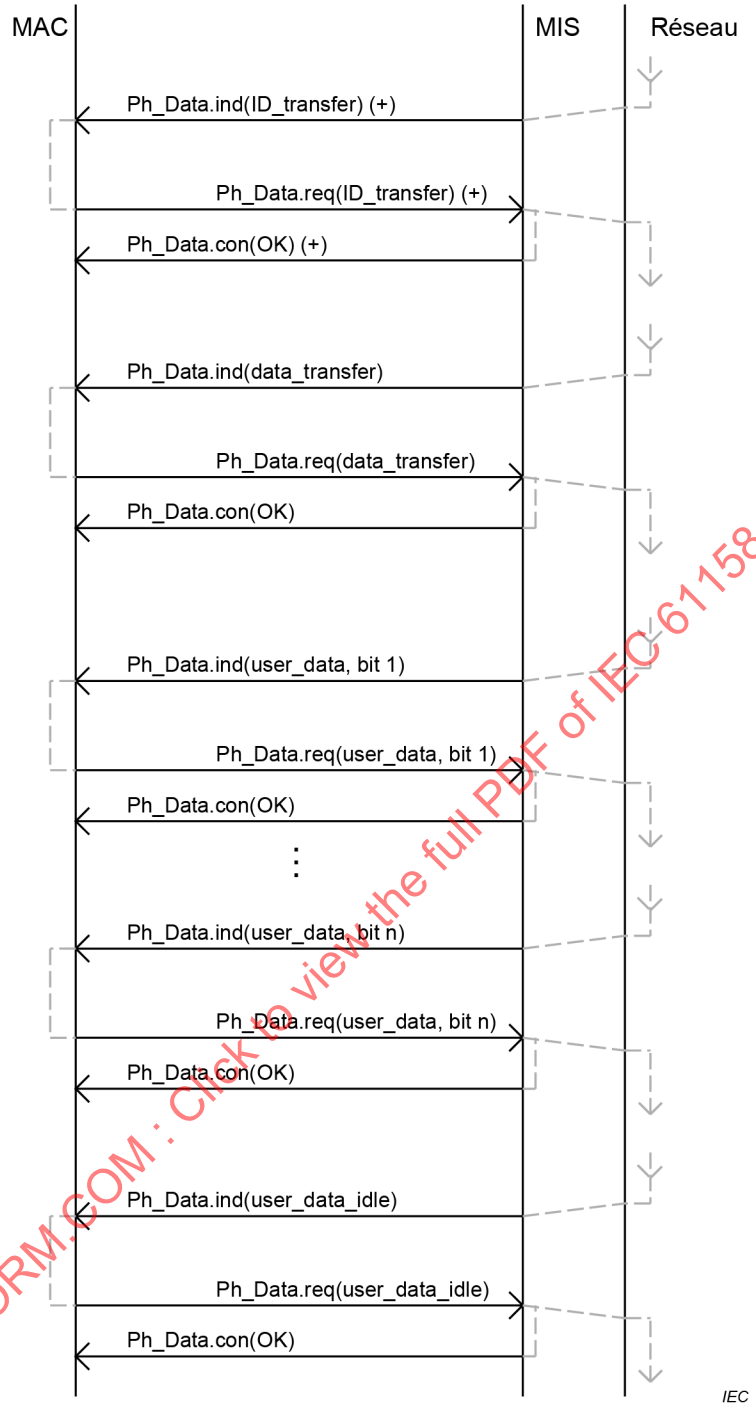


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**Figure 7 – Interactions pour une séquence de données d'esclave: cycle de données**

#### 5.7.3.3 Séquence de contrôle

##### 5.7.3.3.1 Maître

La Figure 8 représente les interactions pour une séquence de contrôle au niveau de l'interface DL-Ph d'un maître.

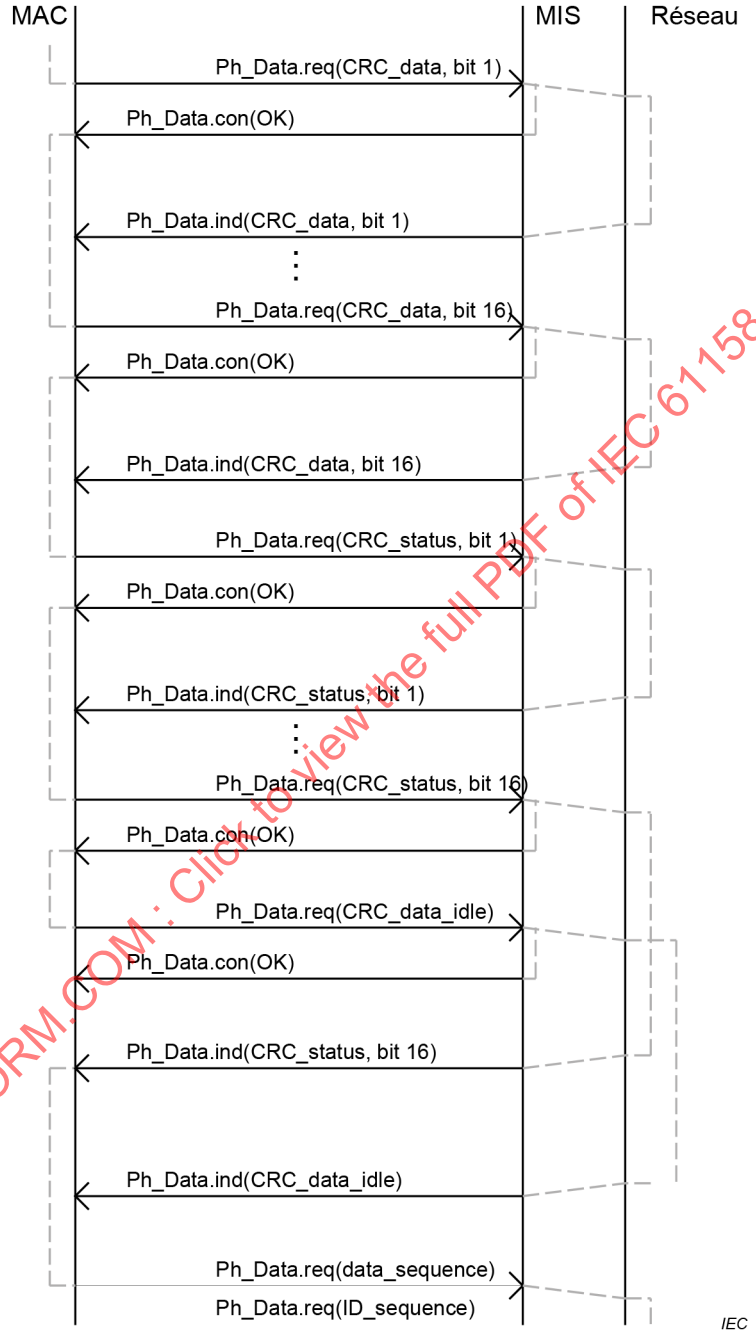


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**Figure 8 – Interactions pour une séquence de contrôle de maître**

#### 5.7.3.3.2 Esclave

La Figure 9 représente les interactions pour une séquence de contrôle au niveau de l'interface DL-Ph d'un esclave.

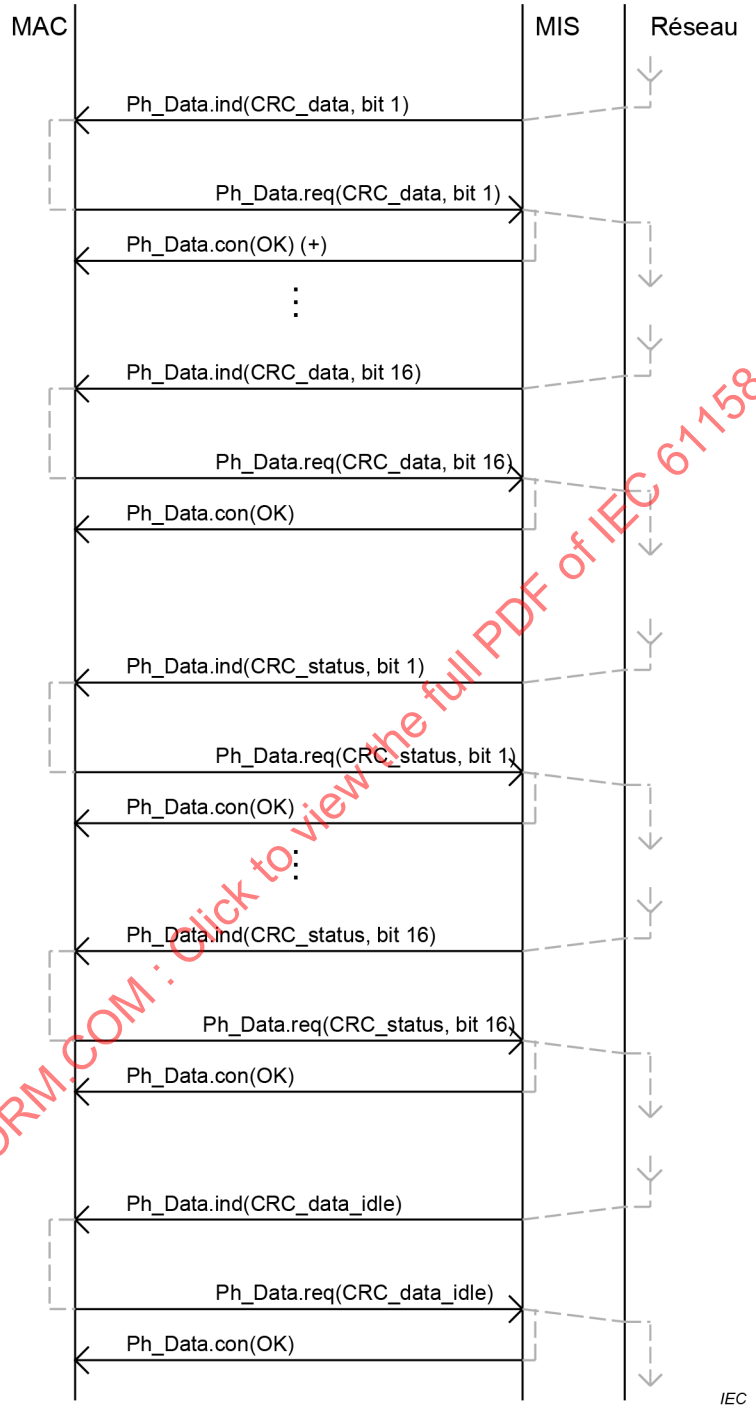


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**Figure 9 – Interactions pour une séquence de contrôle d'esclave**

### 5.8 Type 12: Services exigés

Cette interface est conforme à l'interface indépendante du support décrite à l'Article 22 de l'ISO/IEC/IEEE 8802-3:2021.

## 5.9 Type 16: Services exigés

### 5.9.1 Primitives du PhS

#### 5.9.1.1 Généralités

La granularité des données utilisateur PhS échangées au niveau de l'interface PhL-DLL doit être d'un octet.

#### 5.9.1.2 Services PhS de transmission et de réception

Le PhS doit fournir les primitives de service suivantes pour la transmission et la réception:

– demande de Ph-Data (class, data);
– indication de Ph-Data (class, data);
– confirmation de Ph-Data (status)

où

– classe – doit spécifier la composante PhICI de la PhIDU.

Pour une demande de Ph-Data, les valeurs possibles doivent être:

– start-of-activity – l'émission des PhPDU qui précèdent les Ph user-data doit commencer;
– data – la valeur d'octet unique du paramètre de données correspondant doit être transmise comme partie d'une émission continue correctement formée; et
– end-of-data-and-activity – les PhPDU qui mettent fin aux Ph user-data doivent être émises après le dernier octet précédent des Ph user-data, aboutissant à la cessation de l'émission active.

Pour une indication de Ph-Data, les valeurs possibles doivent être:

– start-of-activity – la réception d'une émission apparente à partir d'une PhE a commencé;
– data – le paramètre de données correspondant a été reçu comme partie d'une réception continue correctement formée;
– end-of-data – la réception continue correctement formée des Ph user-data en cours s'est terminée par la réception correcte des PhPDU impliquant la fin des données;
– data – doit spécifier la composante PhID de la PhIDU. Elle est constituée d'un octet de Ph-user-data à émettre (demande de Ph-Data) ou qui a été reçu avec succès (indication de Ph-Data) ;
– status – doit spécifier soit le succès, soit la raison détectée localement qui a donné lieu à l'échec.

La primitive de confirmation de Ph-Data doit fournir le retour d'informations critiques de temporisation physique nécessaires pour empêcher la DLE de démarrer une seconde émission avant que la première ne soit terminée. La confirmation de Ph-Data finale d'une émission ne doit pas être initiée avant que la PhE n'ait terminé l'émission.

### 5.9.2 Transmission des Ph user-data

La PhE doit déterminer la temporisation de toutes les émissions. Lorsqu'une DLE transmet une séquence de PhSDU, elle doit envoyer la séquence de PhSDU par la réalisation d'une séquence bien formée de demande de Ph-Data, constituée d'une seule demande qui spécifie le start-of-activity, suivie du nombre exigé de demandes consécutives qui spécifient également les données, chacune de ces demandes acheminant une PhSDU et se terminant par une demande unique qui spécifie la end-of-data-and-activity.

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La PhE doit signaler l'achèvement de chaque demande de Ph-Data et indique qu'elle est prête à accepter une nouvelle demande de Ph-Data, par l'émission d'une primitive de confirmation de Ph-Data; le paramètre d'état de la primitive de confirmation de Ph-Data doit acheminer le résultat, succès ou échec, de la demande de Ph-Data correspondante. Une seconde demande de Ph-Data ne doit être lancée par la DLE qu'après que la PhE a émis la confirmation de Ph-Data correspondant à la première demande.

#### 5.9.3 Réception des Ph user-data

La PhE doit rendre compte d'une émission reçue par une séquence bien formée des indications de Ph-Data, qui doit être constituée

a) d'une indication unique qui spécifie le start-of-activity; suivie par des indications consécutives spécifiant les données et acheminant chacune une PhSDU; suivie par une indication unique qui spécifie la end-of-data; et terminée par une indication unique qui spécifie end-of-activity; ou

b) d'une indication unique qui spécifie start-of-activity; suivie par des indications consécutives spécifiant les données et acheminant chacune une PhSDU; et suivie par une indication unique qui spécifie end-of-data-and-activity; ou

c) d'une indication unique qui spécifie le start-of-activity; suivie, facultativement, par une ou des indications consécutives spécifiant des données et acheminant chacune une PhSDU; et terminée par une indication unique qui spécifie end-of-activity.

Cette dernière séquence indique une réception incomplète ou incorrecte. La détection d'une erreur dans la séquence de PhPDU reçues, ou dans le processus de réception des PhE, doit désactiver des indications ultérieures de Ph-Data avec un paramètre de classe qui spécifie data, end-of-data ou end-of-data-and-activity jusqu'à ce que la fin de la période d'activité courante et le début d'une période d'activité suivante aient été consignés par des indications de Ph-Data qui spécifient end-of-activity et start-of-activity, respectivement.

### 5.10 Type 18: Services exigés

#### 5.10.1 Généralités

Il n'est pas nécessaire d'exposer l'interface DLL-PhL lors de la mise en œuvre d'une quelconque variante PhE de Type 18. Cette interface peut être interne au nœud et peut être mise en œuvre comme interne à un appareil à semi-conducteur.

#### 5.10.2 Primitives du PhS

##### 5.10.2.1 Généralités

La granularité des données PhS-user échangées au niveau de l'interface DLL-PhL est d'un bit.

##### 5.10.2.2 Services PhS de transmission et de réception

Le PhS doit fournir les primitives de service suivantes pour la transmission et la réception:

– dmande de PH-DATA (class, data);
– indication de PH-DATA (class, data);
– confirmation de PH-DATA (status).

où:

- **class** – spécifie la composante Ph-interface-control-information (PhICI) de Ph-interface-data-unit (PhIDU).

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Pour une demande de PH-DATA, les valeurs de classe possibles sont:

– START-OF-ACTIVITY – l'émission des PhPDU qui précèdent les Ph user-data doit commencer;

– DATA – la valeur d'octet unique du paramètre de données correspondant doit être transmise comme partie d'une émission continue correctement formée; et

– END-OF-ACTIVITY – les PhPDU qui mettent fin aux données Ph-user doivent être émises après le dernier bit précédent des données Ph-user, aboutissant à la cessation de l'émission active.

Pour une indication de PH-DATA, les valeurs de classe possibles sont:

– START-OF-ACTIVITY – la réception d'une émission apparente d'une ou de plusieurs PhE a commencé;

– DATA – le paramètre de données correspondant a été reçu comme partie d'une réception continue correctement formée;

– END-OF-ACTIVITY – la réception en cours (d'une émission apparente provenant d'une ou de plusieurs PhE) s'est achevée avec aucune preuve supplémentaire de transmission PhE; et

- **données** – doit spécifier la composante PhID de la PhIDU. Elle est constituée d'un bit de Ph-user-data à émettre (demande de PH-DATA) ou qui a été reçu avec succès (indication de PH-DATA).

  et

- **état** – doit spécifier soit le succès, soit la raison détectée localement qui a donné lieu à l'échec.

La primitive de confirmation de PH-DATA doit fournir le retour d'informations critiques de temporisation physique nécessaires pour empêcher la DL-user de démarrer une seconde émission avant que la première ne soit terminée. La confirmation de PH-DATA finale d'une émission ne doit pas être initiée avant que la PhE n'ait terminé l'émission.

### 5.10.3 Transmission des Ph user-data

La PhE doit déterminer la temporisation de toutes les émissions. Lorsqu'une DLE transmet une séquence de PhSDU, elle doit envoyer la séquence de PhSDU par la réalisation d'une séquence bien formée de demandes de PH-DATA, constituée d'une seule demande qui spécifie le START-OF-ACTIVITY, suivie d'une série de demandes consécutives qui spécifient également les DATA, chacune de ces demandes acheminant une PhSDU et se terminant par une demande unique qui spécifie la END-OF-ACTIVITY.

La PhE doit signaler l'achèvement de chaque demande de PH-DATA et indique qu'elle est prête à accepter une nouvelle demande de PH-DATA, par l'émission d'une primitive de confirmation de PH-DATA. Le paramètre d'état de la primitive de confirmation de PH-DATA doit acheminer le résultat, succès ou échec, de la demande de PH-DATA correspondante. Une seconde demande de PH-DATA ne doit être lancée par la DLE qu'après que la PhE a émis la confirmation de PH-DATA correspondant à la première demande.

### 5.10.4 Réception des Ph user-data

La PhE doit rendre compte d'une émission reçue par une séquence bien formée de indications de PH-DATA, qui doit être constituée d'une indication unique qui spécifie le START-OF-ACTIVITY; suivie par des indications consécutives spécifiant les DATA, et acheminant chacune une PhSDU; suivie par une indication unique qui spécifie la END-OF-ACTIVITY.

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### 5.11 Type 24: Services exigés

#### 5.11.1 Généralités

Il n'est pas nécessaire d'exposer l'interface DLL-PhL lors de la mise en œuvre de PhL de Type 24. Cette interface peut être interne au nœud et peut être mise en œuvre comme interne à un appareil à semi-conducteur.

Les primitives et les paramètres qui sont échangés entre la DLL et la PhL sont indiqués dans le Tableau 4.

**Tableau 4 – Primitives et paramètres dans l'interface DLL-PhL**

| Primitives de service | Paramètres |
|---|---|
| PLS_CARRIER.indication {CARRIER_STATUS} | CARRIER_ON, CARRIER_OFF |
| PLS_DATA_VALID.indication {DATA_VALID_STATUS} | DATA_VALID, DATA_NOT_VALID |
| PLS_SIGNAL.indication {SIGNAL_STATUS} | SIGNAL_ERROR, NO_SIGNAL_ERROR |
| PLS_DATA.indication {INPUT_UNIT} | ZÉRO, ONE |
| PLS_DATA.request {OUTPUT_UNIT} | ZÉRO, ONE |

#### 5.11.2 DL_Symbols

Les unités de données de l'interface PhL, présentes à l'interface DLL-PhL, doivent être des DL_symbols. DL_symbol doit prendre l'une des valeurs suivantes:

a) ZÉRO qui correspond à un "0" binaire;

b) ONE qui correspond à un "1" binaire;

#### 5.11.3 Indication PLS_CARRIER

L'indication PLS_CARRIER doit représenter la présence d'une porteuse de signal sur le support. Le paramètre CARRIER_STATUS doit prendre l'une des deux valeurs; CARRIER_ON ou CARRIER_OFF. CARRIER_ON indique que la MDS détecte le changement de Ph_Symbol qui a été entré depuis la MAU. CARRIER_OFF indique que la MDS a détecté l'état sans que la modification de Ph_Symbol ne continue plus de 3 fois. Cette primitive est générée chaque fois que CARRIER_STATUS effectue une transition de CARRIER_OFF à CARRIER_ON ou inversement.

#### 5.11.4 Indication PLS_SIGNAL

L'indication PLS_SIGNAL doit fournir une indication de l'état du décodage par la MDS. Le paramètre SIGNAL_STATUS doit prendre l'une des deux valeurs; NO_SIGNAL_ERROR ou SIGNAL_ERROR. NO_SIGNAL_ERROR indique que la MDS détecte le modèle de code Manchester "L, H" ou "H, L" depuis Ph_Symbols qui a été entré depuis la MAU. SIGNAL_STATUS indique que la MDS détecte une violation de code Manchester. Cette primitive est générée chaque fois que SIGNAL_STATUS effectue une transition de SIGNAL_ERROR à NO_SIGNAL_ERROR ou inversement.

#### 5.11.5 Indication PLS_DATA_VALID

L'indication PLS_DATA_VALID doit fournir une indication de la synchronisation Ph_Symbol par la MDS. Le paramètre DATA_VALID_STATUS doit prendre l'une des deux valeurs; DATA_VALID ou DATA_NOT_VALID. DATA_VALID indique que la MDS détecte la séquence de configuration binaire "0, 1, 0" ou "1, 0, 1" depuis le DL_Symbol à transmettre à la DLL. DATA_NOT_VALID indique que la MDS détecte la disparition de la porteuse. Cette primitive est générée chaque fois que DATA_VALID_STATUS effectue une transition de DATA_NOT_VALID à DATA_VALID ou inversement.

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### 5.11.6 Indication PLS_DATA

L'indication PLS_DATA doit représenter DL_Symbol. Les symboles valides doivent être ZÉRO {0} ou ONE {1}. L'indication PLS_DATA doit représenter DL_Symbol tel que décodé depuis la MAU chaque fois que le paramètre de l'indication PLS_DATA_VALID est DATA_VALID.

### 5.11.7 Demande PLS_DATA

La demande PLS_DATA doit représenter le DL_Symbol à transmettre. Le paramètre OUTPUT_UNIT doit prendre l'une des trois valeurs, ZÉRO, ONE.

## 5.12 Type 20: Services exigés

### 5.12.1 Fonctionnalités des services de la couche physique

La PhE offre les services suivants:

- Data service – il prend en charge le transfert des user-data du service de couche physique (PhS) d'un PhS-user source à un PhS-user cible, et
- services de gestion de la PhL – ils prennent en charge la configuration du PhL.

### 5.12.2 Séquence de primitives

Les relations entre les primitives de chaque type au niveau de l'interface de l'utilisateur PhS et d'une PhE et les primitives au niveau de PhS-user et des autres PhE sont récapitulées dans les schémas de la Figure 10.

Avant d'utiliser la PhE, il convient que PhS-user démarre la transmission de l'activité sur le support utilisant le service représenté à la séquence de la Figure 10 a). Dans la cible, la réception démarre avec indication PH-START lorsque l'activité a été détectée par la PhE. La séquence de la Figure 10 b) représente l'émission de la PhPDU de l'entité PhL source (PhE) à la PhE cible, un octet de données par demande. La réception se termine avec indication de Ph-Data dans la cible. En cas d'erreur dans la réception, la PhE dans la cible l'indique alors par un paramètre d'état et peut délivrer des données PhS-user. Après avoir transmis toutes les données, il convient que l'utilisateur PhS arrête la transmission de l'activité telle qu'elle est représentée dans la séquence de la Figure 10 c).

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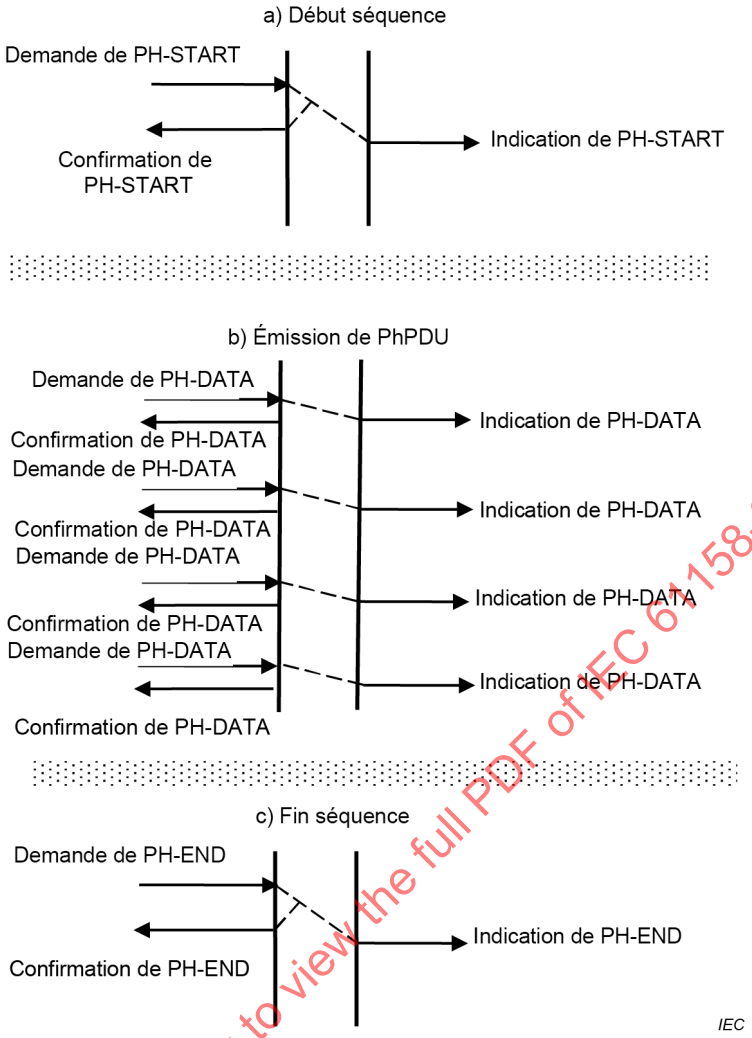


**Figure 10 – Séquences de service de données de la couche physique**

### 5.12.3 Service de PH-START

#### 5.12.3.1 Types de primitives et de paramètres

Les types de primitives et de paramètres nécessaires au service de PH-START sont indiqués dans le Tableau 5. Ce service est utilisé pour démarrer l'activité dans le support et émettre les PhPDU qui précèdent les données Ph-user. Le service de demande est réussi uniquement si le support se trouve à l'état de repos. La primitive de confirmation n'implique pas l'indication réussie à tout autre appareil relié au support. L'appareil de réception détecte la présence de l'activité et après un délai, il fournit l'indication au PhS-user.

**Tableau 5 – Primitives et paramètres de PH-START**

| Nom de paramètre | Demande | Indication | Confirmation |
|---|---|---|---|
| Status | | | O |

#### 5.12.3.2 Paramètres

La primitive de demande ne requiert aucun paramètre. La primitive d'indication n'achemine aucun paramètre. La primitive de confirmation indique un succès ou la raison de l'erreur.

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### 5.12.4 Service de PH-DATA

#### 5.12.4.1 Types de primitives et de paramètres

Les types de primitives et de paramètres nécessaires au service de PH-DATA sont indiqués dans le Tableau 6.

**Tableau 6 – Primitives et paramètres de PH-DATA**

| Nom de paramètre | Demande | Indication | Confirmation |
|---|---|---|---|
| PhS-user-data | O | C(=) | |
| Status | | O | O |

#### 5.12.4.2 Paramètres

##### 5.12.4.2.1 PhS-user-data

Ce paramètre permet la transmission de données à octet unique entre les PhS-users sans altération par le PhS-provider. Après la confirmation de PH-START, il convient que les PhS-users lancent une demande de PH-DATA afin que toutes les données soient transmises comme partie d'une transmission continue correctement formée. En cas d'erreur de réception, soit ce paramètre est absent dans la primitive d'indication, soit sa valeur peut être erronée. Sinon, sa valeur est identique à la valeur dans la primitive de demande.

##### 5.12.4.2.2 Status

Dans la primitive d'indication, ce paramètre indique un succès ou l'une des raisons d'erreur suivantes:

– dépassement de mémoire tampon de réception;
– erreur de parité;
– erreur de trame;
– réception de données discontinue.

Dans la primitive de confirmation, ce paramètre indique un succès ou l'une des raisons d'erreur suivantes:

– émetteur occupé;
– support inactif.

### 5.12.5 Service de PH-END

Ce service est utilisé pour terminer l'activité dans le support et émettre les PhPDU qui succèdent aux données Ph-user. La primitive de confirmation n'implique pas l'indication réussie à tout appareil relié au support. Ce service n'exige aucun paramètre. La primitive d'indication est fournie par la PhE lorsqu'un manque d'activité du support est détecté.

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### 5.13 Type 28: Services exigés

#### 5.13.1 Généralités

L'entité de couche physique (PhE) fournit les services suivants:

Ph-Param – Prend en charge la PhE pour informer l'entité de liaison physique (DLE) de la configuration de paramètre de la couche physique (PhL) en cours.

Ph-Data – Prend en charge la transmission de données entre les utilisateurs du service de couche physique (PhS).

Ph-Clock-Sync – Prend en charge les utilisateurs de la PhS pour mettre en œuvre la synchronisation d'horloge.

#### 5.13.2 Ph-Param (para, value)

La PhE informe le DLE des paramètres en cours relatifs au mode de fonctionnement, au codage et à la modulation. Il convient que le DLE mette en œuvre l'encapsulation et le traitement de l'unité de données de service PhL (PhLSDU) en fonction de ces paramètres. Les primitives et paramètres du service Ph-Param sont présentés dans le Tableau 7. Les paramètres de primitive sont décrits dans le Tableau 8.

**Tableau 7 – Primitives et paramètres du service Ph-Param**

| Nom de paramètre | Indication |
|---|---|
| para | O |
| value | O |

**Tableau 8 – Paramètre de primitive du service Ph-Param**

| para | | value |
|---|---|---|
| para index | para description | |
| 0 | Transmit_mode | 0 à 3, voir le Tableau 50, TM du système en cours |
| 1 | Work_mode | 0 à 21, voir le Tableau 51 et le Tableau 52, paramètre du mode de fonctionnement en cours<br>0 à 9, correspondant aux modes de fonctionnement A0 à A9<br>10 à 21 correspondant aux modes de fonctionnement B0 à B11 |
| 2 | Rs_code | 0 à 11, voir le Tableau 71, mode de code RS |
| 3 | Con_code | 0 à 2, voir le Tableau 72, mode de code de convolution |
| 4 | Qam_mode | 0 à 2, correspondant respectivement à trois modes de mapping de 16QAM, 64QAM et 64QAM |

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Le processus de cette primitive de service est représenté à la Figure 11.

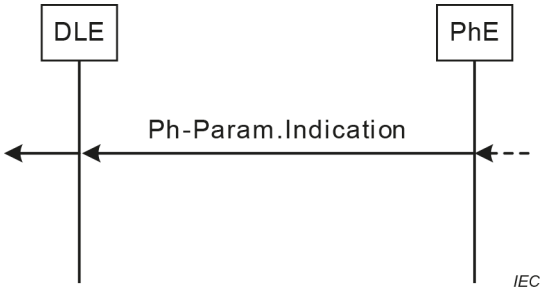


**Figure 11 – Processus de la primitive de service Ph-Param**

### 5.13.3 Ph-Data (length, data, status)

La PhE fournit les fonctions DLL permettant de transmettre et de recevoir des données en fonction du service. Les primitives et paramètres du service sont présentés dans le Tableau 9. La longueur du paramètre de primitive est exprimée en octet. Les données de paramètre sont Data-link Protocol Data Unit (DLPDU) et l'état est le résultat du traitement de la primitive de service correspondante. Les paramètres de primitive sont décrits dans le Tableau 10.

**Tableau 9 – Primitives et paramètres du service Ph-Data**

| Nom de paramètre | Demande | Indication | Confirmation |
|---|---|---|---|
| length | O | O | O |
| data | O | O | |
| status | | O | O |

**Tableau 10 – Paramètre de primitive du service Ph-Data**

| Nom de paramètre | Description |
|---|---|
| length | Spécifier la longueur en octet des données |
| data | Lors de la transmission ou de la réception de la DLPDU, les données ne sont pas valables lorsque le drapeau est la confirmation de transmission |
| status | Ce paramètre est une valeur de 16 bits<br>Informations d'état indiquées par bit<br>le bit 0 indique l'état de transmission ou de réception<br>Le bit correspondant défini sur 0 indique la transmission, et la réception lorsqu'il est défini sur 1<br>le bit 1 indique l'état des données<br>le bit 2 indique l'état du contrôle CRC<br>Le bit correspondant défini sur 0 indique que l'état est correct, et une erreur de statut lorsqu'il est défini sur 1<br>Le bit 3 au bit 15 sont réservés |

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La DLE demande à la PhE de transmettre les données en fonction de la primitive Ph-Data.request. Lorsque la PhL reçoit la primitive de demande DLL Ph-Data, la PhLDE convertit la DLPDU en PhSDU conformément aux informations de commande d'interface (PhICI) et ajoute les informations de commande de protocole de couche physique (PhPCI). La PhPDU doit être transmise au support physique sous la forme d'un signal physique après le codage et la modulation. Le résultat de la transmission est livré à la DLE par l'intermédiaire de la primitive Ph-Data.Confirm.

La PhLDE informe la DLDE de recevoir les données en fonction de la primitive Ph-Data.indication. Lorsque la PhL reçoit la PhPDU sous forme d'un signal physique par l'intermédiaire du support, il convient que la PhLDE décode la PhSDU transmise par la PhLDE homologue et la convertisse en DLPDU conformément à la PhICI après démodulation et décodage, puis envoie les informations à la DLE à l'aide de la primitive Ph-Data.indication.

Le processus de cette primitive de service est représenté à la Figure 12.

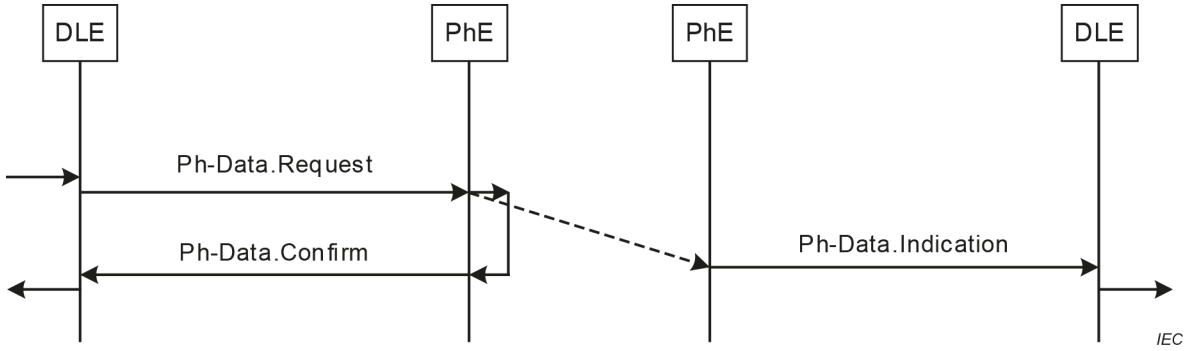


**Figure 12 – Processus de la primitive de service Ph-Data**

### 5.13.4 Ph-Clock-Sync (command, data, ofdmtiming)

La PhE fournit un service de synchronisation d'horloge à la DLL. Il convient que la DLL mette en œuvre la fonction de synchronisation d'horloge et de mesure du retard en s'appuyant sur ce service. Les primitives et paramètres du service sont présentés dans le Tableau 11. Les paramètres de primitive sont décrits dans le Tableau 12.

**Tableau 11 – Primitives et paramètres du service Ph-Clock-Sync**

| Nom de paramètre | Demande | Indication |
|---|---|---|
| command | O | O |
| data | O | O |
| ofdmtiming | | O |

**Tableau 12 – Paramètre de primitive du service Ph-Clock-Sync**

| Nom de paramètre | Description |
|---|---|
| command | La DLL demande la commande de synchronisation d'horloge PhL<br>0: synchronisation d'horloge<br>1: mesurage du retard |
| data | Trame synchrone d'horloge, longueur fixe |
| ofdmtiming | Informations de temporisation OFDM de la PhL<br>Seule la primitive d'indication est valable |

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Lorsque la DLE demande à la PhE de transmettre les informations de synchronisation d'horloge (command = 0 ou 1) à l'aide de la primitive Ph-Clock-Sync.Request, il convient que la PhLDE renseigne le champ d'informations d'horloge de la trame de synchronisation d'horloge avec les informations de temporisation OFDM en cours, puis convertisse la trame de synchronisation d'horloge en PhSDU selon la PhICI et ajoute les informations PhPCI exigées. La PhLDE code et module la PhPDU en signaux physiques, puis transmet les signaux au support physique. Après la démodulation et le décodage des signaux reçus, il convient que la PhLDE décode la PhSDU transmise par l'entité homologue et la convertisse en trame synchrone d'horloge selon la PhICI. Il convient que la PhLDE transmette la PhSDU à la DLL à l'aide de la primitive Ph-Clock-Sync.Indicaton.

Lorsque la PhLDE reçoit la primitive Ph-Clock-Sync.Request (Command = 1), il convient que la PhLDE informe la PhLME de mesurer le retard en plus des trames synchrones d'horloge de transmission.

Le processus de cette primitive de service est représenté à la Figure 13.

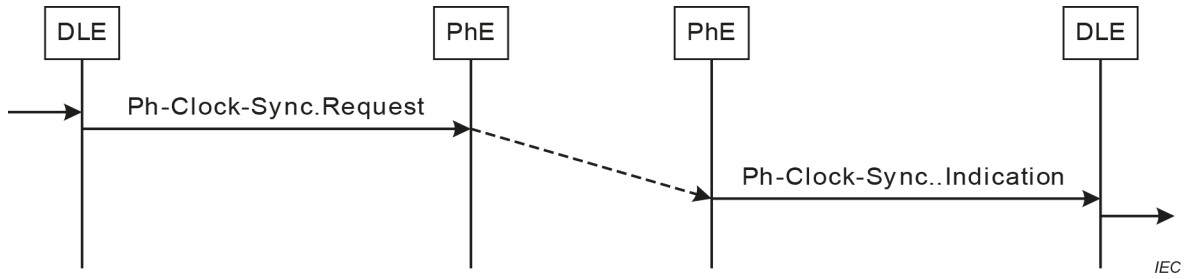


**Figure 13 – Processus de la primitive du service Ph-Clock-Sync**

# 6 Gestion des systèmes – Interface PhL

## 6.1 Généralités

Cette interface fournit à la PhL les services exigés pour l'initialisation et la sélection des options.

L'un des objectifs de la PhL est de permettre la prise en charge de variantes futures, telles que l'utilisation de radiofréquences, de fibres optiques, de canaux redondants (par exemple, des câbles), de techniques de modulation différentes, etc. Il est spécifié un modèle général d'Interface Gestion systèmes – PhL qui fournit les services exigés par la mise en œuvre de ces variantes. Les services fournis par cette interface sont spécifiés de 6.2 à 6.5. Le présent document n'exige pas que cette interface soit exposée.

Le jeu complet de services de gestion ne peut être utilisé que lorsque l'appareil est directement couplé au support. Dans le cas de matériel à couplage actif (par exemple, coupleur actif, répéteur, modem radio/téléphonique, appareils optoélectroniques, etc.), certains des services peuvent implicitement appartenir au coupleur actif. Par ailleurs, chaque appareil peut utiliser un sous-ensemble des primitives décrites.

NOTE Plusieurs interfaces Gestion systèmes – PhL différentes sont spécifiées, sur la base des pratiques industrielles en la matière.

## 6.2 Type 1: Gestion des systèmes – Interface PhL

### 6.2.1 Services exigés

La primitive de service minimal pour la gestion PhL (PhL) doit être:

a) Demande de PH-RESET – réinitialisation de la Ph-layer.

Les services supplémentaires suivants peuvent être fournis:

b) Demande de Ph-SET-VALUE/ confirmation de Ph-SET-VALUE– set parameters;

c) Demande de Ph-ET-VALUE/ confirmation de Ph-GET-VALUE – read parameters;

d) Indication de Ph-EVENT – report Ph-layer events.

### 6.2.2 Exigences relatives aux primitives de service

#### 6.2.2.1 Demande de PH-RESET

Cette primitive n'a pas de paramètre. À la réception de la primitive, la PhL doit réinitialiser toutes ses fonctions.

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#### 6.2.2.2 Demande de Ph-SET-VALUE (nom du paramètre, nouvelle valeur)

Si cette primitive est utilisée, elle doit permettre à la Gestion système de modifier les paramètres de la PhL. Le Tableau 13 donne les noms des paramètres et les plages de valeurs normalisés. Par hypothèse, la valeur que prend chaque paramètre lors de la réinitialisation doit être la première valeur parmi celles indiquées pour le paramètre.

**Tableau 13 – Noms et valeurs de paramètres pour la demande de Ph-SET-VALUE**

| Nom de paramètre | Plage de valeurs |
|---|---|
| Mode d'interface | • FULL_DUPLEX<br>• HALF_DUPLEX |
| Mode Loop-back | • DISABLED<br>• dans la MDS à l'interface DTE – DCE<br>• dans la MAU à proximité de la connexion de la ligne |
| Extension du préambule | • 0..7 (séquences d'extension du préambule) |
| Extension de l'intervalle post-émission | • 0..7 (séquences d'extension de l'intervalle) |
| Dérive maximale du signal entre canaux | • 0..7 (séquences d'extension de l'intervalle) |
| Canal de sortie émetteur *N* (1 ≤ *N* ≤ 8) | • ENABLED<br>• DISABLED |
| Canal d'entrée récepteur *N* (1 ≤ *N* ≤ 8) | • ENABLED<br>• DISABLED |
| Canal de réception préférentiel | • NONE<br>• 1..8 |

NOTE 1 Toutes les mises en œuvre n'exigent pas chacun des paramètres et certaines mises en œuvre peuvent en nécessiter davantage.

NOTE 2 Chaque norme DCE spécifie les séquences de base et les séquences d'extension de PhPDU à envoyer comme préambule. Ces séquences d'extension comportent toujours un préfixe qui renvoie à la séquence de base.

NOTE 3 Chaque norme DCE spécifie les longueurs des séquences de base et d'extension de l'intervalle post-émission au cours duquel l'émetteur reste silencieux.

NOTE 4 À partir de ce qui précède, la valeur par défaut lors de la réinitialisation est: un préambule minimal (pas d'extension), un intervalle post-émission minimal (pas d'extension), un mode d'interface bidirectionnel simultané, pas de rebouclage, avec tous les canaux de transmission et de réception activés et sans aucun canal de réception préférentiel.

#### 6.2.2.3 Confirmation de Ph-SET-VALUE (état)

Cette primitive a un paramètre unique indiquant l'état de la demande: Succès ou échec. Si cette primitive est utilisée, elle doit acquitter l'achèvement de la demande Ph-ET-VALUE dans la PhL.

#### 6.2.2.4 Demande de Ph-GET-VALUE (nom du paramètre)

Si cette primitive est utilisée, elle doit permettre à la Gestion système de lire les paramètres de la PhL. Le paramètre doit prendre l'un des noms donnés dans le Tableau 13.

#### 6.2.2.5 Confirmation de Ph-ET-VALUE (valeur actuelle)

Cette primitive est la réponse de la PhL à la demande de Ph-ET-VALUE. Si cette primitive est utilisée, elle doit avoir un paramètre unique indiquant soit l'échec de la demande – Échec – soit la valeur courante du paramètre demandé. La valeur actuelle doit être l'une de celles admises au 6.2.2.2.

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#### 6.2.2.6 Indication de Ph-EVENT (nom du paramètre)

Si cette primitive est utilisée, elle doit indiquer à la Gestion système la modification d'un paramètre PhL qui n'a pas été demandée par la gestion des systèmes. Ce paramètre doit prendre l'un des noms indiqués dans le Tableau 14, qui repose sur ceux spécifiés au 8.2.

**Tableau 14 – Noms de paramètres pour l'indication de Ph-EVENT**

| Nom de paramètre |
|---|
| Défaut ETTD |
| Défaut DCE |

NOTE Il est possible d'ajouter des noms dans le Tableau 14 si des mises en œuvre spécifiques l'exigent.

### 6.3 Type 3: Gestion des systèmes – Interface PhL

#### 6.3.1 Transmission synchrone

Les services ainsi que les exigences liées aux primitives de service spécifiées pour le Type 1 doivent être utilisés (voir 6.2).

#### 6.3.2 Transmission asynchrone

##### 6.3.2.1 Généralités

Le paragraphe 6.3.2 décrit l'interface entre la transmission asynchrone PhL et un PhMS-user ainsi que les primitives de service et paramètres correspondants.

Le modèle de service, les primitives de service et les schémas de temps-séquence utilisés sont des descriptions totalement abstraites; ils ne constituent pas une spécification pour une mise en œuvre.

Les primitives de service utilisées pour représenter les interactions entre utilisateur de service et fournisseur de service (voir ISO/IEC 10731) acheminent des paramètres qui indiquent les informations disponibles dans l'interaction utilisateur/fournisseur.

Ce type, tel qu'il est décrit dans le présent document, utilise un format tabulaire pour décrire les paramètres constitutifs des primitives PhMS. Chaque tableau comprend jusqu'à trois colonnes, qui donnent le nom du paramètre de service, ainsi qu'une colonne pour ces primitives et les sens de transfert des paramètres utilisés par le PhMS:

– les paramètres d'entrée de la primitive de demande;
– les paramètres de sortie de la primitive d'indication; et
– les paramètres de sortie de la primitive de confirmation.

Un paramètre (ou partie de ce paramètre) est présenté dans chaque rangée de chaque tableau. Dans les colonnes des primitives de service concernées, un code permet de spécifier le type d'utilisation du paramètre sur la primitive et le sens du paramètre spécifié dans la colonne:

**O** – Le paramètre est obligatoire pour la primitive.

**(blank)** – Le paramètre n'est jamais présent.

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#### 6.3.2.2 Fonctionnalités du PhMS

La Gestion Ph organise l'initialisation et la configuration de la PhE ainsi que le traitement des événements et des erreurs entre PhMS-user et les fonctions logiques dans la PhE. PhMS-user comporte les fonctions suivantes.

a) Réinitialisation de la PhE locale

b) Demande et modification des paramètres de fonctionnement réels de la PhE locale

c) Notification des événements inattendus et modification d'état de la PhE locale

#### 6.3.2.3 Vue d'ensemble des services

La Ph-management fournit au PhMS-user les services suivants:

a) Réinitialiser

Le PhMS-user utilise ce service pour que la Ph-management réinitialise la PhE. Une réinitialisation équivaut à une mise sous tension. Le PhMS-user en reçoit confirmation.

b) Établir valeur

Le PhMS-user utilise ce service pour attribuer une nouvelle valeur aux variables de la PhE. Le PhMS-user reçoit une confirmation indiquant si les variables spécifiées ont été établies à la nouvelle valeur.

c) Obtenir valeur

Ce service permet à la Ph-management de lire les variables de la PhE. La réponse de la gestion de Ph-management retourne la valeur réelle des variables spécifiées.

d) Événement

Ce service est utilisé par la Ph-management pour informer le PhMS-user de certains événements ou erreurs dans la PhL.

Les services Réinitialiser et Événement sont obligatoires. Les services Établir valeur et Obtenir valeur sont facultatifs.

#### 6.3.2.4 Vue d'ensemble des interactions

Les services Ph-management et leurs primitives sont résumés dans le Tableau 15.

**Tableau 15 – Résumé des primitives et des services de Ph-management**

| Service | Primitive | Possible pour les stations suivantes |
|---|---|---|
| Réinitialiser | Demande de PhM-RESET<br>Confirmation de PhM-RESET | Maître et esclave |
| Établir valeur | Demande de PhM-SET-VALUE<br>Confirmation de PhM-SET-VALUE | Maître et esclave |
| Obtenir valeur | Demande de PhM-GET-VALUE<br>Confirmation de PhM-GET-VALUE | Maître et esclave |
| Événement | Indication PhM-EVENT | Maître et esclave |

Les relations temporelles des primitives de Ph-management sont représentées à la Figure 14 et la Figure 15.

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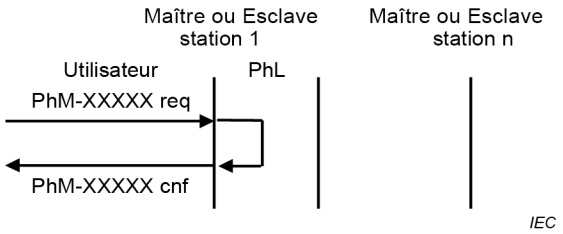


**Figure 14 – Réinitialiser, Établir valeur, Obtenir valeur**

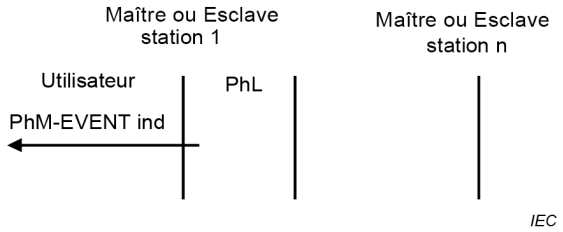


**Figure 15 – Service d'événements**

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### 6.3.2.5 Spécification détaillée des services et interactions

#### 6.3.2.5.1 Réinitialiser

##### 6.3.2.5.1.1 Fonction

PhMS-user transmet une primitive de demande de PhM-RESET au Ph-management pour qu'elle réinitialise la PhE. Cette opération est réalisée de la même manière que lors de la mise sous tension (Transmitter_output: activée; Receiver_signal_source: primaire; Loop: désactivée). En conséquence, le Ph management transmet une primitive de confirmation de PhM-RESET au PhMS-user pour lui indiquer le succès ou l'échec de la demande de service correspondante.

##### 6.3.2.5.1.2 Types de primitives et de paramètres

Les primitives et paramètres du service Réinitialiser sont indiqués dans le Tableau 16.

**Tableau 16 – Primitives et paramètres Réinitialiser**

| PhM-RESET | Demande | Confirmation |
|---|---|---|
| **Nom de paramètre** | | |
| PhM-STATUS | -- | O |
| NOTE La méthode par laquelle une primitive de confirmation est corrélée à sa primitive de demande précédente correspondante relève d'une initiative locale. | | |

**PhM-Status**

Ce paramètre spécifie l'état de l'exécution de la demande de service correspondante. Les valeurs admises pour ce paramètre sont spécifiées dans le Tableau 17.

**Tableau 17 – Valeurs de PhM-Status pour le service Réinitialiser**

| Nom abrégé | Status | Définition | Temporaire (t) ou permanent (p) |
|---|---|---|---|
| OK | succès | La fonction Réinitialiser a été menée avec succès | -- |
| NON | échec | La fonction Réinitialiser a échoué | t/p |
| IV | échec | Paramètres non valides dans la demande | -- |

#### 6.3.2.5.2 Établir valeur

##### 6.3.2.5.2.1 Fonction

PhMS-user transmet une primitive de demande de PhM-SET-VALUE à la Ph-management pour attribuer la valeur souhaitée à une ou plusieurs variables spécifiées de la PhE. Après avoir reçu cette primitive, la Ph-management tente de sélectionner ces variables et d'attribuer de nouvelles valeurs. Si le service demandé a été exécuté, la Ph-management transmet une primitive de confirmation de PhM-SET-VALUE au PhMS-user pour indiquer le succès ou l'échec de la demande de service correspondante.

##### 6.3.2.5.2.2 Types de primitives et de paramètres

Les primitives et paramètres du service Établir valeur sont indiqués dans le Tableau 18.

**Tableau 18 – Primitives et paramètres Établir valeur**

| PhM-SET-VALUE | Demande | Confirmation |
|---|---|---|
| **Nom de paramètre** | | |
| Variable_name (1 à 3) | O | -- |
| Desired_value (1 à 3) | O | -- |
| PhM-STATUS (1 à 3) | -- | O |
| NOTE La méthode par laquelle une primitive de confirmation est corrélée à sa primitive de demande précédente correspondante relève d'une initiative locale. | | |

**Variable_name**

Ce paramètre de la matrice spécifie une ou plusieurs variables (1 à 3) auxquelles doivent être attribuées des valeurs à partir des éléments correspondants du paramètre Desired_value. Les variables qui peuvent être sélectionnées sont des paramètres de fonctionnement; elles sont spécifiées dans le Tableau 19.

**Tableau 19 – Variables PhE obligatoires**

| Paramètres de fonctionnement | |
|---|---|
| **Nom** | **Définition** |
| Transmitter_output | Sortie de l'émetteur |
| Receiver_signal_source | Entrée du récepteur |
| Boucle | La sortie de l'émetteur est dirigée vers l'entrée du récepteur et non vers le support |

**Desired_value**

Ce paramètre de la matrice spécifie la valeur réelle à attribuer aux variables (1 à 3) qui sont spécifiées par le paramètre Variable_name. Ce paramètre spécifie une liste d'une ou plusieurs (1 à 3) nouvelles valeurs pour les PhE-variables spécifiées. La valeur admissible ou la plage de valeurs correspondante pour chacune de ces variables est spécifiée dans le Tableau 20.

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**Tableau 20 – Valeurs admissibles des PhE-variables**

| Paramètres de fonctionnement | |
|---|---|
| **Variable** | **Plage de valeurs** |
| Transmitter_output | activée ou désactivée |
| Receiver_signal_source | primaire: câble bus "a" (origine normalisée)<br>autre possibilité: câble bus "b" (origine alternative)<br>aléatoire: soit "a" soit "b" |
| Boucle | désactivée ou activée |

**PhM-Status**

Ce paramètre de la matrice spécifie, pour chaque variable de la demande correspondante, l'état de cette composante du service demandé. Les valeurs admises pour les composantes individuelles de ce paramètre de matrice sont spécifiées dans le Tableau 21.

**Tableau 21 – Valeurs de PhM-Status pour le service Établir valeur**

| Nom abrégé | Status | Définition | Temporaire (t) ou permanent (p) |
|---|---|---|---|
| OK | succès | La nouvelle valeur de la variable a été établie | -- |
| NON | échec | La variable n'existe pas ou la nouvelle valeur n'a pas pu être établie | t/p |
| IV | échec | Paramètres non valides dans la demande | -- |

#### 6.3.2.5.3 Obtenir valeur

##### 6.3.2.5.3.1 Fonction

PhMS-user transmet une primitive de demande PhM-GET-VALUE au Ph-management pour lire la valeur actuelle d'une ou de plusieurs variables de la PhE. Après réception de cette primitive, la Ph-management tente de sélectionner les variables spécifiées et de remettre leurs valeurs actuelles; elle transmet au PhMS-user une primitive de confirmation de PhM-GET-VALUE pour indiquer le succès ou l'échec de la demande de service correspondante. Cette primitive renvoie comme paramètre une ou plusieurs des valeurs de variables demandées.

##### 6.3.2.5.3.2 Types de primitives et de paramètres

Les primitives et paramètres du service Obtenir valeur sont indiqués dans le Tableau 22.

**Tableau 22 – Primitives et paramètres Obtenir valeur**

| PhM-GET-VALUE | Demande | Confirmation |
|---|---|---|
| **Nom de paramètre** | **entrée** | **sortie** |
| Variable_name (1 à 3) | O | -- |
| Current_value (1 à 3) | -- | O |
| PhM-STATUS | -- | O |
| NOTE La méthode par laquelle une primitive de confirmation est corrélée à sa primitive de demande précédente correspondante relève d'une initiative locale. | | |

**Variable_name**

Ce paramètre spécifie une ou plusieurs variables (1 à 3) dont les valeurs doivent être lues. Les variables qui peuvent être sélectionnées sont spécifiées dans le Tableau 19.

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**Current_value**

Ce paramètre de la matrice spécifie la valeur réelle des variables (1 à 3) qui ont été spécifiées par le paramètre Variable_name de la demande correspondante. La valeur admissible ou la plage de valeurs correspondante pour chacune de ces variables est spécifiée dans le Tableau 23.

**Tableau 23 – Valeurs actuelles des PhE-variables**

| Paramètres de fonctionnement | |
|---|---|
| **Variable** | **Plage de valeurs** |
| Transmitter_output | activée ou désactivée |
| Receiver_signal_source | primaire ou alternative |
| Boucle | désactivée ou activée |

**PhM-Status**

Ce paramètre de la matrice spécifie, pour chaque variable de la demande correspondante, une confirmation de l'exécution du service. Les valeurs admises pour ce paramètre sont spécifiées dans le Tableau 24.

**Tableau 24 – Valeurs de PhM-Status pour le service Obtenir valeur**

| Nom abrégé | Status | Définition | Temporaire (t) ou permanent (p) |
|---|---|---|---|
| OK | succès | La variable a pu être lue | -- |
| NON | échec | La variable n'existe pas ou n'a pas pu être lue<br>La valeur correspondante de Current_value n'est pas définie | t/p |
| IV | échec | Paramètres non valides dans la demande | -- |

#### 6.3.2.5.4 Événement

##### 6.3.2.5.4.1 Fonction

La PhE informe la Ph-management qu'elle a détecté un événement. Ensuite, la Ph-management transmet une primitive d'indication de Ph-EVENT au PhMS-user pour l'informer d'événements importants dans la PhL.

##### 6.3.2.5.4.2 Types de primitives et de paramètres

La primitive et les paramètres du service Événement sont indiqués dans le Tableau 25.

**Tableau 25 – Primitive et paramètres Événement**

| | PhM-EVENT | Indication |
|---|---|---|
| **Nom de paramètre** | | **sortie** |
| Variable_name (1 à 2) | | O |
| New_value (1 à 2) | | O |

**Variable_name**

Ce paramètre de la matrice spécifie une ou plusieurs variables (1 à 2) dont les valeurs ont été modifiées. Les variables qui peuvent être présentes sont spécifiées dans le Tableau 19.

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**New_value**

Ce paramètre spécifie la nouvelle valeur de la variable. Les différentes valeurs sont présentées dans le Tableau 26.

**Tableau 26 – Nouvelles valeurs des PhE-variables**

| Variable | Plage de valeurs |
|---|---|
| Transmitter_output | activée ou désactivée |
| Receiver_signal_source | primaire ou alternative |

## 6.4 Type 4: Gestion des systèmes – Interface PhL

### 6.4.1 Services exigés

Les services spécifiés au 6.2 sont utilisés.

### 6.4.2 Exigences relatives aux primitives de service

Les exigences relatives aux primitives de service sont spécifiées au 6.2.2, avec la restriction suivante:

Les paramètres spécifiés dans le Tableau 13 ne sont pas pris en charge.

Les paramètres qui peuvent être modifiés et lus par les services de gestion PhL sont présentés dans le Tableau 27. Les valeurs prises en charge ainsi que la valeur par défaut de chaque paramètre dépendent du support et de la mise en œuvre réels.

**Tableau 27 – Noms des paramètres et valeurs de gestion**

| Nom de paramètre | Plage de valeurs |
|---|---|
| Mode d'interface | HALF_DUPLEX<br>FULL_DUPLEX_UDP |
| Débit en bauds (kbaud/s) | 230 400<br>76 800<br>38 400<br>19 200<br>9 600 |

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## 6.5 *Vide*

NOTE Dans la présente édition, le 6.5 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

## 6.6 Type 8: Gestion des systèmes – Interface PhL

### 6.6.1 Fonctionnalité de la PhL Management

La gestion de la PhL est la partie de la PhL qui produit la fonctionnalité de gestion de la PhL demandée par la PNM1. La gestion de la PhL traite l'initialisation, la surveillance et la récupération d'erreurs dans la PhL.

### 6.6.2 Interface PhL-PNM1

#### 6.6.2.1 Généralités

Le paragraphe 6.6.2 définit les services de gestion administrative de la PhL qui sont mis à la disposition de la PNM1, ainsi que leurs primitives de service et paramètres correspondants. La Figure 16 représente l'interface entre PhL et PNM1 dans le modèle en couches.

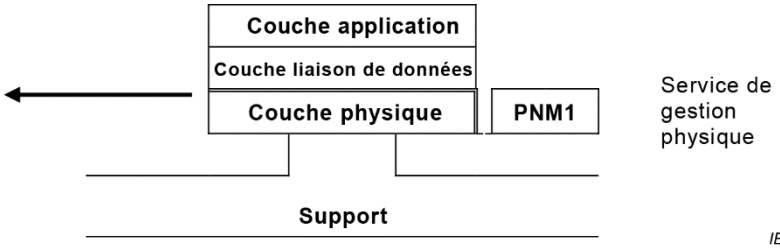


**Figure 16 – Interface entre PhL et PNM1 dans le modèle en couches**

L'interface de service entre PhL et PNM1 assure les fonctions suivantes:

– rinitialisation de la PhL;
– demande et modification des paramètres de fonctionnement courants de la PhL;
– indication d'événements inattendus, d'erreurs et de modifications d'état, qui ont eu lieu ou ont été détectés dans la PhL.

#### 6.6.2.2 Vue d'ensemble des services

La PhL met les services suivants à la disposition de la PNM1:

– réinitialiser PhL;
– établir valeur PhL ou Obtenir valeur PhL;
– événement PhL.

**Réinitialiser PhL (obligatoire)**

La PNM1 utilise ce service pour réinitialiser la PhL. La réinitialisation équivaut à une mise sous tension. Après exécution du service, la PNM1 reçoit une confirmation.

**Établir valeur PhL (facultatif)**

La PNM1 utilise ce service pour établir de nouvelles valeurs des variables PhL. Après achèvement, la PNM1 de la PhL reçoit une confirmation indiquant si les variables définies ont pris par hypothèse de nouvelles valeurs.

**Obtenir valeur PhL (facultatif)**

La PNM1 utilise ce service pour lire des variables de la PhL. La valeur courante de la variable définie est renvoyée dans la réponse de la PhL.

**Événement PhL (obligatoire)**

La PhL utilise ce service pour informer l'utilisateur PNM1 de certains événements ou erreurs dans la PhL.

#### 6.6.2.3 Vue d'ensemble des interactions

Les services PhL sont décrits par les primitives suivantes (commençant par Ph-…):

**Réinitialiser PhL**

Demande de PH-RESET
Confirmation de PH-RESET

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**Établir valeur PhL**

Demande de Ph-SET-VALUE
Confirmation de Ph-SET-VALUE

**Obtenir valeur PhL**

Demande de Ph-GET-VALUE
Confirmation de Ph-GET-VALUE

**Événement PhL**
Indication Ph-Event

La Figure 17 et la Figure 18 représentent les relations temporelles entre primitives de service.

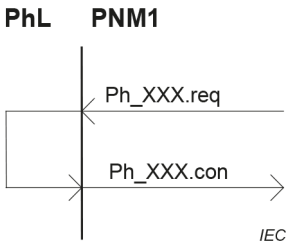


**Figure 17 – Services Réinitialiser, Établir valeur, Obtenir valeur PhL**

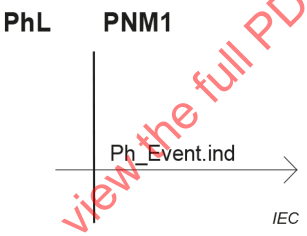


**Figure 18 – Service d'événements PhL**

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#### 6.6.2.4 Définitions détaillées des services et interactions

##### 6.6.2.4.1 PH-RESET

Le service PH-RESET est obligatoire. La PNM1 transfère une primitive de demande de PH-RESET à la PhL pour la réinitialiser (voir le Tableau 28).

**Tableau 28 – PH-RESET**

| Nom de paramètre | Demande | Confirmation |
|---|---|---|
| Argument | O | |
| Résultat(+) | | O |

##### 6.6.2.4.2 Ph-SET-VALUE

Le service Ph-SET-VALUE est facultatif. La PNM1 transfère une primitive de demande de Ph-SET-VALUE pour régler une variable Ph définie à une valeur souhaitée. Après réception de cette primitive, la PhL tente de sélectionner la variable et d'établir la nouvelle valeur. Après achèvement, la PhL transmet une primitive de confirmation de Ph-SET-VALUE à la PNM1 (voir le Tableau 29).

**Tableau 29 – Ph-SET-VALUE**

| Nom de paramètre | Demande | Confirmation |
|---|---|---|
| Argument | O | |
| variable_name: | O | |
| desired_value: | O | |
| Résultat(+) | | O |

**variable_name:**

Ce paramètre définit la variable PhL qui a été établie à une nouvelle valeur.

**desired_value:**

Ce paramètre déclare la nouvelle valeur de la variable PhL.

Le Tableau 30 fournit des informations par l'intermédiaire desquelles la variable PhL peut être modifiée à la nouvelle valeur.

**Tableau 30 – Variables PhL**

| Nom de la variable PhL |
|---|
| loopback_mode |
| medium_attachment |
| bus_ interfaces |
| short_ bus_reset_time |
| long_bus_reset_time |
| data_select |

**loopback_mode:**

Ce paramètre définit si le circuit de réception de la MAU est connecté au circuit de transmission ou au support.

Structure du paramètre:

– numéro d'interface

  Définit le numéro de l'interface d'arrivée et de départ (voir la Figure 19).

– état

  Ce paramètre définit si le circuit de réception de la MAU est connecté (activé) ou non (désactivé). Après mise sous tension, cette valeur est sur "activé".

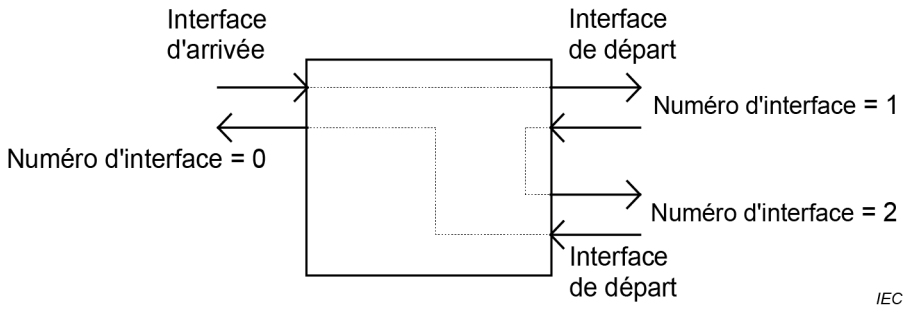


**Figure 19 – Attribution du numéro d'interface**

NOTE Un maître a toujours le numéro d'interface = 2.

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**medium_attachment:**

Ce paramètre indique si la MAU est couplée au support de transmission. Cette information est obtenue en détectant la présence d'un connecteur branché à l'interface de départ.

Structure du paramètre:

– numéro d'interface

  Déclare le numéro de l'interface du bus (voir la Figure 19).

– branchement

  Ce paramètre définit si l'interface est branchée au support de transmission.

**bus_interfaces:**

– numéro d'interface

  Déclare le numéro de l'interface du bus (voir la Figure 19).

– type d'interface

  Définit le type de l'interface physique et du support de transmission:

  - Interface d'arrivée, à 2 conducteurs
  - Interface de départ, à 2 conducteurs

**short_bus_reset_time:**

Ce paramètre définit la durée de la réinitialisation courte. Après mise sous tension, cette valeur est de 5 ms.

**long_bus_reset_time:**

Ce paramètre définit la durée de la réinitialisation longue. Après mise sous tension, cette valeur est de 100 ms.

**data_select:**

Ce paramètre indique qu'une Reset_PhPDU ou une medium_activity_status_PhPDU est envoyée sur le support de transmission pour une MAU passive de départ (mode rebouclage = désactivation)

Structure du paramètre

– numéro d'interface

  Définit le numéro de l'interface du bus (voir la Figure 19). Plage de valeurs (1 à 2)

– couplage

  Désactivation: une PhPDU de réinitialisation est émise sur le support de transmission;

  Activation: la PhPDU d'état d'activité du support est émise sur le support de transmission; après "mis sous tension" cette valeur est "désactivation".

#### 6.6.2.4.3 Ph-GET-VALUE

Le service Ph-GET-VALUE est facultatif. La PNM1 transfère une primitive de demande de Ph-GET-VALUE à la PhL pour relever la valeur actuelle d'une variable PhL définie. Lorsque la PhL a reçu cette primitive, elle tente de sélectionner la variable définie et de transférer sa valeur courante à la PNM1 au moyen de la primitive de confirmation de Ph-GET-VALUE (voir le Tableau 31).

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**Tableau 31 – Ph-GET-VALUE**

| Nom de paramètre | Demande | Confirmation |
|---|---|---|
| Argument | O | |
| variable_name | O | |
| Résultat(+) | | O |
| current_value | | O |

**variable_name:**

Ce paramètre définit la variable PhL dont la valeur doit être relevée.

**current_value:**

Ce paramètre contient la valeur relevée de la variable PhL. Les variables PhL à lire sont les variables qui peuvent être modifiées au moyen de Ph-SET-VALUE.

#### 6.6.2.4.4 Ph-EVENT

Le service Ph-EVENT est obligatoire. La PhL transfère une primitive d'indication de Ph-EVENT à la PNM1 pour l'informer d'événements importants ou d'erreurs dans la PhL (voir le Tableau 32).

**Tableau 32 – Ph-EVENT**

| Nom de paramètre | Indication |
|---|---|
| Argument | O |
| event | O |

**événement:**

Ce paramètre définit l'événement qui a eu lieu ou la source de l'erreur dans la PhL et peut prendre les valeurs indiquées dans le Tableau 33:

**Tableau 33 – Événements PhL**

| Nom | Signification |
|---|---|
| stop_bit_error | Une erreur de bit d'arrêt a été détectée dans la sous-couche MDS |
| medium_attachment | Le branchement d'un support a été modifié au niveau d'une MAU de départ |

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### 6.7 Type 12: Gestion des systèmes – Interface PhL

Cette interface est conforme aux fonctions de gestion décrites au 22.2.4 de l'ISO/IEC/IEEE 8802-3:2021.

### 6.8 Type 18: Gestion des systèmes – Interface PhL

#### 6.8.1 Généralités

Il n'est pas nécessaire d'exposer l'interface Gestion systèmes – PhL lors de la mise en œuvre d'une PhE de Type 18. Cette interface peut être interne au nœud et peut être mise en œuvre comme interne à un appareil à semi-conducteur.

### 6.8.2 Services exigés

La primitive de service minimal pour la gestion PhL doit être:

a) demande de PH-RESET – réinitialisation de la Ph-layer;

b) demande de Ph-SET-VALUE – réglage des paramètres.

### 6.8.3 Exigences relatives aux primitives de service

#### 6.8.3.1 Demande de PH-RESET

Cette primitive n'a pas de paramètre. À la réception de la primitive, la PhL doit réinitialiser toutes ses fonctions.

#### 6.8.3.2 Demande de Ph-SET-VALUE (nom du paramètre, nouvelle valeur)

Cette primitive doit permettre à la Gestion système de modifier les paramètres de la PhL. Le Tableau 34 donne les noms des paramètres et les plages de valeurs normalisés.

Toutes les valeurs ne sont pas prises en charge par toutes les variantes de PhE de Type 18. Des limites de débits en bauds sont associées à la variante de MAU de Type 18 mise en œuvre.

**Tableau 34 – Noms et valeurs de paramètres pour la demande de Ph-SET-VALUE**

| Nom de paramètre | Plage de valeurs |
|---|---|
| Débit en bauds (kbaud/s) | 10 000 |
| | 5 000 |
| | 2 500 |
| | 625 |
| | 156 |

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## 6.9 Type 24: Gestion des systèmes – Interface PhL

Les primitives de service suivantes pour la gestion PhL doivent être prises en charge: Une spécification détaillée pour chaque primitive de service dépend du support et de la mise en œuvre réels.

a) Demande de PH-RESET – réinitialisation de la Ph-Layer

b) Demande de Ph-SET-VALUE/ confirmation de Ph-SET-VALUE – réglage des paramètres

c) Demande de Ph-GET-VALUE/ confirmation de Ph-GET-VALUE – lecture des paramètres

d) Indication de Ph-EVENT – rapport d'événements de la Ph-Layer

## 6.10 Type 28: Gestion des systèmes – Interface PhL

### 6.10.1 Généralités

Cette interface fournit à la PhL les services exigés pour l'initialisation et la sélection des options.

L'utilisateur de la gestion système traite le contenu connexe de la PhLME en fonction de cette interface. Il convient que le paramètre d'interface parameter_index corresponde à la PhLME. Voir 6.10.2 pour des informations connexes relatives à l'entité PhL et à la gestion système. Le paragraphe 6.10 n'exige pas que cette interface soit exposée. Chaque appareil du réseau peut utiliser un sous-ensemble des primitives décrites dans le présent document.

### 6.10.2 Tableau d'informations de gestion relatives à PhL

#### 6.10.2.1 Généralités

Les informations de gestion PhL incluent les informations relatives à la configuration de l'appareil, à la configuration du système, à la gestion des informations de gestion PhL, au diagnostic et à la maintenance du système, et à la gestion des ressources de communication physiques. L'utilisateur de la gestion système ou de la gestion de liaison de données est autorisé à accéder au tableau d'informations correspondant par l'intermédiaire de l'interface de service fournie par la PhL.

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#### 6.10.2.2 Tableau d'informations physiques relatives à la configuration de l'appareil

Le Tableau 35 définit les informations physiques relatives à la configuration de l'appareil.

**Tableau 35 – Tableau d'informations physiques relatives à la configuration de l'appareil**

| Index de paramètre | Nom de paramètre | RW | Type de données | Description |
|---|---|---|---|---|
| 0x0000 | node_id | R/W | UINT16 | Identifiant de nœud de l'appareil (NodeID)<br>Les 8 bits de poids fort sont réservés, les 8 bits de poids faible sont valides<br>Valeur de "Nombre valide" comprise entre 0 et 255<br>0: nœud de gestion<br>1 à 253: nœud terminal ou NodeID du groupe multidiffusion. Le NodeID du groupe multidiffusion diminue à partir de 253 et prend en charge jusqu'à 16 groupes<br>254: Réservé aux nœuds auxquels aucun NodeID n'a été attribué<br>255: Numéro d'adresse de diffusion |
| 0x0001 | mcn_bmp | RW | UINT16 | Groupe multidiffusion auquel appartient le nœud<br>bit 0 à bit 15: NodeID du groupe multidiffusion correspondant compris entre 238 et 253<br>Le bit correspondant défini sur 0 indique que l'appareil de nœud n'appartient pas au groupe multidiffusion, et la valeur 1 indique que l'appareil de nœud appartient au groupe multidiffusion. |
| 0x0002 | device_role | R/W | UINT8 | Rôle du nœud du type d'appareil représenté par un bit<br>le bit 0 indique s'il s'agit d'un nœud de gestion<br>le bit 1 indique s'il s'agit d'un nœud terminal<br>La valeur 1 attribuée au bit correspondant indique qu'il s'agit d'un rôle correspondant, et la valeur 0 indique qu'il ne s'agit pas d'un rôle correspondant<br>Il convient que les valeurs du bit 0 et du bit 1 sur le nœud de fonctionnement soient différentes<br>bit 2 au bit 7: réservés |
| 0x0003 | device_state | RO | UINT8 | État du nœud aux différentes phases représenté par un bit<br>bit 0: état d'initialisation<br>bit 1: état de configuration<br>bit 2: état de fonctionnement<br>bit 3: état de synchronisation<br>La valeur 0 attribuée au bit correspondant indique que l'état est normal, et la valeur 1 indique que l'état n'est pas normal.<br>bit 5 au bit 7: réservés |
| 0X0004 à 0x008F | réservé | | | Protocole réservé |
| 0X0090 à 0x00FF | réservé | | | Réservé au fabricant de l'équipement |

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#### 6.10.2.3 Tableau d'informations relatives à la configuration du système

Le Tableau 36 définit les informations relatives à la configuration du système.

**Tableau 36 – Tableau d'informations relatives à la configuration du système**

| Index de paramètre | Nom de paramètre | RW | | Type de données | Description |
|---|---|---|---|---|---|
| 0x0100 | trans_mode | R/W | | UINT8 | Mode de transmission<br>Valeur comprise entre 0 et 255, voir le Tableau 50 pour une valeur valide<br>0: mode de transmission 0 correspondant<br>1: mode de transmission 1 correspondant<br>2: mode de transmission 2 correspondant<br>3: mode de transmission 3 correspondant<br>La valeur par défaut est 0<br>Les autres valeurs sont réservées |
| 0x0101 | work_mode_up | R/W | | UINT8 | Mode de fonctionnement sur la bande latérale supérieure<br>Valeur comprise entre 0 et 255 et valeur valide comprise entre 0 et 21 (voir 8.6.2.2.6 pour le mode de fonctionnement).<br>0 à 9: mode de fonctionnement correspondant A0 à A9;<br>10 à 21: mode de fonctionnement correspondant B0 à B11;<br>La valeur par défaut est 0<br>Les autres valeurs sont réservées |
| 0x0102 | work_mode_down | R/W | | UINT8 | Mode de fonctionnement sur la bande latérale inférieure<br>La plage de valeurs et la description de la valeur sont les mêmes que work_mode_up |
| 0x0103 | cb_up | RO | | UINT8 | Mode de codage sur la bande latérale supérieure<br>Plage de valeurs comprise entre 0 et 255<br>La valeur de 5 bits de poids fort correspond au mode de code RS (voir le Tableau 71), et la plage de valeurs valides est comprise entre 0 et 11. Les autres valeurs sont réservées.<br>La valeur de 3 bits de poids faible correspond au mode de code de convolution (voir le Tableau 72) et la plage de valeurs valides est comprise entre 0 et 2. Les autres valeurs sont réservées. |
| 0x0104 | cb_down | RO | | UINT8 | Mode de codage sur la bande latérale inférieure<br>La plage de valeurs et la description de la valeur sont les mêmes que cb_up |

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| Index de paramètre | Nom de paramètre | RW | | Type de données | Description |
|---|---|---|---|---|---|
| 0x0105 | inter_mode | RO | | UINT8 | Mode d'entrelacement<br>Plage de valeurs comprise entre 0 et 255<br>Les 4 bits de poids fort indiquent le mode d'entrelacement<br>de la bande latérale d'entrelacement. Les 4 bits de poids faible indiquent le mode d'entrelacement de la bande latérale inférieure. La plage de valeurs valides des 4 bits est comprise entre 0 et 4, les autres valeurs étant réservées. Voir le Tableau 73 pour la valeur valide. |
| 0x0106 | power_ratio | R/W | | UINT8 | Rapport de puissance de la bande latérale<br>Plage de valeurs comprise entre 0 et 255<br>0: Indique la répartition moyenne de la puissance sur la bande latérale supérieure et la bande latérale inférieure, les autres valeurs étant réservées. |
| 0x0107 | band_flag | R/W | | UINT8 | Drapeau d'occupation de la bande latérale représenté par un bit<br>bit 0: drapeau d'occupation de la bande latérale inférieure.<br>bit 1: drapeau d'occupation de la bande latérale supérieure.<br>La valeur 0 attribuée au bit correspondant indique qu'elle n'est pas occupée, et la valeur 1 indique qu'elle est occupée<br>bit 2 au bit 7: réservés |
| 0x0108 | net_state | RO | | UINT8 | État du réseau<br>Plage de valeurs comprise entre 0 et 255<br>0: état d'initialisation<br>1: état de fonctionnement normal<br>Les autres valeurs sont réservées |
| 0x0109 | reset_en | WO | | UINT8 | Bit du drapeau de réinitialisation représenté par un bit<br>bit 0: Drapeau de réinitialisation PhL<br>Le bit correspondant défini sur 0 indique "désactiver", et la valeur 1 indique ''activer''.<br>bit 1 au bit 7: réservés |
| 0x010A | lb_mode | R/W | | UINT8 | Réglage du mode rebouclage indiqué par un bit.<br>bit 0: rebouclage au niveau des interfaces DCE et ETTD<br>bit 1: rebouclage au niveau de la MAU côté câble.<br>Le bit correspondant défini sur 0 indique "désactiver", et la valeur 1 indique ''activer''.<br>bit 2 au bit 7: réservés |
| 0x010B à 0x018F | réservé | | | | Protocole réservé |
| 0x0190 à 0x01FF | réservé | | | | Réservé au fabricant de l'équipement |

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#### 6.10.2.4 Tableau d'informations relatives à la gestion de la synchronisation PhL

Le Tableau 37 définit le tableau d'informations relatives à la gestion de la synchronisation PhL.

**Tableau 37 – Tableau d'informations relatives à la gestion de la synchronisation PhL**

| Index de paramètre | Nom de paramètre | RW | Type de données | Description |
|---|---|---|---|---|
| 0x0200 | sync_delay | RW | UINT8 | Informations relatives au retard de synchronisation<br>Plage de valeurs comprise entre 0 et 255<br>0: Indique que la synchronisation est normale ou en cours<br>Autres valeurs N: il convient d'attendre N trames de signal (SF) pour commencer le traitement synchrone |
| 0x0201 | cycle_id | RO | UINT16 | Valeur d'ID de cycle<br>Plage de valeurs comprise entre 0 et 65 536<br>Plage de valeurs valides comprise entre 0 et 16 383<br>Les autres valeurs sont réservées |
| 0x0202 | symbol_id | RO | UINT8 | ID de symbole OFDM<br>Plage de valeurs comprise entre 0 et 255<br>La plage de valeurs valides est comprise entre 0 et 63.<br>Les autres valeurs sont réservées |
| 0x0203 | frame_id | RO | UINT64 | ID de trame de signal (SF)<br>Plage de valeurs comprise entre 0 et $(2^{44} - 1)$<br>Les autres valeurs sont réservées |
| 0x0204 | time_mode | R/W | UINT8 | Mode d'informations temporelles actuellement pris en charge par le nœud.<br>Plage de valeurs comprise entre 0 et 255<br>0: Mode TAI<br>1: Mode UTC<br>Les autres valeurs sont réservées |
| 0x0205 | time_high | RO | UINT64 | Informations temporelles du second niveau supérieur actuel du nœud.<br>Plage de valeurs comprise entre 0 et $(2^{48} - 1)$<br>0: informations non disponibles<br>Les autres valeurs sont réservées |
| 0x0206 | time_low | RO | UINT64 | Informations temporelles du second niveau inférieur actuel du nœud.<br>Plage de valeurs valides comprise entre 0 et $(2^{48} - 1)$<br>Les autres valeurs sont réservées |
| 0x0207 à 0x028F | réservé | | | Protocole réservé |
| 0x0290 à 0x02FF | réservé | | | Réservé au fabricant de l'équipement |
| 0x0300 à 0x03FD | delay_cn | RO | UINT32 | Retard de transmission (calculé par le nœud de gestion) entre le nœud de gestion et le nœud terminal, l'unité étant ns. 254 éléments du tableau correspondent au retard entre NodeID 0 et NodeID 253.<br>Plage de valeurs comprise entre 0 et $(2^{32} - 1)$ |
| 0x03FE à 0x03FF | réservé | | | Protocole réservé |

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#### 6.10.2.5 Tableau d'informations relatives au diagnostic et à la maintenance du système

Le Tableau 38 définit les informations relatives à la gestion des ressources de communication physiques.

**Tableau 38 – Tableau d'informations relatives à la gestion des ressources de communication physiques**

| Index de paramètre | Nom de paramètre | RW | Type de données | Description |
|---|---|---|---|---|
| 0x0500 | sym_down_num | R/W | UINT8 | Numéros de symbole de la sous-trame en liaison descendante<br>Plage de valeurs comprise entre 2 et 32<br>Les autres valeurs ne sont pas valides |
| 0x0501 | cycle_frame_num | R/W | UINT8 | Longueur de trame cyclique<br>Plage de valeurs comprise entre 0 et 16<br>Les autres valeurs sont réservées |
| 0x0502 à 0x05FF | réservé | | | Protocole réservé |
| 0x0600 | res_blcok_id | R/W | UINT16 | Blocs de ressources (voir Note 1) utilisés par le nœud.<br>Plage de valeurs comprise entre 0 et 65 535 |
| 0x0601 | sequence_id | R/W | UINT8 | Numéro de séquence du sous-bloc de ressources (voir Note 1).<br>Plage de valeurs comprise entre 0 et 255 |
| 0x0602 | tx_node_id | R/W | UINT8 | NodeID du nœud de dispositif pour la transmission de données en fonction de ressources symboliques.<br>Plage de valeurs comprise entre 0 et 255 |
| 0x0603 | res_rt_attr | R/W | UINT16 | Attribut en temps réel de la ressource<br>Plage de valeurs comprise entre 0 et 512<br>0: ressources statiques, toujours occupé<br>1 à 512: nombre de fois que les blocs de ressources correspondants sont occupés par la circulation<br>Les autres valeurs sont réservées. |
| 0x0604 | sym_reserved | R/W | UINT8 | Champ réservé |
| 0x0605 | bd_flag | R/W | UINT8 | Drapeau d'occupation de la bande latérale indiqué par un bit.<br>bit 0: drapeau d'occupation de la bande latérale supérieure<br>bit 1: drapeau d'occupation de la bande latérale inférieure<br>La valeur 0 attribuée au bit correspondant indique que la mi-bande latérale n'est pas occupée, et la valeur 1 indique que la mi-bande latérale est occupée.<br>bit 2 au bit 7: réservés |

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| Index de paramètre | Nom de paramètre | RW | Type de données | Description |
|---|---|---|---|---|
| 0x0606 | bd_mode | R/W | UINT8 | Mode de codage de la bande latérale correspondante représenté par un bit.<br>La valeur de 5 bits de poids fort correspond au mode de code RS (voir le Tableau 71), et la plage de valeurs valides est comprise entre 0 et 11. Les autres valeurs sont réservées.<br>La valeur de 3 bits de poids faible correspond au mode de code de convolution (voir le Tableau 72) et la plage de valeurs valides est comprise entre 0 et 2. Les autres valeurs sont réservées. |
| 0x0607 | sym_pos | R/W | UINT16 | Position de début de ressource symbolique<br>Plage de valeurs comprise entre 0 et 511<br>Les autres valeurs sont réservées. |
| 0x0608 | sym_len | R/W | UINT16 | Longueur de ressource symbolique<br>Plage de valeurs comprise entre 1 et 512<br>La valeur 0 n'est pas valide<br>Les autres valeurs sont réservées. |
| 0x0609 | sym_cycle_num | R/W | UINT16 | Nombre de recyclages des ressources symboliques<br>Plage de valeurs comprise entre 1 et 512<br>La valeur 0 n'est pas valide.<br>Les autres valeurs sont réservées. |
| 0x060A à 0x060F | réservé | | | Protocole réservé |
| 0x0610 à 0x09FF | | | | Informations de bloc de ressources (voir Note 2) |
| 0x0A00 à 0x0FFF | réservé | | | Protocole réservé |
| NOTE 1 Voir 8.6.2.2.1 pour la trame de signal. Le dispositif de nœud traite les données en fonction de la mi-bande latérale continue ou du symbole de bande latérale dans la SF spécifiée. Ce type de symbole continu est considéré comme un sous-bloc de ressources, et l'appareil met en œuvre la communication de données déterministes par l'intermédiaire d'un ou de plusieurs sous-blocs de ressources. Plusieurs sous-blocs de ressources sont considérés comme un bloc de ressources.<br>NOTE 2 L'index entre 0x0600 et 0x0609 correspond aux informations de bloc de ressources. La Figure 20 représente la structure des informations de bloc de ressources, et les index entre 0x060A et 0x060F sont réservés au bloc de ressources correspondant. 64 informations de blocs de ressources sont admises sur chaque appareil physique, ce qui signifie que la plage d'index valides correspondante de la gestion d'informations de ressource est comprise entre 0x0600 et 0x09FF. | | | | |

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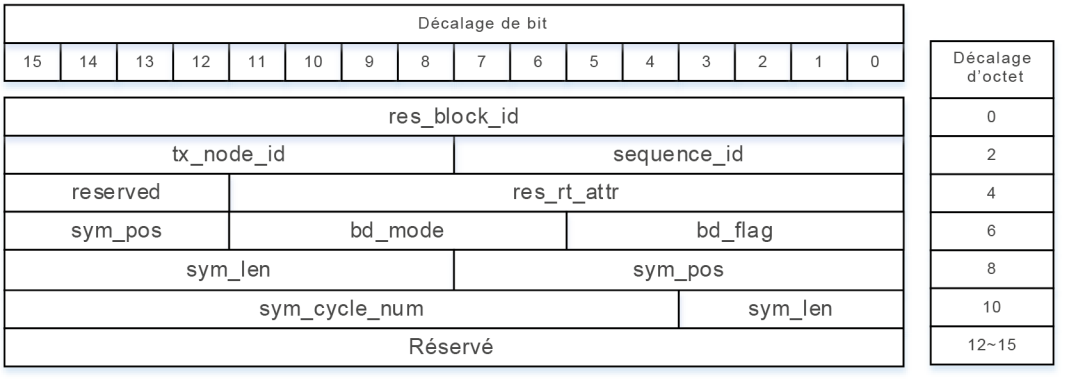


**Figure 20 – Structure des informations de bloc de ressources**

### 6.10.3 Primitive de service

#### 6.10.3.1 Ph-RESET (drapeau)

L'utilisateur de la gestion système PhL informe la PhL de procéder à une réinitialisation en fonction de la primitive de service. Les primitives et paramètres du service sont présentés dans le Tableau 39.

**Tableau 39 – Primitives et paramètres de Ph-RESET**

| Nom de paramètre | Demande | Confirmation |
|---|---|---|
| flag | O | |

La PhL décide s'il est nécessaire de procéder à la réinitialisation en fonction du drapeau de paramètre décrit dans le Tableau 40. Il convient que les utilisateurs de la gestion système reçoivent des informations de confirmation lorsque le drapeau est réinitialisé sur 1.

**Tableau 40 – Description du paramètre de primitive de service Ph-RESET**

| Nom de paramètre | Valeur du paramètre |
|---|---|
| flag | Réinitialiser drapeau:<br>0: ne pas réinitialiser la PhL<br>1: réinitialiser toutes les fonctions de la PhL et il convient de rétablir les valeurs par défaut des paramètres de l'entité PhL. |

Le processus de cette primitive de service est représenté à la Figure 21.

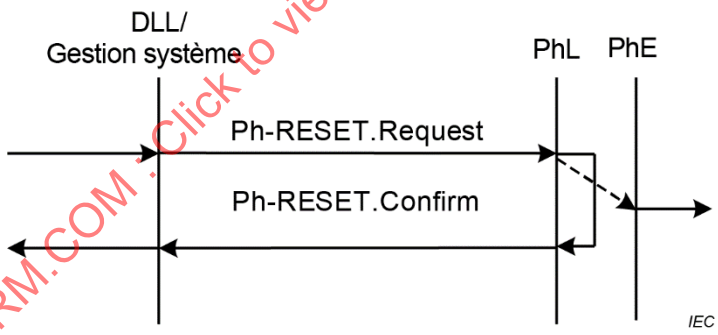


**Figure 21 – Processus de la primitive de service Ph-RESET**

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#### 6.10.3.2 Ph-SET-VALUE (parameter_index, value, status)

L'utilisateur de la gestion système PhL utilise le service pour définir les paramètres associés de la PhLME. Les primitives et paramètres du service sont présentés dans le Tableau 41. Voir 6.10.2 pour la description spécifique des paramètres parameter_index et value. Le paramètre status présenté dans le Tableau 42 indique l'état de confirmation du service de demande correspondant.

**Tableau 41 – Primitives et paramètres de Ph-SET-VALUE**

| Nom de paramètre | Demande | Confirmation |
|---|---|---|
| parameter_index | O | |
| value | O | |
| status | | O |

**Tableau 42 – État du paramètre de primitive Ph-SET-VALUE**

| Nom de paramètre | Valeur du paramètre |
|---|---|
| status | Le service renvoie la valeur d'état<br>0: succès<br>1: échec |

Le processus de cette primitive de service est représenté à la Figure 22.

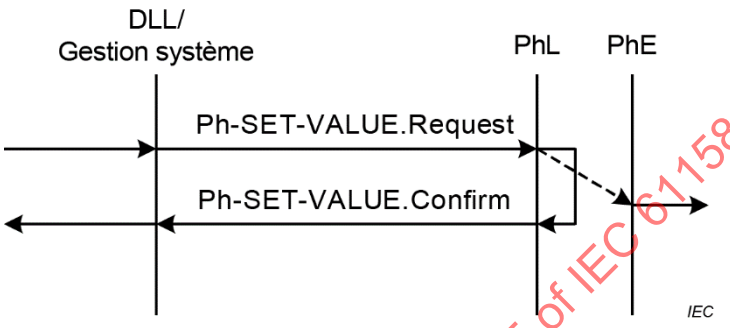


**Figure 22 – Processus de la primitive de service Ph-SET-VALUE**

#### 6.10.3.3 Ph-GET-VALUE (parameter_index, value, status)

L'utilisateur de la gestion système PhL utilise le service pour obtenir les paramètres associés de la PhLME. Les primitives et paramètres du service sont présentés dans le Tableau 43. Voir 6.10.2 pour la description du paramètre parameter_index. Le paramètre status présenté dans le Tableau 43 indique l'état de confirmation du service de demande correspondant.

**Tableau 43 – Primitives et paramètres du service Ph-GET-VALUE**

| Nom de paramètre | Demande | Confirmation |
|---|---|---|
| parameter_index | O | |
| value | | O |
| status | | O |

Le processus de cette primitive de service est représenté à la Figure 23.

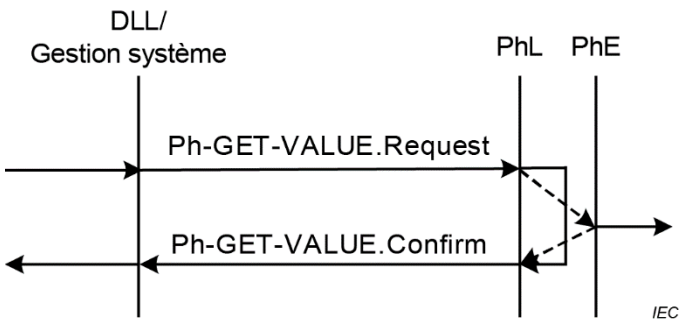


**Figure 23 – Processus de la primitive de service Ph-GET-VALUE**

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#### 6.10.3.4 Ph-EVENT (parameter_index, value)

Il convient que la PhLME informe l'utilisateur de la gestion système en fonction du service lorsqu'il détecte un événement. Il convient que le paramètre de primitive d'indication du service clarifie les informations pertinentes au moment de l'événement. La primitive et les paramètres du service sont présentés dans le Tableau 44.

**Tableau 44 – Primitive et paramètres du service Ph-EVENT**

| Nom de paramètre | Indication |
|---|---|
| parameter_index | O |
| value | O |

Le processus de cette primitive de service est représenté à la Figure 24.

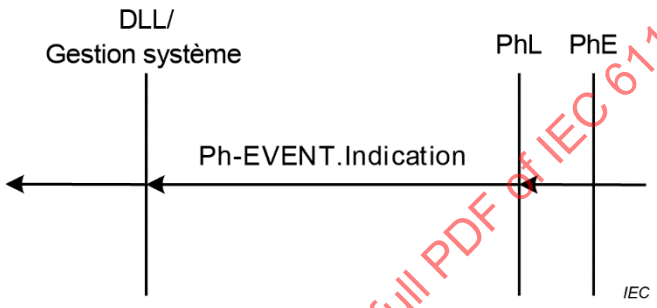


**Figure 24 – Processus de la primitive de service Ph-EVENT**

#### 6.10.3.5 Ph-SYNC (command, parameter_idx, value, status)

L'utilisateur de la gestion système PhL utilise le service pour traiter les paramètres relatifs à la synchronisation de la PhLME (voir 6.10.2.4). Le Tableau 45 présente les primitives et paramètres du service Ph-SYNC.

Le paramètre command indique l'instruction spécifique du traitement de la primitive. Si la valeur du paramètre command est 0, il indique qu'il convient que l'utilisateur de la gestion système PhL lise la valeur correspondante de parameter_idx. Si la valeur du paramètre command est 1, il indique qu'il convient d'attribuer une valeur à parameter_idx dans la PhLME. Le paramètre status indique le résultat de l'exécution de la primitive correspondante. La valeur 0 indique que le processus de la primitive a abouti, et la valeur 1 indique qu'il n'a pas abouti. Les primitives et paramètres du service sont présentés dans le Tableau 45. Voir 6.10.2.4 pour la description du paramètre parameter_index.

**Tableau 45 – Primitives et paramètres du service Ph-SYNC**

| Nom de paramètre | Demande | Indication | Confirmation |
|---|---|---|---|
| command | O | O | |
| parameter_index | O | O | O |
| value | | O | O |
| status | | | O |

Le processus de cette primitive de service est représenté à la Figure 25.

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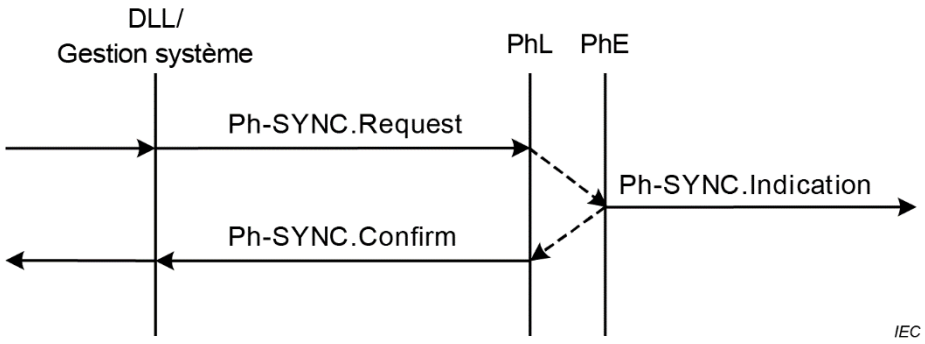


**Figure 25 – Processus de la primitive de service Ph-SYNC**

# 7 Sous-couche indépendante du DCE (DIS)

## 7.1 Généralités

L'entité PhL est subdivisée en une composante Équipement terminal de traitement de données (ETTD) et en une composante Équipement de transmission de données (DCE). La composante ETTD est en interface avec l'entité DLL et constitue la DIS (sous-couche indépendante du DCE). Elle échange des unités de données d'interface sur l'interface DL-Ph définie à l'Article 5 et assure les conversions de base entre la perspective "d'une PhIDU à la fois" de l'interface DL-Ph et la perspective "bit série" exigée pour la transmission et la réception physiques.

La sous-couche est indépendante de toutes les variantes PhL, y compris le codage et/ou la modulation, la vitesse, le mode tension/courant/optique, le support, etc. Toutes ces variantes sont regroupées sous la désignation DCE (Équipement de transmission de données).

NOTE Un certain nombre d'entités DIS différentes sont spécifiées, sur la base des pratiques industrielles en la matière.

## 7.2 Type 1: DIS

La DIS doit ordonner l'émission de la PhID comme une séquence de PhSDU série. De la même manière, la DIS doit constituer la PhID à renvoyer à la DLL à partir de la séquence de PhSDU série reçues.

La PhID doit être convertie en une séquence de PhSDU pour émission série en octets jusqu'à 300 octets, au plus. Une PhSDU représentant des octets de poids fort de la PhID doit être envoyée avant ou en même temps qu'une PhSDU représentant des octets de poids faible et de sorte que, dans chaque octet, une PhSDU représentant un bit de poids fort soit transmise avant ou en même temps qu'une PhSDU représentant un bit de poids faible. À la réception, chaque séquence de PhSDU doit être convertie en PhID de sorte que, en l'absence d'erreurs, la PhIDU indiquée à l'entité DLL de réception ne doit pas varier par rapport à la PhIDU dont l'émission a été demandée par l'entité DLL d'origine.

NOTE Cette opération est une garantie de transparence.

## 7.3 Type 3: DIS

### 7.3.1 Transmission synchrone

La sous-couche indépendante du DCE (DIS) spécifiée pour le Type 1 doit être utilisée (voir 7.2).

### 7.3.2 Transmission asynchrone

Il n'y a pas de DIS (sous-couche indépendante du DCE) en transmission asynchrone.

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### 7.4 *Vide*

NOTE Dans la présente édition, le 7.4 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

### 7.5 Type 8: DIS

#### 7.5.1 Généralités

La PhL est subdivisée en une MIS (Sous-couche indépendante du Support), une MDS (Sous-couche dépendante du support) et la MAU (Unité de liaison au Support). La MIS est indépendante de toutes les caractéristiques de la PhL, telles que le codage, la méthode de transmission, la vitesse de transmission et le type de support de transmission. Toutes ces instances sont décrites par les sous-couches MDS et MAU.

#### 7.5.2 Fonction

D'une part, la MIS doit envoyer à la MDS la PhSDU qui a été reçue par la sous-couche MAC par le biais de l'interface DL-Ph sous la forme d'une PhIDU, par l'intermédiaire de l'interface MIS-MDS. D'autre part, elle constitue la PhIDU d'une PhSDU qui a été reçue par l'intermédiaire de l'interface MIS-MDS et la transfère, par l'interface DLPh, à la sous-couche MAC.

En outre, la MIS permet l'émission d'une PhSDU entre deux MDS par l'intermédiaire de l'interface MIS-MDS (couplage MDS).

La MIS peut comprendre plusieurs canaux qui sont configurés en conséquence. Un canal est utilisé pour émettre la PhSDU à la MDS et pour émettre une PhSDU par l'intermédiaire d'une PhIDU vers la sous-couche MAC. Tous les autres canaux sont utilisés pour transmettre une PhSDU entre deux sous-couches MDS.

#### 7.5.3 Transmission série

Pour la transmission série, une séquence de PhIDU doit être convertie en une séquence de PhSDU. Une PhSDU qui représente un bit de poids fort est transférée à une PhSDU qui représente un bit de poids faible.

Lorsqu'elle est reçue, chaque séquence de PhSDU doit être convertie en une séquence de PhIDU, de sorte que la séquence de PhIDU constituée de cette manière corresponde à celle qui est envoyée de la sous-couche MAC à la PhL.

#### 7.5.4 Couplage MDS

Lorsque des MDS sont couplées par paires et ont des caractéristiques identiques ou différentes (type de transmission alternative), chaque PhSDU qui est reçue d'une MDS par le biais de l'interface MIS-MDS est envoyée inchangée, par l'interface MIS-MDS, à une autre MDS.

Dans ce cas, une PhSDU reçue peut être mise en tampon.

La Figure 26, la Figure 27 et la Figure 28 représentent les configurations possibles pour le maître du bus et les esclaves, en utilisant le support câblé à 2 conducteurs et le type alternatif de transmission.

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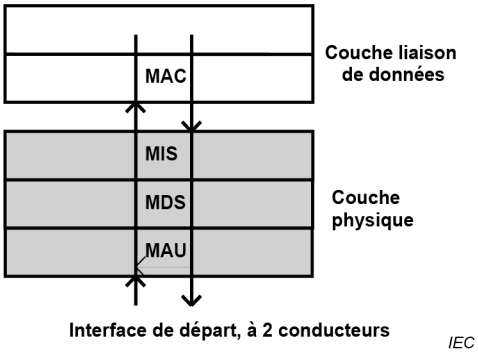


**Figure 26 – Configuration d'un maître**

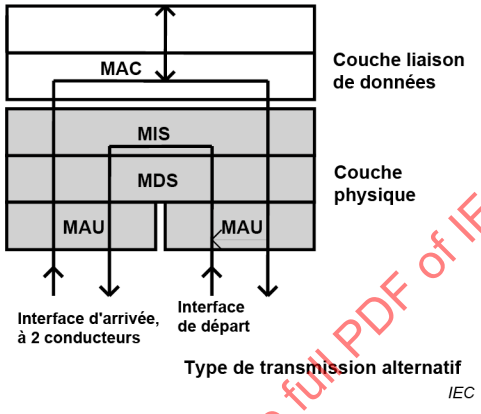


**Figure 27 – Configuration d'un esclave avec un type de transmission alternatif**

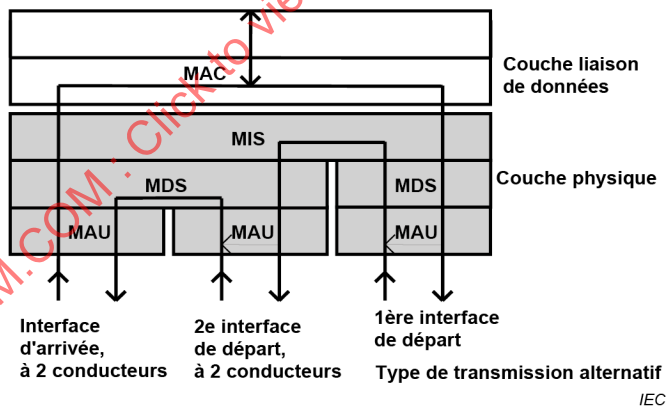


**Figure 28 – Configuration d'un coupleur de bus avec un type de transmission alternatif**

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### 7.6 Type 12: DIS

Aucun DIS n'est spécifié pour le Type 12.

### 7.7 Type 28: DIS

La PhL convertit l'unité de données reçue de la DLL en unité de données de service qui peut être traitée par la PhL. Elle ajoute les informations de contrôle exigées et génère le symbole OFDM par brouillage, codage et mapping. Le signal physique est transmis au support physique correspondant après conversion Numérique/Analogique. Le signal physique est transmis à un ou plusieurs appareils dans le réseau par l'intermédiaire du support. Après réception du signal physique, elle procède à la conversion Analogique/Numérique, à la démodulation et au décodage, puis supprime les informations de contrôle. Le signal récupéré est converti en unité de données qui peut être traitée par l'entité DLL.

L'entité PhL est subdivisée en Équipement terminal de traitement de données (ETTD) et en Équipement de transmission de données (DCE). L'ETTD met en œuvre la conversion entre la DLPDU et la PhLSDU. Le DCE procède au traitement OFDM de la PhLSDU, génère les symboles OFDM et les convertit en signaux physiques qui peuvent être traités par le support.

Il convient que le DIS de la PhL demande la transmission PhID sous la forme d'une séquence PhSDU. Inversement, le DIS convertit la séquence PhSDU reçue en PhID et le transmet à la DLL.

La séquence PhSDU de la PhL est composée de CB. Il convient que le PhID soit converti en PhSDU pour la transmission en octets. Les octets binaires élevés sont envoyés en premier, suivis des octets binaires faibles, les octets binaires élevés étant par conséquent traités en premier. En l'absence d'erreurs, il convient que la PhIDU de l'entité DLL de réception soit la même que la PhIDU qui a été demandée par l'entité DLL d'origine.

## 8 Interface ETTD – DCE et fonctions MIS-specific

### 8.1 Généralités

L'entité PhL est subdivisée en une composante Équipement terminal de traitement de données (ETTD) qui contient la DIS et en une composante Équipement de transmission de données (DCE) qui contient la MDS et des sous-couches de niveau inférieur. L'interface ETTD – DCE connecte ces deux composantes physiques et est elle-même contenue dans la MIS (voir la ).

NOTE Un certain nombre d'interfaces ETTD – DCE différentes sont spécifiées, sur la base des pratiques industrielles en la matière.

Pour l'interface ETTD-DCE ainsi que pour toute autre interface, l'exposition n'est pas obligatoire.

Pour le mode de transmission synchrone de Type 3, de Type 1 et de Type 7, l'interface ETTD – DCE est une interface fonctionnelle et électrique, mais non mécanique, qui prend en charge un ensemble de services. Chacun de ces services est mis en œuvre par une séquence d'interactions de signalisation définies au niveau de l'interface.

### 8.2 Type 1: Interface ETTD − DCE

#### 8.2.1 Services

##### 8.2.1.1 Vue d'ensemble

Les services suivants, définis au 8.2, doivent être pris en charge par l'interface ETTD – DCE:

a) Service de réinitialisation ETTD vers DCE;
b) Service de configuration ETTD vers DCE;
c) Service message-transmission ETTD vers DCE;
d) Service de notification de défauts ETTD vers DCE;
e) Service d'indication media-activity ETTD vers DCE;
f) Service de message-reporting ETTD vers DCE.

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#### 8.2.1.2 Service de réinitialisation ETTD vers DCE

Ce service doit fournir un moyen par lequel l'ETTD peut réinitialiser à tout moment le DCE et de le remettre à son état initial (power-on).

#### 8.2.1.3 Service de configuration ETTD vers DCE

Ce service doit fournir un moyen par lequel l'ETTD peut configurer différentes caractéristiques du DCE, y compris celles que la gestion système peut régler en utilisant des demandes Ph-SET-VALUE (voir le Tableau 13). Il doit également fournir un moyen facultatif au niveau du DCE par lequel le DCE peut lancer des rapports d'état du DCE par utilisation préemptive du service de message-reporting ETTD vers DCE.

#### 8.2.1.4 Service message-transmission ETTD vers DCE

Ce service doit fournir un moyen par lequel l'ETTD peut émettre un message à travers le DCE, destiné soit au(x) support(s) connecté(s), soit en retour vers l'ETTD proprement dit ou les deux à la fois, ces options étant déterminées par les valeurs opérationnelles actuelles des paramètres spécifiés dans le Tableau 13. La régulation de ce service doit être assurée par le DCE.

Ce service est invoqué à la réception d'une demande PH-DATA qui spécifie le START-OF-ACTIVITY à l'interface de service PhL et son exécution se poursuit jusqu'à réception et achèvement de la demande PH-DATA qui spécifie la END-OF-DATA-AND-ACTIVITY.

#### 8.2.1.5 Service de notification de défauts ETTD vers DCE

Ce service doit fournir un moyen par lequel l'ETTD peut à tout moment rendre compte d'un défaut au DCE. La nature spécifique du défaut n'est pas indiquée par ce service, mais peut être déterminée en utilisant le service de configuration ETTD vers le DCE, pour lancer un rapport d'état DCE, facultatif au niveau du DCE.

#### 8.2.1.6 Service d'indication media-activity ETTD vers DCE

Ce service doit fournir un moyen permettant au DCE de rendre compte de la détection supposée, sur l'un de ses supports connectés pour lesquels la réception est activée (voir le Tableau 13), d'une signalisation provenant de lui-même ou d'autres entités de la couche Ph. Lorsque le rebouclage est activé, ce service rend uniquement compte de la signalisation du DCE lui-même.

Lorsque l'interface ETTD – DCE est en mode semi-duplex et que le rebouclage n'est pas activé, ce service peut ne pas rendre compte de l'activité de support résultant directement du service de transmission de messages ETTD vers DCE.

#### 8.2.1.7 Service de message-reporting ETTD vers DCE

Ce service doit fournir un moyen permettant au DCE de rendre compte de la réception d'une séquence de PhPDU provenant de tout support connecté dont la réception est activée. Ce service s'achève par une indication précisant si la séquence de PhPDU reçues était bien formée. Des erreurs dans la séquence, y compris le nombre de PhPDU, laissant supposer une émission incorrecte qui résulte de l'invocation du service message-transmission ETTD vers DCE, doivent être consignées comme une séquence mal formée (erronée).

Des erreurs d'alignement d'octets d'un délimiteur de fin reçu par rapport au délimiteur de début précédent (c'est-à-dire non séparés par un nombre entier d'octets de bits de données) doivent être consignées comme une séquence mal formée.

Lorsque l'interface ETTD – DCE est en mode semi-duplex et que le rebouclage n'est pas activé, il n'est pas nécessaire que ce service rende compte du message transmis par le service message-transmission ETTD vers DCE.

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### 8.2.2 Interfaces de signalisation

#### 8.2.2.1 Vue d'ensemble

Deux interfaces de signalisation sont définies pour les couches PhL de Type 1. La première interface existait dans les éditions précédentes du présent document et elle est conservée à des fins de compatibilité, bien qu'il n'y ait pas de mise en œuvre connue. Elle est définie du 8.2.2.2 au 8.2.2.4.

La seconde interface utilise le protocole bien connu SPI (*serial peripheral interface* – interface périphérique série) ainsi que des signaux, ou équivalent, dont les registres d'octets et les FIFO du DCE sont lus et écrits par l'ETTD, le DCE pouvant interrompre l'ETTD.

NOTE Il n'existe pas de norme officielle pour le protocole SPI, bien qu'il soit utilisé par de nombreux fournisseurs de matériel électronique.

#### 8.2.2.2 Signaux d'interface (version historique des éditions précédentes)

##### 8.2.2.2.1 Vue d'ensemble

Si l'interface ETTD – DCE est exposée, elle doit fournir les signaux spécifiés dans le Tableau 46.

**Tableau 46 – Signaux à l'interface ETTD – DCE**

| Signalisation | Abréviation | Source |
|---|---|---|
| Horloge de transmission | TxC | DCE |
| Request-to-send (Demande pour émettre) | RTS | ETTD |
| Clear-to-send (Prêt à émettre) | CTS | DCE |
| Données de transmission | TxD | ETTD |
| Horloge de réception | RxC | DCE |
| Activité de réception | RxA | DCE |
| Réception de données et verrouillage de trame | RDF | DCE |

Les niveaux de signaux doivent être tels qu'ils sont présentés dans le Tableau 47. En général, les deux côtés de l'interface doivent fonctionner à la même valeur approximative de $V_{DD}$. Il est cependant admis qu'un ETTD et un DCE ayant des alimentations séparées peuvent ne pas atteindre tous deux la tension opérationnelle $V_{DD}$ de manière simultanée. Il est souhaitable, mais non obligatoire, que le service de réinitialisation ETTD vers DCE soit opérationnel avant que le DCE n'atteigne sa tension opérationnelle $V_{DD}$. Il est également souhaitable que l'ETTD invoque ce service dès lors que sa propre tension $V_{DD}$ est inférieure aux marges opérationnelles.

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**Tableau 47 – Niveaux de signaux pour une interface ETTD – DCE exposée**

| Symbole | Paramètre | Condition | Limite | Unité | Remarque |
|---|---|---|---|---|---|
| VOL | Tension de sortie de niveau bas maximale | Iout = ±100 µA | 0,1 | V | voir Note 1 |
| | | Iout = +1,6 mA | 0,4 | V | |
| VOH | Tension de sortie de niveau haut minimale | Iout = ±100 µA | $V_{DD}$ – 0,1 | V | voir Note 1 |
| | | Iout = -0,8 mA | $V_{DD}$ – 0,8 | V | voir Note 2 |
| VIL | Tension d'entrée de niveau bas maximale | | 0,2 $V_{DD}$ | V | |
| VIH | Tension d'entrée de niveau haut minimale | | 0,7 $V_{DD}$ | V | voir Note 3 |

NOTE 1 Donne la capacité d'entraîner deux charges CMOS typiques.

NOTE 2 La compatibilité d'une entrée CMOS avec une sortie TTL exige une résistance de polarisation de l'entrée du signal vers $V_{DD}$.

NOTE 3 La compatibilité d'une sortie CMOS pour 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. La compatibilité d'une sortie TTL (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) exige une résistance de polarisation de l'entrée du signal vers $V_{DD}$.

Les caractéristiques temporelles de ces signaux doivent être au moins égales à celles spécifiées pour le DCE concerné dans les exigences du présent document. Cependant, le temps de transition entre 0,3 $V_{DD}$ et 0,6 $V_{DD}$ ne doit en aucun cas être supérieur à 100 ns ou 0,025 *P*, selon que l'une ou l'autre valeur est la plus faible. *P* est défini comme la période nominale de transmission d'octet – l'inverse du débit nominal des PhSDU.

Une mise en œuvre de l'interface ETTD – DCE doit fonctionner correctement à des fréquences d'horloge de transmission et de réception (TxC et RxC) comprises entre 1 kHz et 8,8 fois le débit des PhSDU le plus élevé pris en charge dans la mise en œuvre de l'ETTD ou du DCE.

NOTE Le débit des PhSDU et le débit binaire équivalent, disponibles dans une mise en œuvre donnée sont fournis dans la Déclaration de conformité d'une mise en œuvre du protocole (PICS).

#### 8.2.2.2.2 Horloge de transmission (TxC)

Le signal d'horloge de transmission (TxC) doit fournir à ETTD un signal de synchronisation continu, de sorte que huit cycles consécutifs complets de ce signal doivent avoir la même période d'octets que la période de transmission nominale d'un octet de données. Le DCE doit fournir ce signal à deux phases nominales, de sorte que chaque phase ait une durée d'au moins 0,04 *P*.

NOTE Cette spécification permet à TxC d'être une horloge continue, à période constante, à un débit binaire nominal (8 fois le débit nominal d'octets) avec un facteur d'utilisation de 32 % à 68 %; ou d'être une horloge de fréquence plus élevée dont certains cycles sont omis et ayant un facteur d'utilisation proche de 50 %. Cela permet par exemple une synchronisation simple dans un DCE qui recode chaque 4 bits en 5 bauds; le DCE peut avoir une horloge égale à 10 fois le débit nominal d'octets avec un facteur d'utilisation compris entre 40 % et 60 %, et peut omettre (les mêmes) deux cycles à chaque octet.

TxC prend en charge les services de configuration et de transmission de messages ETTD vers DCE.

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#### 8.2.2.2.3 Request-to-send (Demande pour émettre) (RTS)

Le signal RTS (demande-to-send – demande pour émettre) prend en charge les services de réinitialisation, de configuration et de transmission de messages ETTD vers DCE. L'ETTD doit fournir ce signal. L'état initial (à la mise sous tension) et au repos (pas de service ETTD vers DCE actif) de ce signal doit être bas.

Lorsqu'il est référencé à TxC à l'interface ETTD-DCE, ce signal doit avoir un temps minimal de montée de 100 ns ou 0,025 *P* selon que l'une ou l'autre valeur est la plus faible; le temps de maintien doit être d'au moins zéro.

#### 8.2.2.2.4 Clear-to-send (Prêt à émettre) (CTS)

Le signal CTS (clear-to-send – prêt à émettre) prend en charge les services de configuration et de transmission de messages ETTD vers DCE. Le DCE doit fournir ce signal. L'état initial (à la mise sous tension) et au repos (pas de service ETTD vers DCE actif) de ce signal doit être bas.

Lorsqu'il est référencé à TxC à l'interface ETTD-DCE, ce signal doit avoir un temps minimal de montée de 100 ns ou 0,025 *P* selon que l'une ou l'autre valeur est la plus faible; le temps de maintien doit être d'au moins zéro.

#### 8.2.2.2.5 Données de transmission (TxD)

Le signal TxD (Transmit Data – données de transmission) prend en charge les services de réinitialisation, de configuration et de transmission de messages ETTD vers DCE. Les données binaires sont transmises de l'ETTD vers le DCE au cours d'une phase des deux derniers services et au cours de cette phase, un binaire 0 est représenté par un niveau bas sur TxD et un binaire 1 par un niveau haut sur TxD, tous deux étant prélevés sur le front descendant de TxC.

L'ETTD doit fournir ce signal. L'état initial (à la mise sous tension) et au repos (pas de service ETTD vers DCE actif) de ce signal doit être haut.

Lorsqu'il est référencé à TxC à l'interface ETTD-DCE, ce signal doit avoir un temps minimal de montée de 100 ns ou 0,025 *P* selon que l'une ou l'autre valeur est la plus faible; le temps de maintien doit être d'au moins zéro.

#### 8.2.2.2.6 Horloge de réception (RxC)

Le signal RxC (Receive Clock – horloge de réception) doit fournir à l'ETTD un signal de synchronisation à deux phases nominales, intermittent (semi-continu), qui définit la synchronisation des informations notifiées par le signal RDF. Le DCE doit fournir ce signal de sorte que lorsque RxC est défini pour être significatif (voir 8.2.2.3.7), chaque phase a une durée d'au moins 0,04 *P*.

NOTE Cette spécification permet à RxC d'être une horloge récupérée au débit binaire nominal (8 fois le débit nominal d'octets) avec un facteur d'utilisation de 32 % à 68 %; ou d'être une horloge de fréquence plus élevée dont certains cycles sont omis et ayant un facteur d'utilisation proche de 50 %. Cela permet par exemple une synchronisation simple dans un DCE qui décode 4 bits de chaque 5 bauds reçus; le DCE peut avoir une horloge égale à 10 fois le débit nominal d'octets avec un facteur d'utilisation compris entre 40 % et 60 %, et peut omettre deux cycles à chaque octet.

Cette spécification permet également au DCE d'omettre des cycles de RxC pendant la reconnaissance de séquences longues de délimiteurs de fin de PhPDU, de sorte que le délimiteur peut être notifié en temps réel par 8 cycles, ou moins, de RxC (voir 8.2.2.3.7).

RxC doit prendre en charge le service de message-reporting DCE vers ETTD.

#### 8.2.2.2.7 Activité de réception (RxA)

Le signal RxA (*Receive Activity* – activité de réception) doit prendre en charge les services de notification de défauts, d'indication de media-activity et de message-reporting DCE vers ETTD.

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Le DCE doit fournir ce signal. L'état initial (power-on) et au repos (pas de service DCE vers ETTD actif) de ce signal doit être bas.

#### 8.2.2.2.8 Réception de données et verrouillage de trame (RDF)

Le signal RDF (*Receive Data and Framing* – réception de données et verrouillage de trame) doit prendre en charge les services de notification de défauts et de message-reporting DCE vers ETTD. Les données binaires sont transmises du DCE vers l'ETTD pendant certaines phases du dernier service et au cours de ces phases, un binaire 0 est représenté par un niveau bas sur RDF et un binaire 1 par un niveau haut sur RDF, tous deux étant prélevés sur le front descendant de RxC.

Le DCE doit fournir ce signal. L'état initial (à la mise sous tension) et au repos (pas de service DCE vers ETTD actif) de ce signal doit être haut.

Lorsqu'il est référencé à TxC à l'interface ETTD-DCE, ce signal doit avoir un temps minimal de montée de 100 ns ou 0,025 *P* selon que l'une ou l'autre valeur est la plus faible; le temps de maintien doit être d'au moins zéro.

### 8.2.2.3 Codage des services dans des signaux

#### 8.2.2.3.1 Récapitulatif

Les services définis au 8.1 doivent être mis en œuvre par les séquences suivantes et les combinaisons de signaux décrites au 8.2.

NOTE Des machines types de séquencement de transmission et de réception sont représentées à la Figure 29. Cette dernière est incluse dans le présent document à des fins d'explication et n'implique pas une mise en œuvre spécifique.

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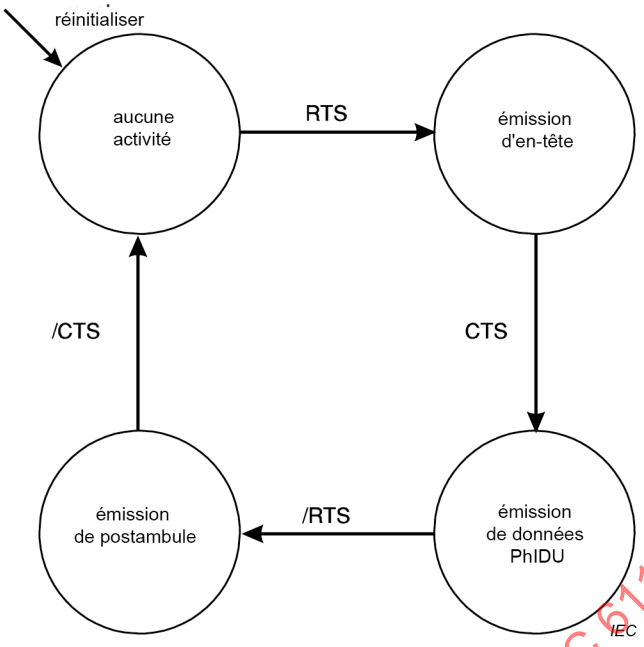
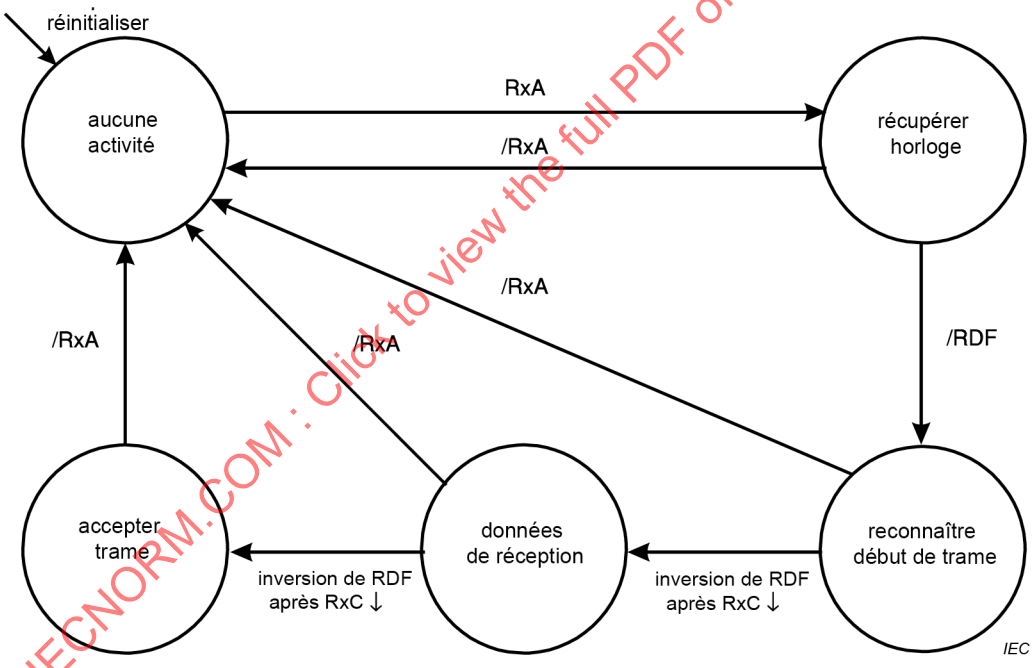



**a) Machine de transmission**




**b) Machine de réception**

**Figure 29 – Machines de séquencement ETTD/DCE**

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#### 8.2.2.3.2 Service de réinitialisation ETTD vers DCE

Ce service doit être mutuellement exclusif avec les services de configuration et de message-transmission ETTD vers DCE; un seul d'entre eux au plus peut être actif à tout moment. Ce service peut à tout moment préempter les services de configuration et de message-transmission ETTD vers DCE.

Ce service doit être codé comme un niveau bas simultané à la fois sur RTS et TxD. Lorsqu'il est affirmé par l'ETTD, ce niveau bas simultané doit être maintenu pendant au moins la période de transmission nominale de deux PhSDU (octets).

NOTE 1 Il s'agit d'un service asynchrone et il n'est pas référencé à TxC.

Lorsqu'un ETTD est lui-même réinitialisé, éventuellement pendant la mise sous tension, il convient qu'il tente de réinitialiser le DCE même lorsque la tension $V_{DD}$ propre aux ETTD est inférieure aux limites opérationnelles normales.

NOTE 2 Cette réinitialisation est sous le contrôle de l'ETTD. Cette disposition n'exclut pas l'existence d'une broche de réinitialisation séparée sur le DCE.

Si l'ETTD modifie simultanément RTS et TxD au cours de la mise en œuvre du service de configuration ou du service message-transmission ETTD vers DCE, alors il doit assurer qu'il existe un intervalle égal à au moins le temps de montée minimal exigé entre le passage d'un signal à un niveau haut et par la suite, le passage de l'autre signal à un niveau bas, de manière à éliminer les dangers logiques potentiels liés à la mise en œuvre dans les DCE du service de réinitialisation ETTD vers DCE.

#### 8.2.2.3.3 Service de configuration ETTD vers DCE

Ce service est mutuellement exclusif avec les services de réinitialisation et de message-transmission ETTD vers DCE; un seul d'entre eux au plus peut être actif à un moment donné. Ce service peut lancer le service de message-reporting DCE vers ETTD pour rendre compte de l'état interne du DCE. Le service de réinitialisation ETTD vers DCE peut à tout moment préempter ce service.

Ce service doit être mis en œuvre en trois phases; chacune des deux dernières phases doit suivre immédiatement l'achèvement de la phase précédente.

Ces phases peuvent être mises en œuvre comme une variation mineure des trois phases spécifiées pour le service message-transmission ETTD vers DCE. De ce fait, le service de configuration ETTD vers DCE induit une complexité supplémentaire minime pour l'ETTD et le DCE.

a) L'ETTD doit affirmer (monter) RTS après le front descendant, et avant le front montant, de TxC. Le DCE doit répondre en anticipant les données de configuration.

b) Lorsqu'il est prêt pour les données de configuration en provenance de l'ETTD, le DCE doit monter CTS avant le front descendant de TxC. L'ETTD doit répondre en codant le premier bit des données de configuration (1 pour haut, 0 pour bas) sur TxD avant le front descendant de TxC suivant, et doit poursuivre ce processus sans interruption jusqu'à ce que de 2 à 200 bits de données (voir 8.2.2.4) aient été ainsi codés. L'ETTD doit ensuite affirmer (monter) TxD et inverser (descendre) RTS avant le front descendant de TxC suivant.

c) Il convient que l'ETTD assure que TxD monte d'au moins une durée de montée avant que RTS ne descende, pour éviter les dangers logiques potentiels liés à la mise en œuvre dans les DCE du service de réinitialisation ETTD vers DCE.

d) Le DCE doit achever toute reconfiguration nécessaire avant d'inverser (descendre) CTS; cela doit avoir lieu entre deux fronts descendants consécutifs de TxC.

Les deux messages de configuration, normalisés et extensibles, sont définis au 8.2.2.4. Les messages normalisés couvrent les plages d'application de cette interface qui peuvent être les plus sensibles au coût. Les messages extensibles permettent différentes formes de configuration du DCE lorsque cela est exigé et peuvent servir à lancer le service de message-reporting DCE vers ETTD pour rendre compte de l'état interne du DCE (une option supplémentaire du DCE est décrite au 8.2.2.4).

#### 8.2.2.3.4 Service message-transmission ETTD vers DCE

Ce service est mutuellement exclusif avec les services de réinitialisation et de configuration ETTD vers DCE; un seul d'entre eux au plus peut être actif à un moment donné. Le service de réinitialisation ETTD vers DCE peut à tout moment préempter ce service.

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Ce service doit être mis en œuvre en trois phases; chacune des deux dernières phases doit suivre immédiatement l'achèvement de la phase précédente.

a) L'ETTD doit affirmer (monter) RTS après le front montant, et avant le front descendant de TxC. Le DCE doit répondre en générant et en émettant la séquence de longueur appropriée de PhPDU de préambule (synchroniseur initial) et de délimiteur de début.

b) Lorsqu'il est prêt pour les données transparentes en provenance de l'ETTD, le DCE doit monter CTS avant le front descendant de TxC. L'ETTD doit répondre en codant le premier bit des données transparentes (1 pour haut, 0 pour bas) sur TxD avant le front descendant suivant de TxC suivant, et doit poursuivre ce processus sans interruption jusqu'à ce que de 3 à 300 bits intégraux de données aient été ainsi codés. L'ETTD doit affirmer (monter) TxD et inverser (descendre) RTS avant que le front descendant suivant de TxC. L'ETTD doit assurer que TxD monte d'au moins une durée de montée avant que RTS ne descende, pour éviter les dangers logiques potentiels liés à la mise en œuvre dans les DCE du service de réinitialisation ETTD vers DCE.

c) Le DCE doit terminer l'émission de toutes les données transparentes codées, reçues de l'ETTD et doit ensuite générer et émettre la séquence de longueur appropriée de PhPDU de délimiteur de fin. Il doit alors cesser l'émission. Le DCE doit ensuite attendre pendant une certaine durée égale à l'intervalle post-émission minimal configuré (voir Tableau 13) avant d'inverser (descendre) CTS, ce qui doit avoir lieu après un front descendant et avant le front descendant suivant de TxC.

#### 8.2.2.3.5 Service de notification de défauts ETTD vers DCE

Ce service doit être mutuellement exclusif avec les services d'indication de media-activity et de message-reporting DCE vers ETTD; un seul d'entre eux au plus peut être actif à un moment donné. Ce service peut à tout moment préempter les services d'indication de media-activity et de message-reporting DCE vers ETTD.

Ce service doit être codé comme un niveau bas simultané à la fois sur RxA et RDF. Lorsqu'il est affirmé par le DCE, ce niveau bas simultané doit être maintenu jusqu'à activation de l'un des deux services de réinitialisation ou de configuration ETTD vers DCE.

NOTE Il s'agit d'un service asynchrone et il n'est pas référencé à RxC.

Le DCE peut simultanément modifier à la fois RxA et RDF pendant l'achèvement simultané des services d'indication de media-activity et de message-reporting DCE vers ETTD. Il incombe à l'ETTD d'éviter les éventuels dangers logiques induits par cette modification concurrente.

#### 8.2.2.3.6 Service d'indication de media-activity ETTD vers DCE

Ce service est mutuellement exclusif avec le service de notification de défauts DCE vers ETTD; un seul d'entre eux au plus peut être actif à un moment donné. Le service de notification de défauts DCE vers ETTD peut à tout moment préempter ce service.

Ce service doit être codé comme un niveau haut sur RxA. Lorsqu'il est affirmé par le DCE, ce niveau haut permet de reconnaître la transition de haut vers bas sur RDF afin de lancer le service de message-reporting DCE vers ETTD. Toute transition suivante de haut vers bas sur RxA met fin à ce service de message-reporting DCE vers ETTD.

NOTE Le service d'indication de media-activity DCE vers ETTD est un service asynchrone et n'est pas référencé à RxC.

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#### 8.2.2.3.7 Service de message-reporting ETTD vers DCE

##### 8.2.2.3.7.1 Généralités

Ce service est mutuellement exclusif avec le service de notification de défauts DCE vers ETTD; un seul d'entre eux au plus peut être actif à un moment donné. Ce service peut uniquement avoir lieu lorsque le service d'indication de media-activity DCE vers ETTD est actif. Le service de notification de défauts DCE vers ETTD peut à tout moment préempter ce service.

##### 8.2.2.3.7.2 Réception non erronée

Ce service doit être mis en œuvre en quatre phases au moment de rendre compte d'un message bien formé; chacune de ces phases doit immédiatement suivre l'achèvement de la phase précédente.

La description suivante s'applique aux DCE qui ont des séquences de délimiteur de fin de huit PhPDU ou moins et qui n'exigent pas un temps de décodage supplémentaire pour un code FEC (correction d'erreurs sans voie de retour). Les DCE qui ne satisfont pas à ces conditions peuvent introduire des délais supplémentaires dans leurs processus de décodage et de rapport, de sorte que, vis-à-vis de la signalisation sur RxC et RDF, ils remplissent effectivement ces conditions.

a) Après détection de la signalisation reçue, apprentissage relatif à cette signalisation et récupération d'une horloge de données dont la fréquence nominale d'octets est la même que TxC, le DCE doit lancer le service de message-reporting DCE vers ETTD en fournissant cette horloge récupérée sur RxC et en inversant (descendant) RDF après le front montant et avant le front descendant suivant de RxC.

   NOTE 1 À ce moment-là, RxA est déjà affirmé.

b) Le DCE doit continuer l'apprentissage et tenter de faire correspondre la signalisation reçue à ses PhPDU de préambule et de délimiteur de début attendues.

   Si le DCE prend en charge *N* canaux de supports redondants, alors il peut rendre compte sur RDF de l'identité du canal dont la signalisation est reçue en codant ce numéro de canal dans une plage de 0 à *N*–1, comme nombre binaire qui est notifié par l'envoi du bit de poids fort en premier lieu, pendant la réception des trois derniers de ces PhPDU de délimiteur de début. Les bits notifiés sur RDF doivent être présentés en série après des fronts montants successifs de RxC et à chaque fois avant le front descendant de RxC qui le suit immédiatement.

   Sur détection d'une correspondance exacte entre la signalisation reçue et le délimiteur de début attendu, le DCE doit inverser RDF après le front descendant et avant le front montant suivant de RxC.

   NOTE 2 Lorsque l'identité du canal de réception a été notifiée sur RDF, cette inversion a généralement lieu au cours de la phase de niveau bas de \1,\2 qui suit immédiatement la phase de niveau haut (de \1,\2) au cours de laquelle le dernier bit (de poids faible) du numéro de canal a été notifié.

c) Le DCE doit poursuivre la réception et tenter de faire correspondre la signalisation reçue aux données éventuelles et aux PhPDU de délimiteur de fin attendues.

   Le DCE doit rendre compte de chaque bit de données décodé à partir de la signalisation reçue sur RDF. Les bits notifiés sur RDF doivent être présentés en série après des fronts montants successifs de \1,\2, à chaque fois avant le front descendant immédiatement suivant de RxC. En l'absence d'erreurs, ces bits doivent être notifiés dans le même ordre et avec les mêmes valeurs qu'en cas de transmission par une entité PhL homologue.

   NOTE 3 Cela est une garantie de transparence.

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Un délimiteur de fin peut être constitué de PhPDU données et non données. Le DCE peut de la même manière rendre compte sur RDF de chaque bit de données décodé à partir d'un délimiteur de fin et peut également rendre compte sur RDF d'un nombre approprié de valeurs de données pour les PhPDU non données décodées à partir d'un délimiteur de fin, à l'exception du fait que

1) le nombre total de "bits" ainsi notifié doit être de sept ou moins, et

2) sur détection d'une correspondance exacte entre la signalisation reçue et les délimiteurs de fin attendus, le DCE ne doit pas rendre compte sur RDF d'un autre bit correspondant au dernier "bit" du délimiteur de fin, mais doit plutôt d'abord affirmer (monter) RDF après le front montant et avant le front descendant suivant de RxC, et ensuite il doit inverser (descendre) RDF après le front descendant et avant le front montant suivant de RxC.

NOTE 4 La plupart des applications décodent et notifient, en tant que données, sur RDF, toutes les PhPDU de données initiales dans une séquence de délimiteur de fin reçue. Il n'est pas nécessaire de notifier la première PhPDU non données et les PhPDU suivantes. Cependant, un rapport final est effectué sur RDF pour indiquer la reconnaissance d'un délimiteur de fin correct.

NOTE 5 Chaque bit notifié, à l'exception du dernier, est maintenu sur RDF pendant un cycle complet de RxC. Le dernier bit est remplacé par une séquence haut-bas, chacune étant maintenue pendant seulement une phase de RxC.

NOTE 3 La séquence haut-bas d'achèvement a lieu au cours des rapports des huit premiers "bits" qui ont lieu après que le dernier bit de données (prédélimiteur) a été notifié. Le dernier bit de données (prédélimiteur) a été le 8*N*'ème bit de données ainsi notifié au cours de cette phase et dans ce cas, il convient que *N* soit au moins égal à trois et ne dépasse pas 300.

d) Le DCE doit affirmer (monter) RDF avant le front descendant suivant de RxC et ne doit lancer une autre instance du service de message-reporting DCE vers ETTD uniquement lorsque le service d'indication de media-activity DCE vers ETTD en cours est terminé.

#### 8.2.2.3.7.3 Réception erronée

Une erreur peut être détectée au cours de toute phase du processus de réception décrit au 8.2.2.3.7.2. Lorsque cette détection a lieu, le DCE doit modifier le séquencement de ces phases de la manière suivante:

S'il convient que le DCE détecte des PhPDU non valides ou une séquence non valide de PhPDU, ou encore une séquence valide de PhPDU de délimiteur de fin qui n'est pas séparée des PhPDU de délimiteur de début par un nombre entier d'octets de données de PhPDU, et si le DCE peut établir un signal valide sur RxC (par exemple, en remplaçant au besoin la source d'horloge récupérée par TxC ou par un autre signal local); dans ce cas

a) si la phase 2 n'a pas encore été lancée, le DCE doit immédiatement lancer la phase 2;

b) si la phase 2 ne s'est pas encore terminée, le DCE doit immédiatement terminer la phase 2 aussi rapidement que possible, en ignorant l'exigence de correspondance de la séquence de PhPDU de délimiteur de début;

c) dans le cas contraire, le DCE doit immédiatement inverser (descendre) RDF après le front montant et avant le front descendant suivant de RxC, puis il doit affirmer (monter) RDF après le front descendant et avant le front montant suivant de RxC.

NOTE Cette séquence permet au DCE

– d'activer l'utilisation de RxC par l'ETTD;

– d'identifier le canal qui comporte la signalisation erronée; et

– d'indiquer une erreur de réception.

Lorsque le DCE a achevé autant d'étapes a), b) et c) ci-dessus que nécessaire et que possible, le DCE doit immédiatement lancer la phase 4.

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#### 8.2.2.4 Messages de configuration DCE

##### 8.2.2.4.1 Récapitulatif

Le paragraphe 8.2.2.4 définit les messages de configuration normalisés, ainsi que la partie normalisée des messages de configuration extensibles. Les messages normalisés couvrent les domaines d'application de cette interface qui sont vraisemblablement les plus communément utilisés. Les messages extensibles permettent différentes formes de configuration du DCE, lorsque cela est exigé, et peuvent servir à lancer le service de message-reporting DCE vers ETTD pour rendre compte de l'état interne du DCE (une option du DCE).

Deux messages normalisés et deux classes de messages extensibles sont définis. Tous les messages sont transmis sur l'interface dans l'ordre de définition des bits. Les entiers sont transmis avec le bit de poids fort (MSB) en premier.

Les deux messages normalisés et les deux classes de messages extensibles sont différenciés par les deux premiers bits de données du message de configuration, de la manière suivante:

00 – message de configuration de base;

01 – message de commande de diversité de trajectoires;

10 – message de configuration extensible;

11 – message d'invocation du rapport d'état extensible.

##### 8.2.2.4.2 Message de configuration de base

Après ses deux bits initiaux (00), le message de configuration de base spécifie les aspects opérationnels communs à la plupart des DCE. Les composantes définies de ce message sont, par ordre de transmission:

a) le mode opérationnel du DCE, codé sur un bit de données comme cela est présenté. La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 0;

0 Simultané bidirectionnel (full-duplex), où chaque invocation du service message-transmission ETTD vers DCE active automatiquement les services d'indication de media-activity et de message-reporting DCE vers ETTD. Ce mode est souhaitable pour les supports à deux canaux, tels que le câblage à paire de fibres optiques.

NOTE 1 Certains ETTD peuvent ne fonctionner que dans ce mode.

1 Bidirectionnel à l'alternat (semi-duplex), avec lequel une invocation du service de message-transmission ETTD vers DCE n'active pas automatiquement les services d'indication de media-activity et de message-reporting DCE vers ETTD.

NOTE 2 Ce mode réduit le plus possible la consommation d'énergie du DCE et de l'interface ETTD-DCE. Certains ETTD peuvent ne fonctionner que dans ce mode.

b) la sélection de l'origine des données internes au DCE pour le service de messages-reporting, codé sur deux bits de données comme cela est présenté (voir Tableau 13). La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 00. Lorsque la sélection est non zéro, l'émission sur tous les supports connectés doit être désactivée et l'interface ETTD-DCE doit fonctionner en mode bidirectionnel simultané (full-duplex);

00 signalisation décodée, reçue de l'un des supports connectés, comme cela est spécifié au 8.2.2.4.3 b) et c). Le mode d'interface est tel qu'il est spécifié au 8.2.2.4.2 a);

01 rapport internal-status, voir 8.2.2.5.2 et 8.2.2.6;

10 rebouclage aussi proche que possible de l'interface ETTD-DCE, avec aucune émission vers les supports connectés, et dans ce cas, chaque invocation du service message-transmission ETTD vers DCE active automatiquement les services d'indication media-activity et de message-reporting DCE vers ETTD. Ce mode est souhaitable pour le DCE, par rapport à l'ETTD, en ce qui concerne la localisation des défauts d'interconnexion.

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11 rebouclage aussi proche que possible de la ou des interfaces de support, avec aucune émission vers les supports connectés, et dans ce cas, chaque invocation du service message-transmission ETTD vers DCE active automatiquement les services media-activity et de message-reporting DCE vers ETTD. Ce mode est souhaitable pour une auto-évaluation avant entrée sur un réseau opérationnel.

c) il convient d'étendre la valeur du préambule qui est la séquence initiale de PhPDU dans chaque émission. Sa plage est de zéro à sept unités d'extension, codée en trois bits de données comme 0 (000) à 7 (111). La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 0 (000) (Voir la Note 2 du 6.2.2.2);

d) il convient d'étendre la valeur de l'intervalle post-émission obligatoire qui est la période de non émission entre des séquences successives de PhPDU. Sa plage est de zéro à sept unités d'extension, codée en trois bits de données comme 0 (000) à 7 (111). La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 0 (000) (Voir la Note 3 du 6.2.2.2).

#### 8.2.2.4.3 Message de commande de diversité de trajectoires

Après ses deux bits initiaux de (01), le message de commande de diversité de trajectoires spécifie des données de configuration supplémentaires, généralement exigées pour la gestion et l'évaluation de défauts de trajectoires redondantes: les commandes séparées de transmission et de réception pour chacun des supports redondants connectés (canaux et trajectoires). Les composantes définies de ce message sont, par ordre de transmission:

a) deux bits zéro (00), qui assurent l'alignement des quartets et des octets dans le message pour les champs suivants;

b) l'algorithme de choix entre supports redondants comme origine de la signalisation reçue lorsque plusieurs supports sont activés pour la réception, codé en quatre bits comme cela est indiqué. La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 0000;

   0000 – Il convient que le support sélectionné pour la réception soit le premier support sur lequel est détectée la signalisation appropriée pour l'apprentissage du récepteur;

   1000 à 1111 (= 7 + *N*, 1 ≤ *N* ≤ 8) – Il convient de sélectionner le *N*ème support, sauf lorsque la signalisation appropriée pour l'apprentissage du récepteur a été détectée sur un autre support pendant une période égale à la période supplémentaire d'extension de l'intervalle entre trames, spécifiée au 8.2.2.4.2 d), auquel cas il convient de sélectionner cet autre support;

c) la sélection de l'activation (0) ou de l'inhibition (1) de la réception sur chacun des huit supports redondants, ou moins, codée sur huit bits consécutifs pour les canaux 1 à 8, respectivement (voir Tableau 13). La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 0000 0000;

d) la sélection de l'activation (0) ou de l'inhibition (1) de la transmission sur chacun des huit supports redondants, ou moins, codée sur huit bits consécutifs pour les canaux 1 à 8, respectivement (voir Tableau 13). La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 0000 0000;

e) la valeur d'extension de l'intervalle post-transmission, due à une éventuelle dérive du signal entre supports redondants. Sa plage est de zéro à sept unités d'extension, codée en trois bits de données comme 0 (000) à 7 (111). La valeur de ce paramètre après activation du service de réinitialisation ETTD vers DCE est 0 (000) (voir 8.2.2.4.2 d), 8.2.2.4.3 b), et la Note 3 du 6.2.2.2).

### 8.2.2.5 Messages de configuration extensible

#### 8.2.2.5.1 Format général

Après ses deux bits initiaux (10), le codage des messages de configuration extensible peut dépendre de l'application. La structure et la forme des messages de configuration extensible doivent être les mêmes que celles du message de configuration de base spécifiées au 8.2.2.4.2.

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#### 8.2.2.5.2 Messages d'invocation du rapport d'état extensible

Après ses deux bits initiaux (11), le codage des messages d'invocation de rapport d'état extensible peut dépendre de l'application. La structure et la forme des messages de configuration d'invocation de rapport d'état extensible doivent être les mêmes que celles du message de configuration de base spécifiées au 8.2.2.4.2. Les informations spécifiées doivent sélectionner une source interne au DCE de signalisation reçue et si le mode DCE-internal-data-source est "status-reporting" (voir 8.2.2.4.2 b)), alors le DCE doit générer un message multi-data-octet, rempli (bourrage) autant que nécessaire pour obtenir un multiple d'octets et il doit le notifier à l'aide des services d'indication de media-activity et de message-reporting DCE vers ETTD.

### 8.2.2.6 Rapports d'état générés par le DCE

Ces rapports sont générés dans le DCE sur demande et notifiés lorsque DCE-internal-data-source est "internal-status report" (voir 8.2.2.4.2 b)).

## 8.3 Type 3: Interface ETTD − DCE

### 8.3.1 Transmission synchrone

L'interface ETTD-DCE spécifiée pour le Type 1 doit être utilisée (voir 8.2).

### 8.3.2 Transmission asynchrone

L'interface ETTD-DCE n'est pas exposée en transmission asynchrone.

## 8.4 Type 8: Interface MIS – MDS

### 8.4.1 Généralités

La PhL est subdivisée en une MIS (sous-couche indépendante du support) et une MDS (sous-couche dépendante du support). Ces deux couches sont connectées par l'interface MIS-MDS.

L'interface MIS-MDS est une interface fonctionnelle qui prend en charge certains services; il n'est pas obligatoire que cette interface soit réalisée électriquement. Chacun de ces services est mis en œuvre par une séquence d'interactions des signaux d'interface.

### 8.4.2 Services

#### 8.4.2.1 Généralités

L'interface MIS-MDS prend en charge les services décrits ci-dessous:

– service de demande de cycle d'identification;
– service de demande de cycle de données;
– service de classification de séquences de données;
– service d'identification de séquences de données;
– service de transmission de messages;
– service de réception de messages;
– réinitialisation du bus.

#### 8.4.2.2 Service de demande de cycle d'identification

Ce service permet à la MIS de démarrer une séquence de données pour transmettre des données d'identification et de commande (cycle d'identification).

NOTE Ce service est utilisé par un maître uniquement.

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#### 8.4.2.3 Service de demande de cycle de données

Ce service permet à la MIS de démarrer une séquence de données pour la transmission de données utilisateur (cycle de données).

NOTE Ce service est utilisé par un maître uniquement.

#### 8.4.2.4 Service de classification de séquences de données

Ce service permet à la MIS de démarrer un cycle d'identification ou de données.

NOTE Ce service est utilisé uniquement par un coupleur de bus ou un esclave.

#### 8.4.2.5 Service d'identification de séquences de données

Ce service permet à la MDS d'indiquer le début d'un cycle d'identification ou de données.

#### 8.4.2.6 Service de transmission de messages

Ce service permet à la MIS d'envoyer un message, par la MDS, soit au support connecté, soit en retour vers une autre MDS. La MDS détermine la vitesse d'exécution de ce service.

NOTE 1 Ce service émet les PhIDU acheminées vers la PhL.

NOTE 2 Ce service est exécuté simultanément au service de réception de messages.

#### 8.4.2.7 Service de réception de messages

Ce service permet à la MDS d'indiquer la réception d'un message à la MIS ou à une autre MDS connectée. Le service se termine par une indication qui spécifie si la PhPDU reçue était correctement formée.

Ce service doit être précédé par un service d'identification de séquences de données.

#### 8.4.2.8 Réinitialisation du bus

Ce service permet d'envoyer et de recevoir une réinitialisation de tous les esclaves. Le Tableau 48 affiche le paramètre de la réinitialisation du bus MDS.

**Tableau 48 – Réinitialisation du bus MDS**

| Paramètre du service | Demande | Indication |
|---|---|---|
| reset_type | O | O |

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**reset_type:**

Ce paramètre de service indique si la réinitialisation est courte ou longue.

Plage de valeurs: courte, longue

NOTE Ce service est utilisé par un maître uniquement.

### 8.4.3 Signaux d'interface

L'interface MIS-MDS met à disposition les signaux énumérés dans le Tableau 49.

**Tableau 49 – Signaux à l'interface MIS-MDS**

| Signal d'interface | Mnémonique | Source |
|---|---|---|
| Horloge de transmission | TxC | MIS |
| Request-to-send (Demande pour émettre) | RTS | MIS |
| Clear-to-send (Prêt à émettre) | CTS | MDS |
| Séquence de transmission | TxS | MIS |
| Ligne de sélection de transmission | TxSL | MIS |
| Ligne de commande de transmission | TxCR | MIS |
| Données de transmission | TxD | MIS |
| Délai de demande 1 | RqDly1 | MIS |
| Délai de demande 2 | RqDly2 | MIS |
| Busy (occupé) | BSY | MDS |
| Horloge de réception | RxC | MDS |
| Activité de réception | RxA | MDS |
| Séquence de réception | RxS | MDS |
| Ligne de sélection de réception | RxSL | MDS |
| Ligne de commande de réception | RxCR | MDS |
| Données de réception | RxD | MDS |
| Réinitialisation sortie | RO | MIS |
| Réinitialisation entrée | RI | MDS |

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### 8.4.4 Conversion des services en signaux d'interface

#### 8.4.4.1 Généralités

Les services de l'interface MIS-MDS sont représentés par des machines de protocole et des séquences de signaux décrites du 8.4.4.1 au 8.4.4.8.

NOTE La convention suivante s'applique aux diagrammes d'états représentés de la Figure 30 à la Figure 38.

Le symbole "*" correspond au "Et Logique", le symbole "/" correspond à "inversion".

#### 8.4.4.2 Service de demande de cycle d'identification

La Figure 30 décrit ce service avec les quatre services en gris ainsi que leurs transitions.

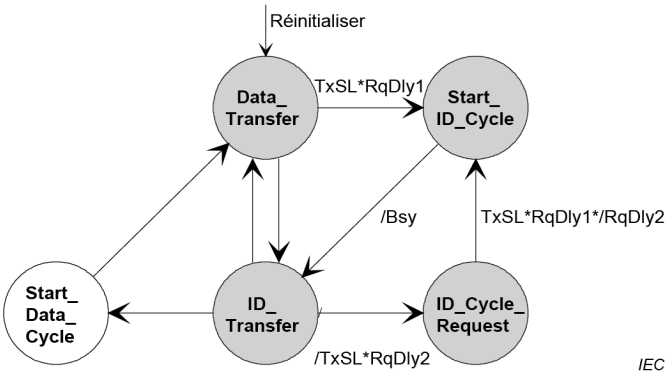


**Figure 30 – Transitions d'état avec le service de demande de cycle d'identification**

NOTE 1 Les transitions qui ne sont pas représentées à la Figure 30 sont utilisées pour d'autres services; voir la Figure 33 et la Figure 35 pour les états et transitions correspondants.

Le cycle d'identification était précédé d'un cycle de données ou d'une réinitialisation:

État **Data_Transfer**:
La MIS lance un service de demande de cycle d'identification par modification du signal TxSL (du niveau logique 0 au niveau logique 1) ainsi que, simultanément, le signal RqDly1 (du niveau logique 0 au niveau logique 1).

État **Start_ID_Cycle**:
Ensuite, la MDS transmet l'état PhPDU correspondant, démarre un temporisateur d'une durée t1 et établit le signal BSY en le faisant passer du niveau logique 0 au niveau logique 1. Le MIS réinitialise le signal RqDly1 sur niveau logique 0.

À la fin de la durée t1, la MDS met le signal BSY au niveau logique 0 et achève le service de demande de cycle d'identification. La MIS communique cela à la DLL au moyen d'une primitive de confirmation de PH-DATA et prend par hypothèse l'état ID_Transfer.

La durée minimale de t1 est de 5 temps binaires.

La Figure 31 représente les formes de signaux correspondantes à l'interface MIS-MDS pour un service de demande de cycle d'identification après un cycle de données précédent.

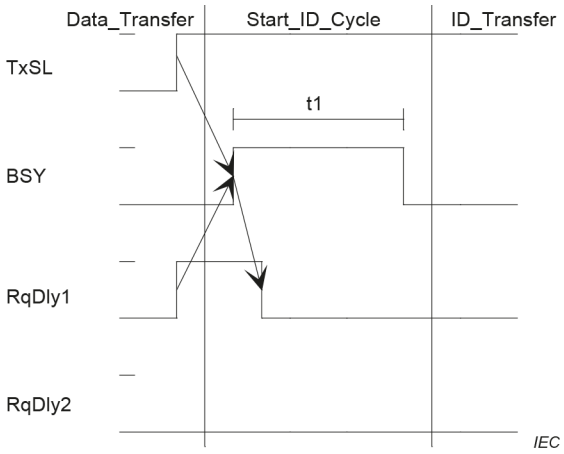


**Figure 31 – Interface MIS-MDS: service de demande de cycle d'identification**

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Le cycle d'identification était précédé d'un cycle d'identification:

État **ID_Transfer**:
La MIS lance un service de demande de cycle d'identification par modification du signal TxSL (du niveau logique 1 au niveau logique 0) ainsi que, simultanément, le signal RqDly2 (du niveau logique 0 au niveau logique 1).

État **ID_Cycle_Request**:
Ensuite, la MDS transmet l'état PhPDU correspondant, démarre un temporisateur d'une durée t2 et établit le signal BSY en le faisant passer du niveau logique 0 au niveau logique 1. Le MIS réinitialise le signal RqDly2 sur 0 logique.

Après l'écoulement du temps T2, le MDS réinitialise le signal BSY sur le niveau logique 0. La sous-couche MIS modifie ensuite le signal TxSL (du niveau logique 0 au niveau logique 1) ainsi que, simultanément, le signal RqDly1 (du niveau logique 0 au niveau logique 1).

La durée minimale de t2 est de 25 temps binaires.

État **Start_ID_Cycle**:
Ensuite, la MDS transfère l'état PhPDU correspondant, démarre un temporisateur d'une durée T1 et établit le signal BSY (occupé) en le faisant passer du niveau logique 0 au niveau logique 1. Le MIS réinitialise le signal RqDly1 sur le niveau logique 0.

À la fin de la durée t1, la MDS met le signal BSY au niveau logique 0 et achève le service de demande de cycle d'identification. La MIS communique cela à la DLL au moyen d'une primitive de confirmation de PH-DATA et prend par hypothèse l'état ID_Transfer.

La Figure 32 représente les formes de signaux correspondantes à l'interface MIS-MDS pour un service de demande de cycle d'identification après un cycle d'identification précédent.

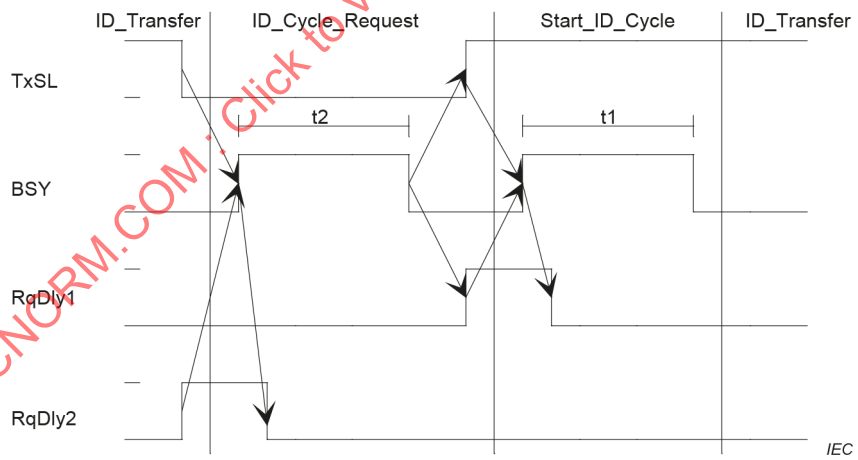


**Figure 32 – Interface MIS-MDS: service de demande de cycle d'identification**

NOTE 2 Le service de demande de cycle d'identification est un service asynchrone et n'est pas lié à TxC.

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#### 8.4.4.3 Service de demande de cycle de données

La Figure 33 décrit ce service avec les trois états en gris ainsi que leurs transitions.

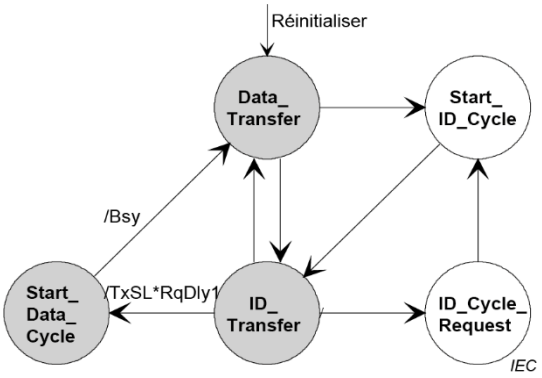


**Figure 33 – Transitions d'état du service de demande de cycle de données**

NOTE 1 Les transitions qui ne sont pas représentées à la Figure 33 sont utilisées pour d'autres services; voir la Figure 30 et la Figure 35 pour les états et transitions correspondants.

**Le cycle de données était précédé d'un cycle d'identification:**

État ID_Transfer:
La MIS lance un service de demande de cycle de données par modification du signal TxSL (du niveau logique 1 au niveau logique 0) ainsi que, simultanément, le signal RqDly1 (du niveau logique 0 au niveau logique 1).

État Start_Data_Cycle:
Ensuite, la MDS transmet l'état PhPDU correspondant, démarre un temporisateur d'une durée t1 et établit le signal BSY en le faisant passer du niveau logique 0 au niveau logique 1. Le MIS réinitialise le signal RqDly1 sur le niveau logique 0.

À la fin de la durée t1, la MDS met le signal BSY au niveau logique 0 et achève le service de demande de cycle de données. La MIS communique cela à la DLL au moyen d'une primitive de confirmation de PH-DATA et prend par hypothèse l'état Data_Transfer.

La Figure 34 représente les formes de signaux correspondantes à l'interface MIS-MDS pour un service de demande de cycle de données après un cycle d'identification précédent.

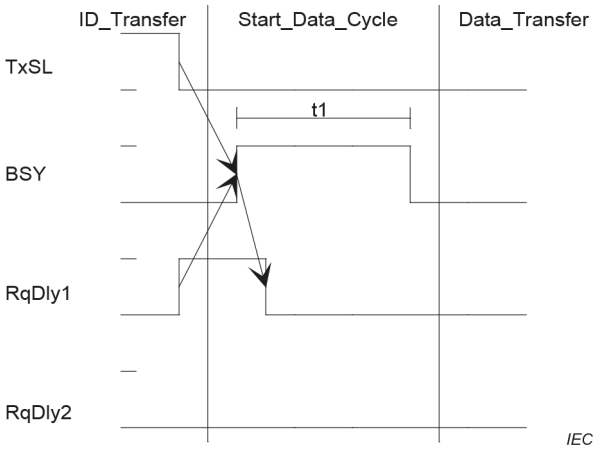


**Figure 34 – Interface MIS-MDS: service de demande de cycle de données**

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**Le cycle de données était précédé d'un cycle de données:**

Si la DLL demande le début d'un cycle de données avec une primitive de demande PH-DATA (PhICI=start_data_cycle), et si la DLL n'a pas auparavant demandé le début d'un cycle d'identification au moyen d'une primitive de demande PH-DATA (PhICI=start_ID_cycle), la MIS communique à la DLL la fin du service de demande de cycle de données au moyen d'une primitive de confirmation PH-DATA. L'état des signaux TxSL, RqDly1 et RqDly2 demeure inchangé.

NOTE 2 Le service de demande de cycle de données est un service asynchrone et n'est pas lié à TxC.

#### 8.4.4.4 Service de classification de séquences de données

La Figure 35 décrit ce service avec les deux états en gris ainsi que leurs transitions.

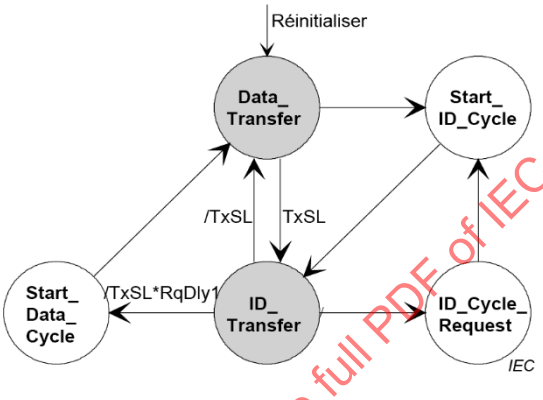


**Figure 35 – Transitions d'état du service de classification de séquences de données**

NOTE 1 Les transitions qui ne sont pas représentées à la Figure 35 sont utilisées pour d'autres services; voir la Figure 30 et la Figure 33 pour les états et transitions correspondants.

État **Data_Transfer**:
La MIS lance un cycle d'identification (transmission de données d'identification et de commande dans la PhPDU) par modification du signal TxSL (du niveau logique 0 au niveau logique 1).

État **ID_Transfer**
La MIS lance un cycle de données (transmission de données utilisateur dans la PhPDU) par modification du signal (du niveau logique 1 au niveau logique 0).

NOTE 2 Le service de classification de séquences de données est un service asynchrone et n'est pas lié à TxC.

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#### 8.4.4.5 Service de transmission de messages

La Figure 36 décrit ce service avec les six états ainsi que leurs transitions.

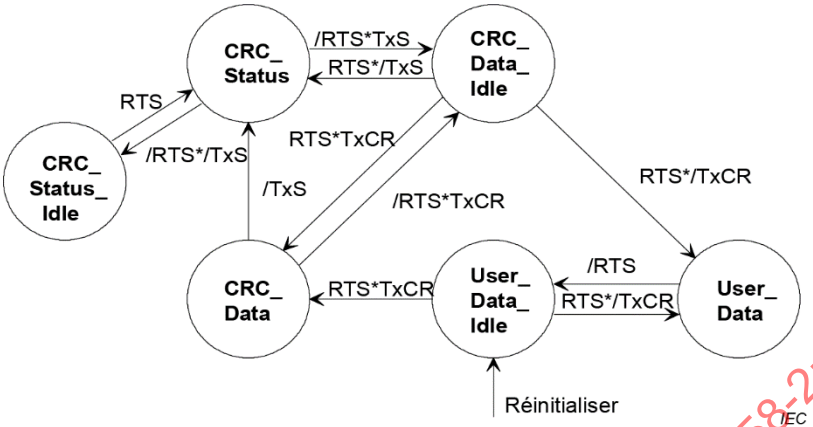


**Figure 36 – Machine de protocole du service de transmission de messages**

NOTE 1 Une séquence de bits de données est émise en multiples d'octets. Lorsque la MIS a établi son signal d'interface RTS du niveau logique 1 au niveau logique 0, elle attend le front descendant du signal CTS actif à l'état bas provenant de la MDS. La MIS communique cela à la DLL au moyen d'une primitive de confirmation de PH-DATA (obligatoire pour le maître uniquement).

État **CRC_Data_Idle**:
La MIS lance un service de transmission de messages par établissement du signal RTS au niveau logique 1 au cours du front montant de TxC, par établissement simultané du signal TxCR au niveau logique 0 et par émission avec le signal TxD du premier bit de données dans un octet destiné à la MDS.

NOTE 3 Au lieu de lancer un service de transmission de messages, la MIS peut commencer à transmettre l'état de la somme de contrôle par établissement du signal RTS au niveau logique 1 au cours du front montant suivant de TxC, par établissement simultané du signal TxS au niveau logique 0 et par envoi à la MDS du premier bit de l'état de la somme de contrôle avec le signal TxD.

État **User_Data**:
La MIS doit continuer la transmission des données par transmission à la MDS du bit de données suivant dans un octet avec le signal TxD, au cours de chaque front montant de TxC. La MIS achève la transmission des données par établissement du signal RTS au niveau logique 0, lorsque le dernier bit a été transmis et avant le front descendant suivant de TxC.

NOTE 4 La MIS poursuit la transmission des données par établissement du signal RTS au niveau logique 1 au cours du front montant de TxC, et par transmission simultanée avec le signal TxD du premier bit de données dans un octet destiné à la MDS.

État **User_Data_Idle**:
La MIS démarre la séquence de contrôle par établissement du signal RTS au niveau logique 1 au cours du front montant de TxC, par établissement simultané du signal TxCR au niveau logique 1 et par envoi à la MDS du premier bit de la somme de contrôle (données CRC) dans le signal TxD.

NOTE 5 Au lieu de la séquence de contrôle, la MIS peut lancer un nouveau service de transmission de messages par établissement du signal RTS au niveau logique 1 au cours du front montant de TxC et par envoi simultané à la MDS, avec le signal TxD, du premier bit de données. Cela équivaut à une poursuite du service de transmission de messages.

État **CRC_Data**:
La MIS doit continuer la transmission des données de somme de contrôle par l'envoi du bit de données suivant dans un octet, en même temps que le signal TxD destiné à la MDS, au cours de chaque front montant de TxC.

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Lorsque la transmission des données de la somme de contrôle est terminée, la MIS démarre la transmission de l'état de la somme de contrôle (état CRC) par l'envoi du signal TxS au niveau logique 0 au cours du front montant de TxC et par transmission simultanée à la MDS, avec le signal TxD, du premier bit de l'état de la somme de contrôle.

NOTE 6 La MIS poursuit la transmission de la somme de contrôle par établissement du signal RTS au niveau logique 1 avant le front descendant de TxC et par envoi simultané à la MDS, avec le signal TXD, du premier bit de l'octet suivant de la somme de contrôle.

NOTE 7 La MIS commence par transmettre l'état de la somme de contrôle par établissement du signal RTS au niveau logique 1 au cours du front montant de TxC, par établissement simultané du signal TxS au niveau logique 0, et par envoi à la MDS du premier bit de l'état de la somme de contrôle.

État **CRC_Status**:
La MIS doit continuer l'émission de l'état de la somme de contrôle par transmission à la MDS du bit suivant dans un octet, avec le signal TxD, au cours de chaque front montant de TxC. La MIS achève l'émission de l'état de la somme de contrôle par établissement du signal RTS au niveau logique 0 et du signal TxS au niveau logique 1 avant le front descendant de TxC et après le dernier bit de l'octet à transmettre.

État **CRC_Status_Idle**:
La MIS poursuit la transmission de l'état de la somme de contrôle par établissement du signal RTS au niveau logique 1 au cours du front montant de TxC et par envoi simultané à la MDS, avec le signal TXD, du premier bit de l'octet suivant.

#### 8.4.4.6 Service d'identification de séquences de données

La Figure 37 décrit ce service avec les deux états ainsi que leurs transitions.

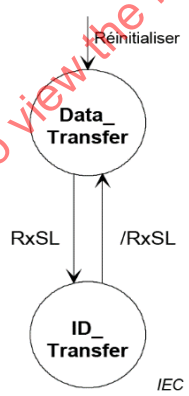


**Figure 37 – Machine de protocole du service d'identification de séquences de données**

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État **Data_Transfer**:
Le début d'un cycle d'identification (transmission de données d'identification ou de données de commande dans la PhPDU reçue) est indiqué à la MIS par une modification du signal RxSL (passage du niveau logique 1 au niveau logique 0).

État **ID_Transfer**:
Le début d'un cycle de données (transmission de données utilisateur dans la PhPDU reçue) est indiqué à la MIS par une modification du signal RxSL (passage du niveau logique 1 au niveau logique 0).

NOTE Le service d'identification de séquences de données est un service asynchrone et n'est pas lié à RxC.

#### 8.4.4.7 Service de réception de messages

La Figure 38 décrit ce service avec les six états ainsi que leurs transitions.

NOTE 1 Les données sont reçues en multiples d'octets.

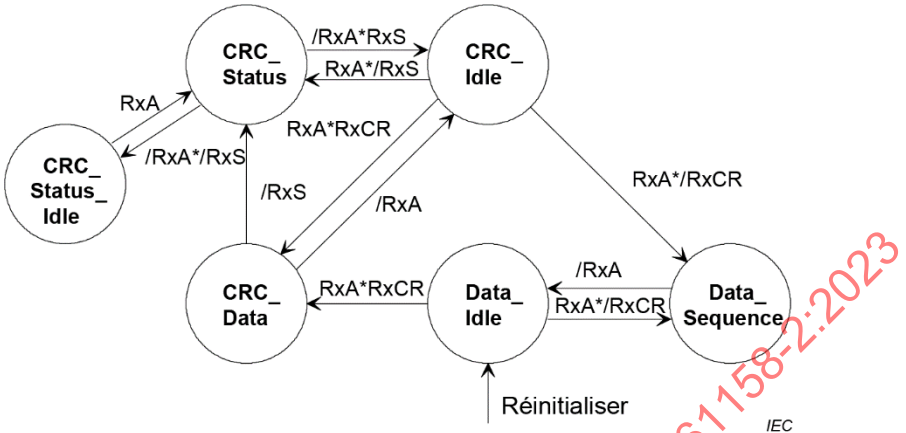


**Figure 38 – Machine de protocole du service de réception de messages**

État **CRC_Idle**:
Si la MDS reconnaît le début d'une PhPDU de séquence de données, elle lance le service de réception de messages par adaptation des impulsions temporelles émises avec le signal RxC à celles qui sont reçues et par établissement simultané, au cours du front montant du signal RxC, du signal RxA au niveau logique 1, du signal RxCR au niveau logique 0, ainsi que par envoi à la MIS du premier bit de données décodé d'un octet avec le signal RxD.

Si la MDS reconnaît le début d'un état de la somme de contrôle dans une PhPDU de séquence de contrôle au lieu du début d'une PhPDU de séquence de données, elle établit le signal RxA au niveau logique 1 et en même temps le signal RxS au niveau logique 0 et envoie à la MIS le premier bit décodé avec le signal RxD.

Tant que la MDS reconnaît l'état CRC_Idle, elle doit conserver le signal RxA au niveau logique 0 et le signal RxCR au niveau logique 1.

État **Data_Sequence**:
La MDS doit continuer à envoyer à la MIS les données reçues et décodées avec le signal RxD, par adaptation des impulsions temporelles émises à celles qui sont reçues avec le signal RxC. Si la MDS reconnaît l'état Data_Idle après avoir reçu le dernier bit de données dans un octet, elle doit établir le signal RxA au niveau logique 0 au cours du front descendant de RxC.

État **Data_Idle**:
Tant que la MDS reconnaît l'état Data_Idle, elle doit conserver le signal RxA au niveau logique 0 et le signal RxCR au niveau logique 0.

Si la MDS reconnaît le début d'une PhPDU de séquence de contrôle, elle adapte les impulsions temporelles transmises avec le signal RxC à celles qui sont reçues, elle établit le signal RxA au niveau logique 1 au cours du front montant de RxC et établit en même temps le signal RxCR au niveau logique 1 et transmet à la MIS, avec le signal RxD, le premier bit reçu et décodé de la somme de contrôle (données CRC).

Si la MDS reconnaît le premier bit dans un octet d'une PhPDU de séquence de données au lieu du début d'une séquence de contrôle, elle continue la réception de la séquence de données par adaptation des impulsions temporelles émises à celles qui sont reçues avec le signal RxC et par établissement simultané du signal RxA au niveau logique 1, au cours du front montant de RxC, et par envoi à la MIS du bit de données reçu et décodé avec le signal RxD.

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État **CRC_Data**:
La MDS doit continuer à envoyer à la MIS les données reçues et décodées de la somme de contrôle avec le signal RxD et à adapter avec le signal RxC les impulsions temporelles émises à celles qui sont reçues.

Si la MDS reconnaît le premier bit de l'état de la somme de contrôle après avoir entièrement reçu les données de la somme de contrôle, elle doit adapter les impulsions temporelles émises avec le signal RxC, établir au niveau logique 0 le signal RxS au cours du front montant de RxC et envoyer en même temps à la MIS le bit reçu et décodé de l'état de la somme de contrôle avec le signal RxD.

Si la MDS reconnaît l'état CRC_Idle après avoir reçu le dernier bit dans un octet, elle doit établir le signal RxA au niveau logique 0 au cours du front descendant de RxC.

Si la MDS reconnaît le premier bit dans un octet des données de la somme de contrôle, elle doit poursuivre la réception des données de la somme de contrôle, par adaptation des impulsions temporelles émises à celles qui sont reçues avec le signal RxC et par établissement du signal RxA au niveau logique 1 au cours du front montant de RxC, ainsi que par envoi simultané à la MIS, avec le signal RxD, du bit reçu et décodé de la somme de contrôle.

État **CRC_Status**:
La MDS doit continuer à envoyer à la MIS l'état de la somme de contrôle reçu et décodé avec le signal RxD, par adaptation simultanée des impulsions temporelles émises à celles qui sont reçues avec le signal RxC. Après avoir entièrement reçu l'état de la somme de contrôle, le MDS établit le signal RxA au niveau logique 0 au cours du front descendant de RxC et établit en même temps le signal RxS au niveau logique 1.

Si la MDS reconnaît l'état CRC_Idle après avoir reçu le dernier bit dans un octet, elle doit établir le signal RxA au niveau logique 0 au cours du front descendant de RxC.

État **CRC_Status_Idle**:
Si la MDS reconnaît le premier bit dans un octet des données de la somme de contrôle, elle doit poursuivre la réception de l'état de la somme de contrôle, par adaptation des impulsions temporelles émises à celles qui sont reçues avec le signal RxC et par établissement du signal RxA au niveau logique 1 au cours du front montant de RxC, ainsi que par envoi simultané à la MIS, avec le signal RxD, du bit reçu et décodé de l'état de la somme de contrôle.

#### 8.4.4.8 Service Réinitialiser

Ce service est envoyé de la MIS à la MDS par établissement du signal RO. La réception d'une réinitialisation est transmise de la MDS à la MIS avec le signal RI. Plages de valeurs: courte, longue

### 8.5 Type 12: Interface ETTD − DCE

L'interface ETTD-DCE n'est pas exposée en transmission de Type 12.

### 8.6 Type 28: Interface ETTD – DCE et fonction spécifique à la MIS

#### 8.6.1 Généralités

La PhE est subdivisée en une composante ETTD qui contient la DIS et en une composante DCE qui contient la MDS et des sous-couches de niveau inférieur. L'interface ETTD- DCE connecte ces deux composantes physiques et est elle-même contenue dans la MIS.

Pour l'interface ETTD-DCE ainsi que pour toute autre interface, l'exposition n'est pas obligatoire.

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### 8.6.2 Fonction spécifique à la MIS

#### 8.6.2.1 Généralités

La fonction MIS inclut le traitement de ressources physiques spécifiques dans le DCE selon le mode de fonctionnement défini.

#### 8.6.2.2 Ressource PhL

##### 8.6.2.2.1 Trame de signal

Dans le réseau de Type 28, la trame de données envoyée par la DLL est convertie en bloc de code (CB) qui peut être traité par la PhL par l'intermédiaire de l'interface DLL-PhL. Il convient que le CB fasse l'objet d'un codage Reed-Solomon (RS) et d'un codage convolutif. Après le mapping QAM dans la PhL, le CB est mis en correspondance avec la ressource physique définie par le symbole OFDM et la sous-porteuse, puis modulé par IFFT. Ensuite, la trame de signal PhL (SF) est formée et transmise au câble. Le récepteur reçoit le signal numérique et le flux à l'inverse.

L'intervalle d'échantillonnage dans le domaine temporel $T_S$ est donné par la Formule (1).

$$T_S = \frac{1}{24\,000 \times 4\,096} \tag{1}$$

Cela dure 10,17 nanosecondes. L'intervalle d'échantillonnage est fixe dans différents modes de transmission (TM).

L'unité de base du signal PhL est SF, 64 symboles OFDM formant une SF. Chaque symbole OFDM est divisé en bande latérale supérieure et en bande latérale inférieure dans la sous-porteuse du domaine fréquentiel. La sous-porteuse haute fréquence (16,896 MHz à 32,256 MHz) est appelée bande latérale supérieure, et la sous-porteuse basse fréquence (1,536 MHz à 16,896 MHz) est appelée bande latérale inférieure. La bande latérale supérieure et la bande latérale inférieure peuvent être attribuées à différents MN ou TN.

La Figure 39 représente la structure de la SF et du symbole OFDM.

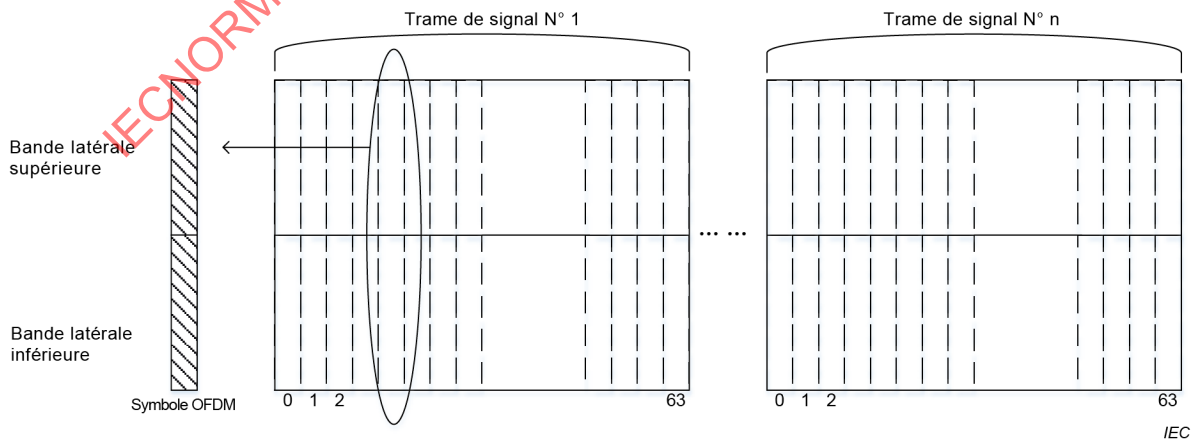


**Figure 39 – SF et symbole OFDM**

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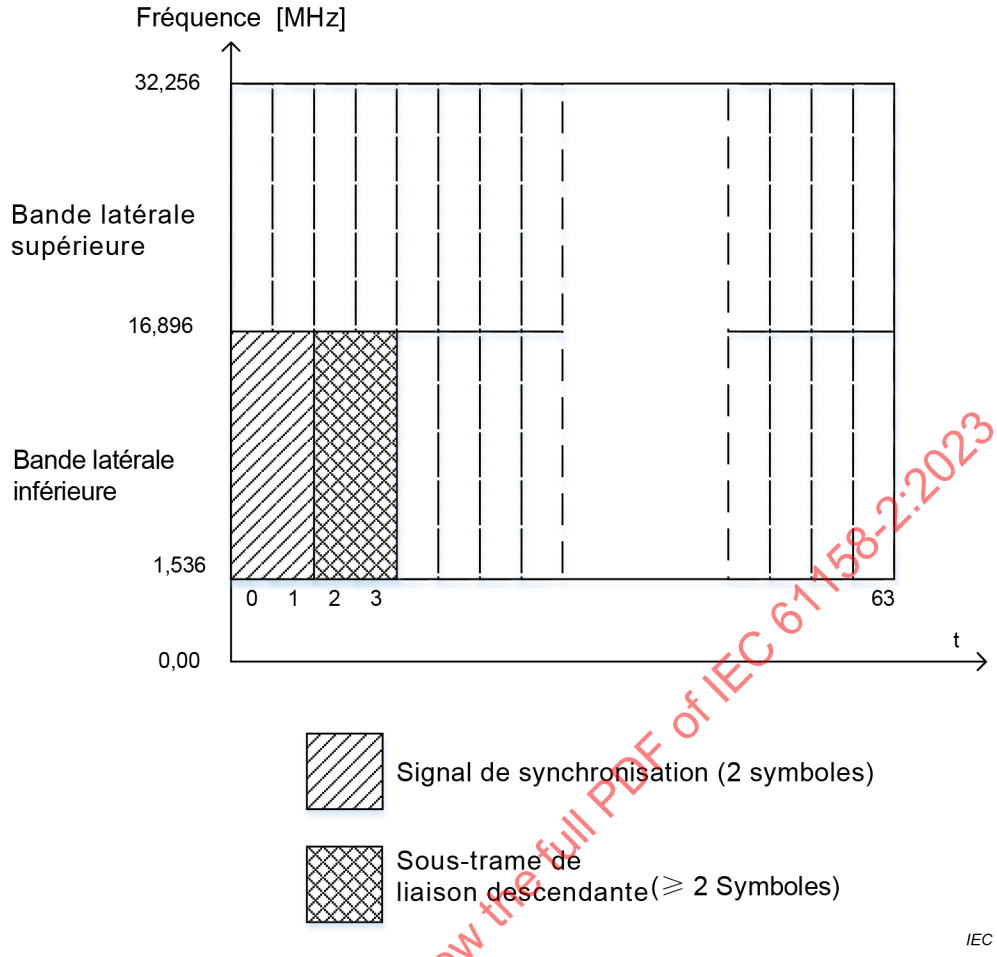


**Figure 40 – Structure SF**

La Figure 40 représente le diagramme de la SF. Il convient que la SF soit décomposée par les éléments suivants: signal de synchronisation (SynS), sous-trame en liaison descendante et sous-trame de données.

– Le **signal de synchronisation (SynS)** est utilisé pour identifier le début d'une SF. SynS a la fonction de synchronisation SF et de positionnement d'en-tête de trame. Le SynS est fixe dans la bande latérale inférieure du premier et du second symboles OFDM de chaque SF (voir la Figure 40).

– La **sous-trame en liaison descendante** est utilisée pour envoyer des données et des informations des MN aux TN. Elle contient des informations sur le canal, le résultat de l'allocation de largeur de bande, l'état de maintenance du système, etc. La sous-trame en liaison descendante contient la bande latérale inférieure qui est supérieure ou égale à 2 symboles OFDM (voir la Figure 41).

– La **sous-trame de données** se rapporte aux ressources de communication PhL attribuables. L'unité d'allocation minimale est la mi-bande latérale d'un symbole OFDM (voir le mode de porteuse A) ou la mi-bande latérale de deux symboles OFDM (voir le mode de porteuse B). À la Figure 40, toutes les parties vierges sont des sous-trames de données. Il convient que les MN et TN demandent ou configurent la sous-trame de données correspondante en fonction de leurs exigences en matière de transmission de données.

#### 8.6.2.2.2 Sous-trame de données

Après que l'utilisateur PhS a alloué la sous-trame de données au MN ou à chaque TN, il convient d'insérer des signaux pilotes dans la sous-trame de données selon une forme spécifique, afin de permettre au destinataire de décoder les informations rapidement et avec exactitude, ce pilote étant nommé "pilote de symbole". Le pilote de symbole de la sous-trame de données prend en charge le pilote discret et le pilote continu.

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En fonction de la différence entre le pilote d'insertion de symbole et la structure de porteuse de données de la sous-trame de données, cette dernière prend en charge deux types de modes de porteuse: le mode de porteuse A et le mode de porteuse B. Ils sont définis comme suit:

– **Mode de porteuse A:** Le signal de données et le signal de pilote de symbole sont transmis par l'intermédiaire d'une seule mi-bande latérale OFDM à l'aide du pilote continu, dont le rapport de sous-porteuse occupée entre le signal de pilote de symbole et le signal de données est de 1:8.
– **Mode de porteuse B:** Le signal de pilote de symbole est transmis par l'intermédiaire de la première mi-bande latérale OFDM de la sous-trame de données déjà obtenue, et les signaux de données sont transmis par les symboles OFDM qui suivent.

La Figure 41 représente la différence entre le mode de porteuse A et le mode de porteuse B.

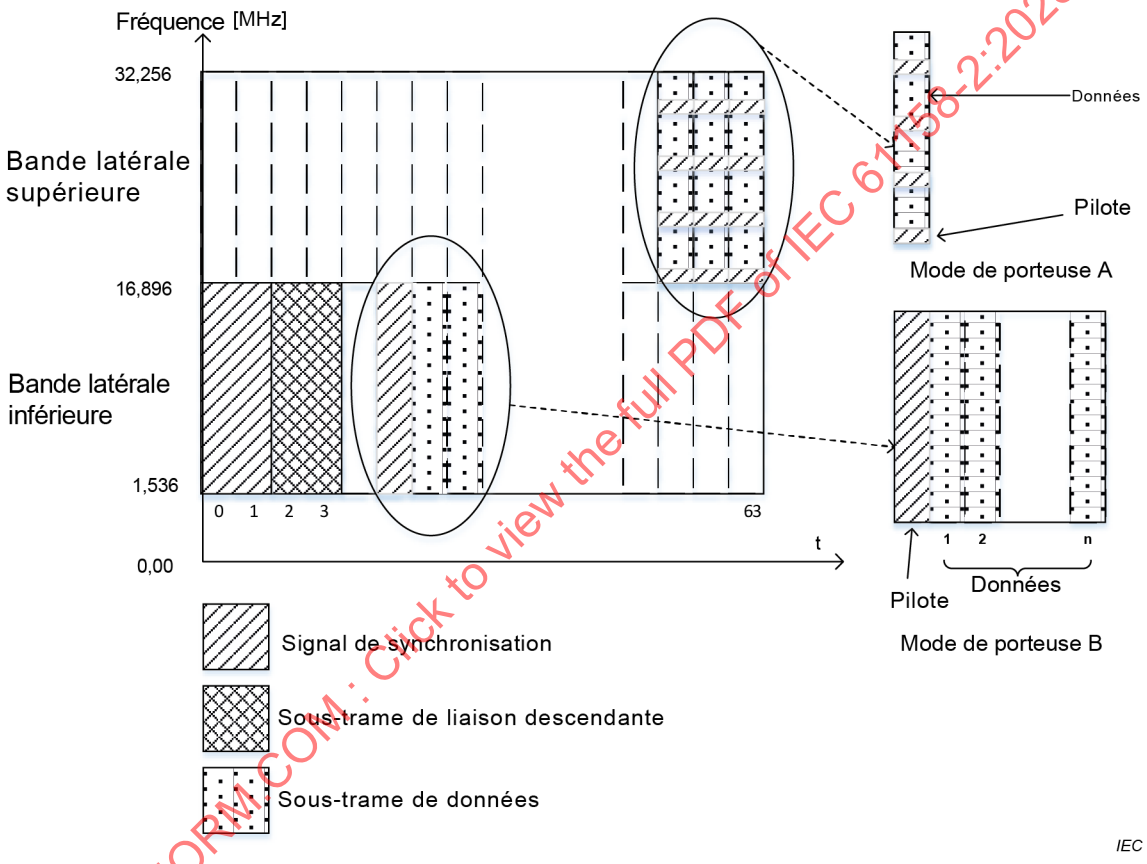


**Figure 41 – Mode de porteuse A et mode de porteuse B de la sous-trame de données**

Le mode de porteuse A est en général utilisé pour la transmission périodique de données cyclique. La sous-trame de données prend en charge jusqu'à 8 intervalles si le mode de porteuse A est utilisé. Le mode de porteuse A prend également en charge l'application et l'utilisation d'allocation équivalente de ressources d'intervalle pour plusieurs utilisateurs.

Le mode de porteuse B est utilisé tant pour la transmission de données cyclique à débit fixe que pour la transmission de données à débit variable.

NOTE Transmission de données à débit fixe signifie que les données sont transmises dans un cycle fixe sur le bus, et que la taille des données transmises par cycle est fixe. Transmission de données à débit variable signifie que les données transmises ne sont pas traitées sur le bus dans le cadre d'un cycle fixe, et la taille des données en cours de traitement n'est pas fixe.

Voir l'Annexe V pour la distinction et le choix du mode de porteuse A ou du mode de porteuse B.

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#### 8.6.2.2.3 Symbole OFDM

Chaque symbole OFDM dans la PhL contient des informations de maintenance (voir la Figure 42) pour maintenir la disponibilité des symboles OFDM.

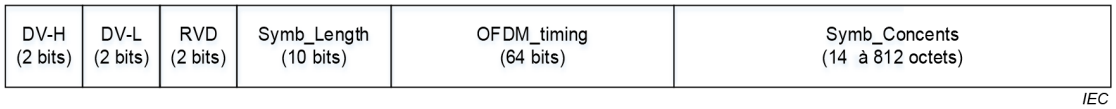


**Figure 42 – Structure de symbole OFDM de la PhL**

- **DV-H** fait référence à la disponibilité de la bande latérale supérieure et au mode de porteuse du symbole OFDM. 0b00 signifie "impossible". 0b01 est le mode de porteuse A. 0b10 est le mode de porteuse B, et 0b11 est réservé.
- **DV-L** fait référence à la disponibilité de la bande latérale inférieure et au mode de porteuse du symbole OFDM, 0b00 signifie "impossible". 0b01 est le mode de porteuse A, 0b10 est le mode de porteuse B, et 0b11 est réservé.
- **RVD** fait référence aux bits réservés.
- **Symb_Length** est le nombre d'octets de données valides chargés par ce symbole OFDM.
- **OFDM_timing** est l'information temporelle contenue dans ce symbole OFDM.
- **Symb_Contents** représente les données chargées par ce symbole OFDM et est composé de 1 ou 2 CB (voir 8.6.2.2.4).

La Figure 43 représente la structure de temporisation OFDM. La structure contient 64 bits et constitue la base de la synchronisation d'horloge entre les nœuds.

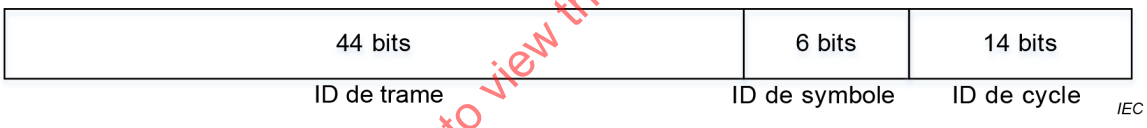


**Figure 43 – Structure de temporisation OFDM**

- L'**ID de trame** est le numéro de trame du symbole OFDM actuel, qui part de 0 lorsque le MN fonctionne normalement. La plage de valeurs valides est comprise entre 0 et $(2^{44} - 1)$. Lorsque le nombre est égal à $(2^{44} - 1)$, il repart de 0.
- L'**ID de symbole** indique la position du symbole OFDM actuel dans une SF. La plage de valeurs valides est comprise entre 0 et 63. La numérotation d'indice de symbole commence lors de la réception d'un SynS d'une SF.
- L'**ID de cycle** est le numéro de la sous-porteuse d'échantillonnage actuelle. La plage de valeurs valides est comprise entre 0 et 4 095. La numérotation d'ID de cycle commence lors de la réception d'un symbole OFDM.

#### 8.6.2.2.4 Bloc de code

L'unité de base de l'interaction des données entre la PhL et la DLL est le bloc de code (CB). Le CB est composé d'un certain nombre de séquences d'octets, qui présentent les caractéristiques suivantes:

- Le nombre d'octets d'un CB est fixe en fonction des différents modes de fonctionnement de la PhL (voir 8.6.2.2.6). 1 à 2 CB peuvent être traités sur chaque mi-bande latérale de symbole OFDM.
- Une DLPDU peut être placée dans un ou plusieurs CB après avoir été sérialisée par des octets. Un CB peut stocker les informations de séquence d'octets de plusieurs DLPDU. La Figure 44 représente la relation entre la DLPDU et le CB.
- L'entité PhL ajoute automatiquement les codes de contrôle CRC d'une longueur de quatre octets pour chaque CB avant de commencer à traiter le CB.

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– Si le CB contient une séquence d'octets non valide, la valeur des octets est définie sur 0 par défaut.

– Le MSB du bloc de code stocke les informations de séquence d'octets correspondant aux données MSB de la DLPDU, et le LSB stocke les informations de séquence d'octets correspondant aux données LSB de la DLPDU.

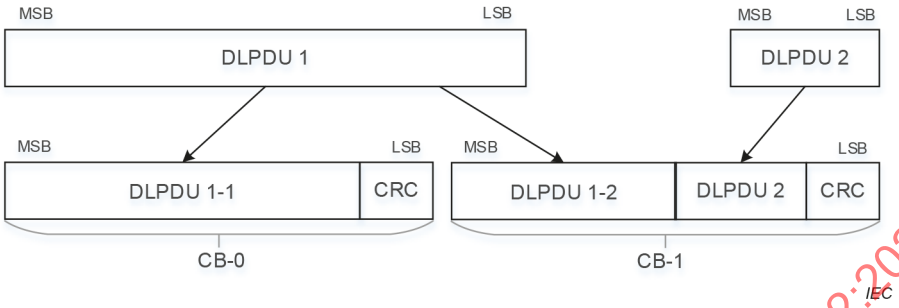


**Figure 44 – DLPDU et CB**

#### 8.6.2.2.5 Élément de ressource

Le signal de transmission de chaque SF est défini comme un réseau de ressources avec $N_{SD}$ sous-porteuses et $N_{SYM}$ symboles OFDM, où $N_{SD}$ est déterminé par le mode de transmission. La valeur de configuration est représentée à la Figure 45, et $N_{SYM}$ est égal à 64. La Figure 45 représente la structure du réseau de ressources. Chaque élément du réseau de ressources est appelé élément de ressource, et chacun d'eux est défini de manière unique par $(k,l)$, où $k = 0,\dots,N_{SD}-1$ et $l = 0,\dots,N_{SYM}-1$. $k$ représente le domaine fréquentiel et $l$ le domaine temporel. L'élément de ressource $(k,l)$ correspond à la valeur complexe $a_{k,l}$. La ressource $a_{k,l}$ correspondante est définie sur 0 si elle n'est pas utilisée pour la transmission de signaux physiques.

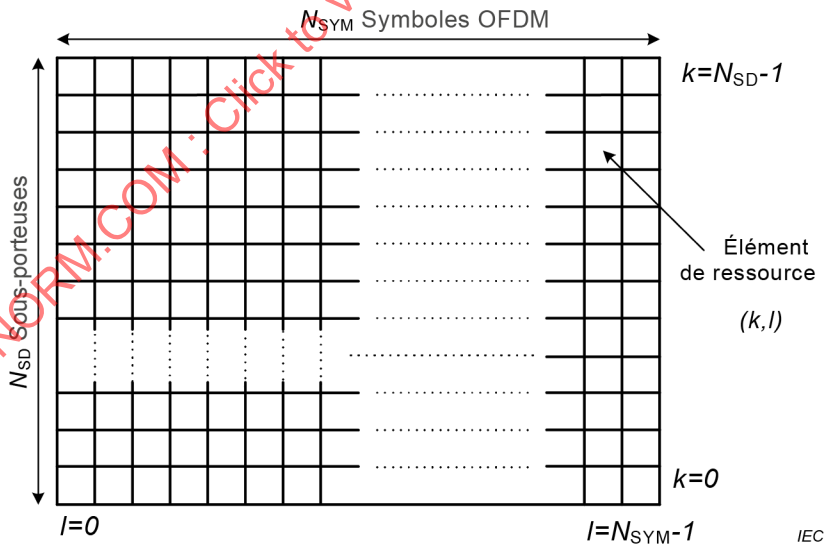


**Figure 45 – Schéma de l'élément de ressource**

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#### 8.6.2.2.6 Mode de fonctionnement

La PhL adopte la technologie OFDM et prend en charge le multiplexage temporel (TDM) et le multiplexage en fréquence (FDM). La PhL fournit quatre modes de transmission différents (TM 0 / 1 / 2 / 3) dans le domaine fréquentiel. Il convient que les utilisateurs PhS choisissent le mode de transmission en fonction du rapport signal sur bruit (SNR – *signal-to-noise ratio*) réel de l'environnement d'application. Il convient de configurer la longueur temporelle d'un symbole OFDM à 64 µs, 32 µs, 16 µs ou 8 µs selon les différents modes de transmission. La période de SF varie de 500 µs à 4,0 ms. Le Tableau 50 présente les paramètres correspondants dans les différents modes de transmission de la PhL.

**Tableau 50 – Modes de transmission et paramètres correspondants**

| Paramètres | Mode de transmission | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Plage de fréquences [MHz] | 1,536 à 32,256 | 1,536 à 32,256 | 1,536 à 32,256 | 1,536 à 32,256 |
| Plage de fréquences dans la bande latérale inférieure [MHz] | 1,536 à 16,896 | 1,536 à 16,896 | 1,536 à 16,896 | 1,536 à 16,896 |
| Plage de fréquences dans la bande latérale supérieure [MHz] | 16,896 à 32,256 | 16,896 à 32,256 | 16,896 à 32,256 | 16,896 à 32,256 |
| Largeur de bande de fréquence [MHz] | 30,72 | 30,72 | 30,72 | 30,72 |
| Espacement entre sous-porteuses, *B* [KHz] | 24 | 48 | 96 | 192 |
| Nombre de sous-porteuses $N_{SD}$ | 1 280 | 640 | 320 | 160 |
| Taille FFT [K = 1 024] | 4K | 2K | 1K | 0,5K |
| Schéma de modulation de sous-porteuse | 16QAM, 64QAM, 256QAM | 16QAM, 64QAM, 256QAM | 16QAM, 64QAM, 256QAM | 16QAM, 64QAM, 256QAM |
| Longueur de symbole utile [µs] | 41,666 7 | 20,833 3 | 10,416 7 | 5,208 3 |
| Longueur de préfixe cyclique [µs] | 20,833 3 | 10,416 7 | 5,208 3 | 2,604 2 |
| Longueur de symbole [µs] | 62,5 | 31,25 | 15,625 | 7,812 5 |
| Intervalle d'échantillonnage [ns] | 10,17 | 10,17 | 10,17 | 10,17 |
| Longueur de trame [ms] | 4,0 | 2,0 | 1,0 | 0,5 |
| Symboles OFDM par trame $N_{SYM}$ | 64 | 64 | 64 | 64 |
| Canal disponible par symbole | 1 ou 2 | 1 ou 2 | 1 ou 2 | 1 ou 2 |

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La PhL a plusieurs modes de fonctionnement pour transporter les données DLL. Les différents modes de fonctionnement s'adaptent aux différents environnements de canal et aux différentes exigences de transmission de données. Dans chaque mode de fonctionnement, l'allocation de ressources physiques et l'efficacité du transport de données varient en fonction du choix du mode de transmission, du format de trame et de la stratégie de codage de modulation (MCS – *modulation coding strategy*).

À l'issue de la configuration, il convient que le MN diffuse le mode de fonctionnement à chaque TN du réseau. En cas de réussite de la configuration du réseau, ce dernier fonctionne dans ce mode et met en œuvre la communication entre les nœuds tant que le MN n'a pas reconfiguré le mode de fonctionnement.

Le CB est l'unité de base du traitement des données dans la PhL. Le nombre d'octets valides transportés par un symbole OFDM est un entier multiple du nombre d'octets valides d'un CB. La PhL prend en charge un total de 22 modes de fonctionnement, dont le mode de porteuse A et le mode de porteuse B prennent respectivement en charge 10 et 12 modes de fonctionnement. La configuration de paramètre et la largeur de bande disponible équivalente dans chaque mode sont présentées dans le Tableau 51 et le Tableau 52.

**Tableau 51 – Mode de fonctionnement en mode de porteuse A**

| Mode de fonctionnement | Mode de transmission | Points FFT | Données valides dans le CB (octets) | Données valides dans un symbole OFDM (octets) | $N_{SD}$ valide du symbole OFDM | Largeur de bande disponible équivalente (Mbit/s) |
|---|---|---|---|---|---|---|
| A0 | 0 | 1 024 | 173 | 346 | 1 280 | 44,288 |
| A1 | 0 | 1 024 | 103 | 412 | 1 280 | 52,736 |
| A2 | 0 | 1 024 | 173 | 692 | 1 280 | 88,576 |
| A3 | 1 | 512 | 84 | 168 | 640 | 43,008 |
| A4 | 1 | 512 | 103 | 206 | 640 | 52,736 |
| A5 | 1 | 512 | 173 | 346 | 640 | 88,576 |
| A6 | 2 | 256 | 57 | 114 | 320 | 58,368 |
| A7 | 2 | 256 | 84 | 168 | 320 | 86,016 |
| A8 | 3 | 128 | 22 | 44 | 160 | 45,056 |
| A9 | 3 | 128 | 39 | 78 | 160 | 79,872 |

**Tableau 52 – Mode de fonctionnement en mode de porteuse B**

| Mode de fonctionnement | Mode de transmission | Points FFT | Données valides dans le CB (octets) | Données valides dans un symbole OFDM (octets) | $N_{SD}$ valide du symbole OFDM | Largeur de bande disponible équivalente (Mbit/s) |
|---|---|---|---|---|---|---|
| B0 | 0 | 1 024 | 123 | 246 | 1 280 | 31,488 |
| B1 | 0 | 1 024 | 203 | 406 | 1 280 | 51,968 |
| B2 | 0 | 1 024 | 123 | 492 | 1 280 | 62,976 |
| B3 | 0 | 1 024 | 203 | 812 | 1 280 | 103,936 |
| B4 | 1 | 512 | 59 | 118 | 640 | 30,208 |
| B5 | 1 | 512 | 99 | 198 | 640 | 50,688 |
| B6 | 1 | 512 | 123 | 246 | 640 | 62,976 |
| B7 | 1 | 512 | 203 | 406 | 640 | 103,936 |
| B8 | 2 | 256 | 59 | 118 | 320 | 60,416 |
| B9 | 2 | 256 | 99 | 198 | 320 | 101,376 |
| B10 | 3 | 128 | 27 | 54 | 160 | 55,296 |
| B11 | 3 | 128 | 47 | 94 | 160 | 96,256 |

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### 8.6.3 Interface ETTD − DCE

#### 8.6.3.1 Généralités

Lorsque les données sont sérialisées dans la DIS, il convient que le DCE en soit informé pour transmettre les données par l'intermédiaire de cette interface. Après la réception et le traitement du signal de données, il convient d'informer l'ETTD de procéder au traitement de la sérialisation des données. L'interface PhL DTE-DCE réalise les services par un ensemble d'interactions définies de signaux d'interface.

#### 8.6.3.2 Signal d'interface

##### 8.6.3.2.1 Demande de synchronisation (SyR)

Le signal SyR est un signal de temporisation continu fourni par le DCE à l'ETTD. L'unité de base du signal de temporisation est une période de symbole OFDM. Le DCE demande à l'ETTD de mettre en œuvre la synchronisation SF et de continuer à traiter la SF physique en fonction du signal SynS. Le signal de demande de synchronisation est fixé à 2 périodes de symbole, et toutes les 64 périodes de symbole OFDM traitent une synchronisation SF.

##### 8.6.3.2.2 Confirmation de synchronisation (SyC)

L'ETTD transmet le signal SyC à au DCE pour mettre en œuvre la confirmation de synchronisation, et en même temps, il convient que l'ETTD transmette les informations de synchronisation à l'entité DLL et à l'utilisateur supérieur pour un traitement ultérieur.

##### 8.6.3.2.3 Demande de transmission (TxR)

Le DCE prépare la transmission de données en fonction du signal SyC transmis par l'ETTD. Il convient que le DCE soit prêt à recevoir le signal TxD provenant de l'ETTD après que les paramètres pertinents de transmission ont été confirmés. En cas d'erreur dans les données transmises, il convient que l'ETTD informe le DCE par l'intermédiaire de ce signal et ne confirme pas le traitement de ce signal par le DCE.

##### 8.6.3.2.4 Données de transmission (TxD)

L'ETTD demande au DCE de transmettre les données en envoyant un signal TxD. Le DCE procède au brouillage, au codage, à l'entrelacement, à la modulation et au mapping sur le CB afin de générer un signal physique en fonction du CB déterminé et des informations relatives au paramètre, puis transmet le signal physique sur le support.

##### 8.6.3.2.5 Demande de réception (RxR)

L'ETTD prépare la réception des données en fonction du signal RxR transmis par le DCE. Il convient que l'ETTD soit prêt à recevoir le signal RxD provenant du DCE après que les paramètres pertinents de réception ont été confirmés. En cas d'erreur dans les données reçues, il convient que le DCE informe l'ETTD par l'intermédiaire de ce signal et ne confirme pas le traitement de ce signal par l'ETTD.

##### 8.6.3.2.6 Données de réception (RxD)

Le DCE demande à l'ETTD de recevoir les données en envoyant un signal RxD. Après la réception du signal, l'ETTD obtient les données valides auprès du CB déterminé et procède à la conversion des données sérialisées en unité de données d'interface, puis informe l'entité DLL pour un traitement ultérieur.

#### 8.6.3.3 Processus de signal

Le déclencheur temporel du signal d'interface ETTD-DCE dans la PhL est confirmé conformément à la configuration des paramètres associés de durée de cycle du bus. L'unité de base de la période de déclencheur temporel du signal d'interface est une période de symbole OFDM. La Figure 46 représente le processus du signal d'interface ETTD-DCE sur l'appareil.

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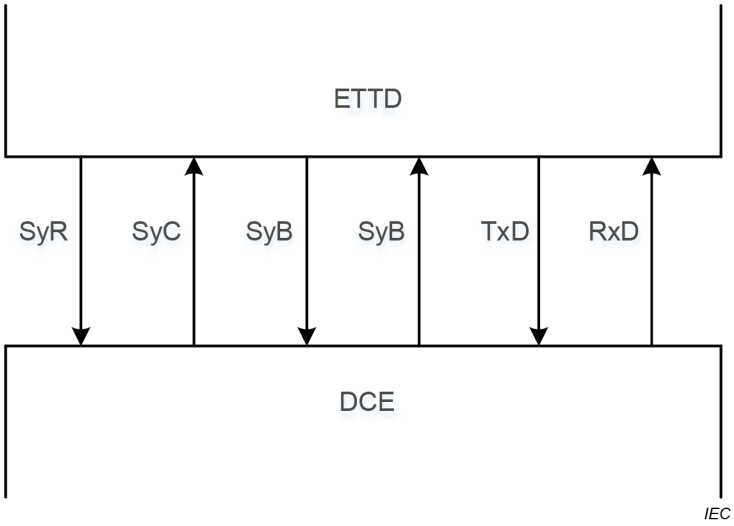


**Figure 46 – Processus du signal d'interface ETTD-DCE**

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# 9 Sous-couche dépendante du support (MDS)

## 9.1 Généralités

La sous-couche dépendante du support (MDS) fait partie de l'équipement de transmission de données (DCE). (Voir la ). Elle échange des informations à travers l'interface ETTD – DCE décrite à l'Article 8 et communique des Ph-symbols codés à travers l'interface MDS – MAU décrite à l'Article 10. La MDS assure des fonctions logiques de codage et de décodage, respectivement pour la transmission et la réception, d'ajout/retrait de préambule et de délimiteurs, ainsi que des fonctions de temporisation et de synchronisation.

NOTE Un certain nombre d'entités sous-couches MDS différentes sont spécifiées, sur la base des pratiques industrielles en la matière.

## 9.2 Type 1: MDS: Supports câblés et optiques

### 9.2.1 PhPDU

La MDS doit produire la PhPDU représentée à la Figure 47 par l'ajout d'un préambule et de délimiteurs afin d'encadrer la séquence série de PhSDU (bits) transférée depuis la DIS par l'intermédiaire de l'interface ETTD– DCE. La séquence de transmission doit aller de gauche à droite comme cela est représenté à la Figure 47, c'est-à-dire le préambule en premier, suivi par le délimiteur de début, la séquence de PhSDU et enfin le délimiteur de fin.

| PRÉAMBULE | DÉLIMITEUR DE DÉBUT | SÉQUENCE DE PhSDU | DÉLIMITEUR DE FIN |
|---|---|---|---|

**Figure 47 – Unité de données de protocole (PhPDU)**

En revanche, la MDS doit retirer le préambule et les délimiteurs d'une PhPDU reçue pour générer une séquence série correspondante de PhSDU. Si une unité de données non binaires est détectée dans la séquence de PhSDU reçue, la MDS doit immédiatement arrêter de transférer les PhSDU à la DIS, la MDS doit rendre compte d'une erreur et doit indiquer la fin de l'activité à la DIS au moment auquel elle a lieu.

### 9.2.2 Codage et décodage

Les unités de données doivent être codées par la MDS pour application à la MAU à l'aide du code représenté à la Figure 48 (Manchester Biphase L). Les règles de codage formelles sont données à la Figure 49 et dans le Tableau 53.

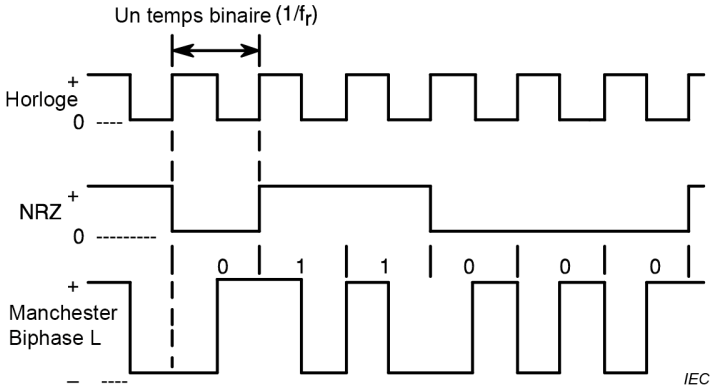


**Figure 48 – Codage et décodage PhSDU**

NOTE La Figure 48 est incluse à des fins d'explication et n'implique aucune mise en œuvre spécifique.

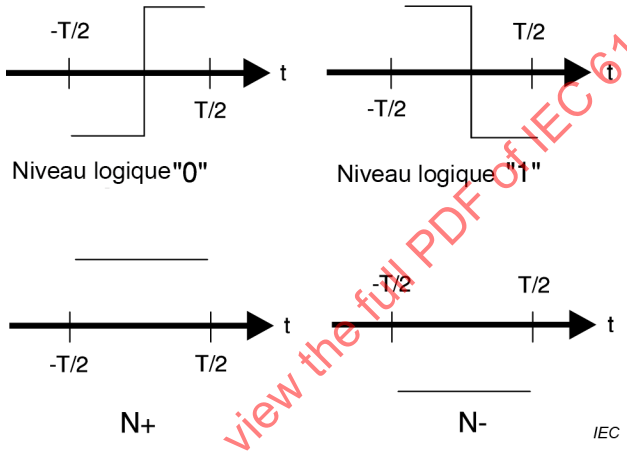


**Figure 49 – Règles de codage Manchester**

**Tableau 53 – Règles de codage Manchester**

| Symboles | Codage |
|---|---|
| 1 (ONE) | Transition Hi–Lo (à mi-bit) |
| 0 (ZÉRO) | Transition Lo–Hi (à mi-bit) |
| N+ (NON-DATA PLUS) | Hi (Pas de transition) |
| N- (NON-DATA MINUS) | Lo (Pas de transition) |
| NOTE Les symboles de données (1 et 0, acheminés par des PhSDU) sont codés pour contenir toujours une transition à mi-bit. Les symboles non données (N+ et N–) sont codés de sorte ce qu'il n'y ait jamais de transition à mi-bit. Les délimiteurs de trame (voir 9.2.4 et 9.2.5) sont construits pour que les symboles non données soient acheminés dans des paires de polarité opposée. | |

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Le décodage doit normalement correspondre à l'opposé du codage. À la réception, la MDS doit vérifier que chaque symbole est codé conformément à la Figure 49 et au Tableau 53 et doit détecter les erreurs suivantes:

a) code Manchester invalide;

b) erreurs de glissement d'un demi-bit.

Chacune de ces erreurs doit être notifiée comme une indication de PH-DATA (PhIDU, erreur).

### 9.2.3 Détection de polarité

L'option de détection automatique de polarité d'un signal codé Manchester reçu doit être exigée lorsque cela est spécifié dans la MAU correspondante.

### 9.2.4 Délimiteur de début de trame

La séquence de symboles suivante, présentée de gauche à droite, dans l'ordre de transmission, doit précéder immédiatement la séquence de PhSDU pour délimiter le début d'une trame:

1, N+, N–, 1, 0, N–, N+, 0.

(représenté sous forme d'onde à la Figure 50)

La MDS ne doit accepter un train de signaux reçus comme une PhPDU qu'après avoir vérifié cette séquence et doit retirer cette séquence avant de transférer la séquence de PhSDU à la DIS.

### 9.2.5 Délimiteur de fin de trame

La séquence de symboles suivante, présentée de gauche à droite, dans l'ordre de transmission, doit immédiatement suivre la séquence de PhSDU pour délimiter la fin d'une trame:

1, N+, N–, N+, N–, 1, 0, 1.

(représenté sous forme d'onde à la Figure 50)

La MDS doit retirer cette séquence de la PhPDU avant de transférer la séquence de PhSDU à la DIS. La MDS doit rendre compte à l'entité DLL correspondante des éventuelles trames reçues par le support lorsque ces trames ne comprennent pas cette séquence dans les 300 octets à compter du début de la trame (du commencement du délimiteur de début) comme indication de Ph-Data (PhIDU, frame_too_long – trame trop longue). La MDS doit rendre compte à l'entité DLL associée, par la DIS correspondante, des éventuelles trames reçues par l'intermédiaire du support si celles-ci ont un délimiteur de fin qui n'est pas placé à une frontière d'octet, comme une indication de PH-DATA (PhIDU, received_timing_error – erreur de temporisation reçue).

### 9.2.6 Préambule

Pour synchroniser des temps binaires, un préambule doit être transmis au début de chaque PhPDU; ce préambule est constitué de la séquence suivante de bits, présentée de gauche à droite dans l'ordre de transmission:

1, 0, 1, 0, 1, 0, 1, 0.

(représenté sous forme d'onde à la Figure 50)

NOTE 1 Il est possible que le préambule reçu contienne au moins quatre bits du fait de la perte d'un bit à travers chacun des quatre répéteurs (comme cela est spécifié dans les règles de configuration du réseau pour la MAU).

La période peut être étendue mais non réduite par la Gestion systèmes, comme cela est indiqué dans le Tableau 13. Une séquence d'extension de préambule, comme cela est indiqué dans le Tableau 13, doit être définie comme la séquence suivante de bits, présentée de gauche à droite dans l'ordre de transmission:

1, 0, 1, 0, 1, 0, 1, 0.

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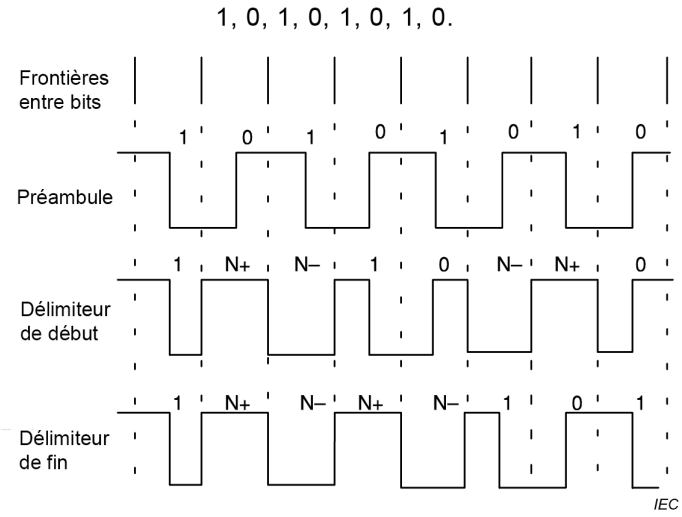


**Figure 50 – Préambule et délimiteurs**

NOTE 2 Ces formes d'onde n'étendent pas la plage de fréquences au-delà de la bande exigée pour la transmission de PhSDU binaires (acheminant les symboles de données) conformément à la Figure 49 et au Tableau 53.

### 9.2.7 Synchronisation

Après réception du quatrième bit de la trame et jusqu'à la fin de la trame ou sa terminaison, le récepteur doit détecter et rendre compte des erreurs de glissement d'un demi-bit.

NOTE 1 Cette spécification de synchronisation admet la perte de 4 bits du préambule.

Après le préambule, les erreurs de glissement d'un demi-bit doivent être consignées comme indication de PH-DATA (PhIDU, erreur).

NOTE 2 Les erreurs de glissement d'un demi-bit peuvent être détectées comme une instabilité excessive (gigue) de bit élémentaire et/ou une variation excessive de la période binaire.

### 9.2.8 Intervalle post-émission

Après transmission d'une PhPDU, il doit y avoir une période minimale au cours de laquelle la transmission suivante ne doit pas commencer. Pendant cette même période minimale, après réception d'une PhPDU, l'entité PhL de réception doit ignorer toute signalisation reçue. Une entité MDS doit établir une période minimale post-émission de quatre temps binaires nominaux. La période peut être étendue mais non réduite par la Gestion systèmes, comme cela est indiqué dans le Tableau 13 ou par une entité MAU associée. Une séquence d'extension d'intervalle, comme cela est présenté dans le Tableau 13, doit être définie comme égale à quatre temps binaires nominaux.

NOTE Le délai d'activation/désactivation de transmission de la MAU peut réduire la durée du silence entre trames.

### 9.2.9 Dérive du signal entre canaux

Si l'appareil est configuré (par la Gestion systèmes) pour recevoir simultanément sur plusieurs canaux, alors le délai différentiel maximal admis entre deux canaux actifs, quels qu'ils soient, tel qu'il est mesuré à partir de la première PhPDU d'un délimiteur de début, ne doit pas dépasser cinq temps binaires nominaux. Cette période peut être étendue, mais non réduite par la Gestion systèmes, comme cela est indiqué dans le Tableau 13. Une séquence d'extension d'intervalle, comme cela est présenté dans le Tableau 13, doit être définie comme égale à quatre temps binaires nominaux. La valeur de l'intervalle post-émission doit être supérieure à la valeur de la dérive entre canaux.

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### 9.3 Vide

NOTE Dans la présente édition, le 9.3 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

### 9.4 Type 2: MDS: Supports câblés et optiques

#### 9.4.1 Généralités

NOTE La sous-couche dépendante du support (MDS) fait partie de l'équipement de transmission de données (DCE). Elle communique des bits codés par le biais de l'interface MDS-MAU spécifiée au 10.4.

#### 9.4.2 Exactitude d'horloge

Les spécifications temporelles de la signalisation PhL doivent être telles qu'elles sont définies dans le Tableau 54.

**Tableau 54 – Caractéristiques temporelles de la MDS**

| Spécification | Limites / caractéristiques | Commentaires |
|---|---|---|
| Débit binaire | 5 Mbit/s avec une tolérance de ± CA | Également appelé débit de M-symbol, données 'zéro' ou 'un' |
| Temps binaire | 200 ns avec une tolérance de ± CA | Également appelé durée de M-symbol, données 'zéro' ou 'un' |
| Durée de symbole PhL | 100 ns avec une tolérance de ± CA | Également appelée durée de Ph-symbol, voir les règles de codage de données |
| Exactitude d'horloge (CA – Clock Accuracy) | ± 150 µHz/Hz max. | Tenant compte de la température, ainsi que de la stabilité à long et à court termes |

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#### 9.4.3 Régénération de données

Les signaux à l'interface DLL-PhL doivent être synchronisés sur le débit binaire local, comme cela est présenté dans le Tableau 54. Chaque application PhL doit prévoir un mécanisme de régénération des données qui récupère ou reconstruit les données reçues à partir du support approprié, de manière à satisfaire aux exigences de temporisation du Tableau 54. Lorsque la synchronisation des données a été atteinte par la MDS, l'indication de PH-LOCK doit être "vrai".

Une partie de la trame des données reçue peut être perdue ou ignorée lors du processus d'obtention de la synchronisation des données. La spécification de temporisation des données présentée dans le Tableau 54 doit être atteinte avant le commencement du délimiteur de début (voir l'IEC 61158-4-2).

#### 9.4.4 Règles de codage de données

Les M-symbols présents à l'interface DLL-PhL doivent être codés en Ph-symbols appropriés comme cela est indiqué dans le Tableau 55 et à la Figure 51. Les symboles M_0 et M_1 doivent être codés en Ph-symbols qui représentent les règles de codage de données Manchester Biphase L, comme cela est indiqué dans le . Les symboles M_ND doivent être utilisés pour créer des modèles de données uniques utilisés pour les délimiteurs de début et de fin. La forme d'onde de tension du signal (provenant de la MAU) est présentée sous forme théorique à la Figure 51 de manière à fournir un exemple des règles de codage de données du Tableau 55.

**Tableau 55 – Règles de codage des données MDS**

| Bits de données (nom commun) | Représentation M_symbol | Codage Ph-symbol | codé Manchester |
|---|---|---|---|
| données "ZÉRO" | M_0 ou {0} | {L,H} | 0 |
| données "one" | M_1 ou {1} | {H,L} | 1 |
| 'non_data+' | M_ND+ ou {+} | {H,H} | aucune donnée |
| 'non_data-' | M_ND- ou {-} | {L,L} | aucune donnée |

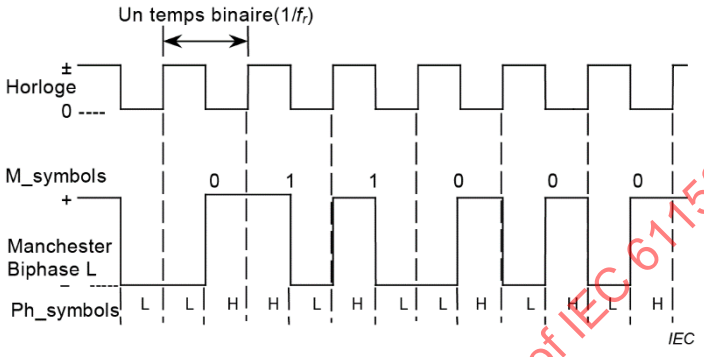


**Figure 51 – Symboles codés Manchester**

## 9.5 Type 3: MDS: Supports câblés et optiques

### 9.5.1 Transmission synchrone

La sous-couche dépendante du support (MDS) spécifiée pour le Type 1 doit être utilisée (voir 9.2).

### 9.5.2 Transmission asynchrone

Il n'y a pas de MDS (sous-couche dépendante du support) en transmission asynchrone.

## 9.6 Type 4: MDS: Support câblé

### 9.6.1 Semi-duplex

#### 9.6.1.1 Vue d'ensemble

NOTE 1 L'entité PhL est subdivisée en une composante Équipement terminal de traitement de données (ETTD) qui contient la MDS et en une composante Équipement de transmission de données (DCE) qui contient la MAU.

NOTE 2 La fonctionnalité de la MDS est semblable à la fonctionnalité de ce qui est communément appelé un UART (*Universal Asynchronous Receiver Transmitter* – émetteur-récepteur asynchrone universel). En outre, la MDS semi-duplex a une certaine fonctionnalité de temporisation. La fonctionnalité de la MAU est semblable à la fonctionnalité de ce qui est communément appelé un circuit d'excitation (ou d'attaque).

La MDS semi-duplex doit ordonner la transmission de la PhID comme une séquence de bits. De la même manière, la MDS doit constituer la PhID à renvoyer à la DLL à partir de la séquence de bits reçue. Les bits sont envoyés et reçus en code NRZ (non-return-to-ZÉRO).

La PhID doit être convertie en une séquence de bits pour transmission série dans des PhPDU. Dans chaque PhPDU, un bit représentant un bit de poids fort doit être transmis avant un bit représentant un bit de poids faible. À la réception, chaque séquence de bits doit être convertie en PhID de sorte que, en l'absence d'erreurs, la PhID indiquée à l'entité DLL de réception demeure inchangée par rapport à la PhID dont l'émission a été demandée par l'entité DLL d'origine.

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La MDS reçoit une seule PhID ou une séquence d'octets de PhID à partir de la DLE. Le premier octet est reçu à partir de la DLE par l'un des services START-OF-ACTIVITY-**11** ou START-OF-ACTIVITY-**2**. Les octets restants sont reçus à partir de la DLE par le service DATA. La fin de transmission est indiquée par le service END-OF-ACTIVITY. À partir de chaque octet de PhID, la MDS doit constituer une PhPDU et transmettre à la MAU la PhPDU formée comme une séquence de bits. Chaque PhPDU doit être constituée de 1 bit de départ, de 8 bits de données, de 1 bit d'adresse/données, et finalement de 1 bit d'arrêt. Cette PhPDU est représentée à la Figure 52.

| Départ | Donnée8 ... Donnée1 | Adresse/donnée | Arrêt |
|---|---|---|---|
| 0 | X....X | 1 pour le premier octet, 0 pour le reste | 1 |

**Figure 52 – Format d'une PhPDU, semi-duplex**

La MDS doit notifier le fait que le niveau du signal sur le support connecté est demeuré au repos pendant 30, 35 et 40 ou plus périodes binaires, par des indications **LINK-IDLE** destinées à la DLE.

Le débit binaire transmis doit être celui du débit en bauds sélectionné, avec une tolérance de ± 0,2 %.

### 9.6.1.2 Transmission

#### 9.6.1.2.1 START-OF-ACTIVITY-11

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA START-OF-ACTIVITY-**11**:

a) attendre que le compteur de repos atteigne ou dépasse 11;

b) constituer la première PhPDU avec bit d'adresse/données = "1" et données = paramètres de données de la demande START-OF-ACTIVITY-**11**;

c) confirmer la réception à la DLE pour lui permettre d'émettre la demande de transmission suivante;

d) activer TxE (activation de la transmission);

e) commencer à transmettre la PhPDU à la MAU.

#### 9.6.1.2.2 START-OF-ACTIVITY-2

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA START-OF-ACTIVITY-**2**:

a) attendre que le module 10 de compteur de repos atteigne ou dépasse 2;

b) constituer la première PhPDU avec bit d'adresse/données = "1" et données = paramètres de données de la demande START-OF-ACTIVITY-**2**;

c) confirmer la réception à la DLE pour lui permettre d'émettre la demande de transmission suivante;

d) activer TxE (activation de la transmission);

e) commencer à transmettre la PhPDU à la MAU.

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#### 9.6.1.2.3 DATA

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA DATA:

a) attendre que l'émission des PhPDU précédentes soit terminée;

b) constituer une nouvelle PhPDU avec bit d'adresse/données = "0" et données = paramètres de données de la demande DATA;

c) confirmer la réception à la DLE pour lui permettre d'émettre la demande de transmission suivante;

d) commencer à transmettre la PhPDU à la MAU.

Il faut assurer qu'il n'y a pas de périodes de repos entre émissions de PhPDU. Il convient que la DLE envoie la demande de transmission suivante dans les 11 périodes binaires qui suivent la confirmation de la précédente.

#### 9.6.1.2.4 END-OF-ACTIVITY

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA END-OF-ACTIVITY:

a) attendre que l'émission des PhPDU précédentes soit terminée;

b) attente de 3 périodes binaires au moins et de 10 périodes binaires au plus;

c) désactiver TxE (activation de la transmission).

### 9.6.1.3 Réception

#### 9.6.1.3.1 START-OF-ACTIVITY

Après la réception d'une trame en provenance de la MAU avec bit d'adresse/données = "1", ou la réception d'une trame dont la valeur du compteur de repos est supérieure ou égale à 11, la MDS doit émettre une indication PH-DATA de classe START-OF-ACTIVITY. Le paramètre de données correspondant doit détenir les données reçues. La valeur du paramètre d'état correspondant doit être établie de la manière suivante:

a) la réception d'une trame avec bit d'adresse/données = "1" et bit d'arrêt = "1", la valeur du compteur de repos étant supérieure ou égale à 11 doit provoquer l'indication SUCCESS dans le paramètre d'état correspondant;

b) la réception d'une trame avec bit d'arrêt = "0" doit provoquer l'indication FRAMING_ERROR dans le paramètre d'état correspondant;

c) la réception d'une trame avec bit d'adresse/données = "1", la valeur du compteur de repos étant inférieure ou égale à 11, doit provoquer l'indication IDLE_ERROR dans le paramètre d'état correspondant;

d) la réception d'une trame avec bit d'adresse/données = "0", la valeur du compteur de repos étant supérieure ou égale à 11, doit provoquer l'indication ADDRESS_DATA_ERROR dans le paramètre d'état correspondant.

#### 9.6.1.3.2 DATA

Après la réception d'une trame en provenance de la MAU avec bit d'adresse/données = "0", la valeur du compteur de repos étant inférieure à 11, la MDS doit émettre une indication de PH-DATA de classe DATA. Le paramètre de données correspondant doit détenir les données reçues. La valeur du paramètre d'état correspondant doit être établie de la manière suivante:

a) la réception d'une trame avec bit d'arrêt = "1" en provenance de la MAU doit provoquer l'indication SUCCESS dans le paramètre d'état correspondant;

b) la réception d'une trame avec bit d'arrêt = "0" doit provoquer l'indication FRAMING_ERROR dans le paramètre d'état correspondant.

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#### 9.6.1.4 Compteur de repos

La MDS détient un compteur de repos. Ce compteur est incrémenté de un à chaque période binaire et il est remis à zéro dès lors qu'un bit de valeur "0" est envoyé ou reçu de la MAU. Lorsque le compteur de repos atteint 30, la MDS doit en rendre compte par une indication de PH-DATA de classe LINK-IDLE et l'indication de 30 périodes binaires dans l'état correspondant. 5 périodes binaires plus tard, si la liaison est toujours au repos, la PhE en rend compte au moyen d'une autre indication de PH-DATA de classe LINK-IDLE et en indiquant 35 périodes binaires dans l'état correspondant. 5 périodes binaires plus tard, si la liaison est toujours au repos, la PhE en rend compte au moyen d'une autre indication de PH-DATA de classe LINK-IDLE et en indiquant 40 périodes binaires ou plus dans l'état correspondant. Cela continue à chaque 10 périodes binaires avec des indications qui spécifient 40 périodes binaires ou plus. La vitesse du compteur de repos doit être celle du débit en bauds sélectionné, avec une tolérance de ± 0,2 %.

### 9.6.2 Bidirectionnelle simultanée

#### 9.6.2.1 Vue d'ensemble

NOTE 1 L'entité PhL est subdivisée en une composante Équipement terminal de traitement de données (ETTD) qui contient la MDS et en une composante Équipement de transmission de données (DCE) qui contient la MAU.

NOTE 2 La fonctionnalité de la MDS est semblable à la fonctionnalité de ce qui est communément appelé un UART (*Universal Asynchronous Receiver Transmitter* – émetteur-récepteur asynchrone universel). En outre, la MDS bidirectionnelle simultanée a une certaine fonctionnalité de "bourrage d'octet". La fonctionnalité de la MAU est semblable à la fonctionnalité de ce qui est communément appelé un circuit d'excitation (ou d'attaque).

La MDS bidirectionnelle simultanée doit ordonner l'émission de la PhID comme une séquence de bits. De la même manière, la MDS doit constituer la PhID à renvoyer à la DLL à partir de la séquence de bits reçue. Les bits sont envoyés et reçus en code NRZ (non-return-to-ZÉRO).

La PhID doit être convertie en une séquence de bits pour transmission série dans des PhPDU. Dans chaque PhPDU, un bit représentant un bit de poids fort doit être transmis avant un bit représentant un bit de poids faible. À la réception, chaque séquence de bits doit être convertie en PhID de sorte que, en l'absence d'erreurs, la PhID indiquée à l'entité DLL de réception demeure inchangée par rapport à la PhID dont l'émission a été demandée par l'entité DLL d'origine.

La MDS reçoit une seule PhID ou une séquence d'octets de PhID à partir de la DLE. Le premier octet est reçu de la DLE par le service START-OF-ACTIVITY-**2**. Les octets restants sont reçus à partir de la DLE par le service DATA. La fin de transmission est indiquée par le service END-OF-ACTIVITY. À partir de chaque octet de PhID, la MDS doit constituer une PhPDU et transmettre à la MAU la PhPDU formée comme une séquence de bits. Chaque PhPDU doit être constituée de 1 bit de départ, de 8 bit de données et de 1 bit d'arrêt. Cette PhPDU est représentée à la Figure 53.

| Départ | Donnée8 … Donnée1 | Arrêt |
|---|---|---|
| 0 | X….X | 1 |

**Figure 53 – Format d'une PhPDU, bidirectionnelle simultanée**

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#### 9.6.2.2 Transmission

##### 9.6.2.2.1 START-OF-ACTIVITY-2

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA START-OF-ACTIVITY-**2**:

a) constituer la première PhPDU avec données = $D7 (hex);

b) constituer la seconde PhPDU avec données = paramètre de données de demande **START-OF-ACTIVITY-2**;

c) confirmer la réception à la DLE pour lui permettre d'émettre la demande de transmission suivante;

d) activer le signal request-to-send (RTS);

e) attendre l'activation du signal clear-to-send (CTS);

f) commencer à transmettre à la MAU les PhPDU formées.

##### 9.6.2.2.2 DATA

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA DATA:

a) attendre que l'émission des PhPDU précédentes soit terminée;

b) attendre l'activation du signal clear-to-send (CTS);

c) former une ou des PhPDU nouvelles avec des données selon les indications suivantes:

d) si la valeur de paramètre de données de la demande DATA = $D7 (hex), constituer une PhPDU ayant la valeur de données $D9 (hex), suivie par une PhPDU supplémentaire avec la valeur de données $00;

e) si la valeur de paramètre de données de la demande DATA = $D9 (hex), constituer une PhPDU avec la valeur de données $D9 (hex), suivie par une PhPDU supplémentaire avec la valeur de données $01;

f) si la valeur de paramètre de données de la demande DATA est différente de $D7 (hex) et $D9, constituer une PhPDU avec la valeur de données = paramètre de données de la demande DATA;

g) confirmer la réception à la DLE pour lui permettre d'émettre le service transmission suivant;

h) commencer à transmettre la ou les PhPDU à la MAU.

##### 9.6.2.2.3 END-OF-ACTIVITY

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA END-OF-ACTIVITY:

a) attendre que l'émission des PhPDU précédentes soit terminée;

b) désactiver le signal request-to-send (RTS).

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#### 9.6.2.3 Réception

##### 9.6.2.3.1 START-OF-ACTIVITY

Après la réception d'une PhPDU en provenance de la MAU, avec une valeur de données de $D7 (hex), la MDS doit attendre la PhPDU suivante et lorsque celle-ci est reçue, émettre une indication PH-DATA de classe START-OF-ACTIVITY. Le paramètre de données correspondant doit détenir les données de réception de la PhPDU qui suivent $D7 (hex). La valeur du paramètre d'état correspondant doit être établie de la manière suivante:

a) la réception d'une PhPDU avec bit d'arrêt = "1" doit provoquer l'indication SUCCESS dans le paramètre d'état correspondant;

b) la réception d'une PhPDU avec bit d'arrêt = "0" doit provoquer l'indication FRAMING_ERROR dans le paramètre d'état correspondant.

##### 9.6.2.3.2 DATA

La réception d'une PhPDU en provenance de la MAU, avec une valeur de données différente de $D7 (hex) doit entraîner ce qui suit:

la réception d'une trame avec bit d'arrêt = "1" et valeur de données = $D9 (hex) doit provoquer l'attente par la MDS de la PhPDU suivante en provenance de la MAU. Le résultat de la réception de la PhPDU suivante doit être:

a) si la valeur de données de la PhPDU suivante est $00 (hex) et si le bit d'arrêt = "1", émission d'une indication PH-DATA de classe DATA. Le paramètre de données correspondant doit détenir la valeur $D7. La valeur du paramètre d'état correspondant doit indiquer SUCCESS;

b) si la valeur de données de la PhPDU suivante est 01$ (hex) et si le bit d'arrêt = "1", émission d'une indication PH-DATA de classe DATA. Le paramètre de données correspondant doit détenir la valeur $D9. La valeur du paramètre d'état correspondant doit indiquer SUCCESS;

c) si la valeur de données de la PhPDU suivante est différente de $00 (hex) et de $01 (hex) et si le bit d'arrêt = "1", émission d'une indication PH-DATA de classe DATA. Le paramètre de données correspondant doit détenir la valeur des données de réception. La valeur du paramètre d'état correspondant doit indiquer BYTE_STUFFING_ERROR;

d) si le bit d'arrêt est "0", émission d'une indication PH-DATA de classe DATA. Le paramètre de données correspondant doit détenir la valeur reçue. La valeur du paramètre d'état correspondant doit indiquer FRAMING_ERROR;

e) la réception d'une PhPDU avec bit d'arrêt = "1" et une valeur de données différente de $D9 (hex), doit entraîner l'émission par la MDS d'une indication PH-DATA de classe DATA. Le paramètre de données correspondant doit détenir la valeur reçue. La valeur du paramètre d'état correspondant doit indiquer SUCCESS;

f) la réception d'une PhPDU avec bit d'arrêt = "0" doit entraîner dans la MIS l'émission d'une indication PH-DATA de classe DATA. Le paramètre de données correspondant doit détenir la valeur reçue. La valeur du paramètre d'état correspondant doit indiquer FRAMING_ERROR.

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### 9.6.3 UDP bidirectionnel simultané

#### 9.6.3.1 Vue d'ensemble

La PhID doit être envoyée conformément à l'ISO/IEC/IEEE 8802-3:2021.

La MDS reçoit une seule PhID ou une séquence d'octets de PhID à partir de la DLE. Le premier octet est reçu de la DLE par le service START-OF-ACTIVITY**-2**. Les octets restants sont reçus à partir de la DLE par le service DATA. La fin de transmission est indiquée par le service END-OF-ACTIVITY.

#### 9.6.3.2 Transmission

##### 9.6.3.2.1 START-OF-ACTIVITY-2

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA START-OF-ACTIVITY-**2**:

a) réserver le paquet de sous-couche MAC;

b) constituer la PhPDU avec données = paramètre de données de demande **START-OF-ACTIVITY-2**;

c) insérer la PhPDU formée au premier emplacement dans le paquet réservé;

d) confirmer la réception à la DLE pour lui permettre d'émettre la demande de transmission suivante;

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA DATA:

a) constituer la PhPDU avec données = paramètre de données de la demande DATA;

b) insérer la PhPDU formée à l'emplacement suivant dans le paquet réservé;

c) confirmer la réception à la DLE pour lui permettre d'émettre le service transmission suivant;

##### 9.6.3.2.2 END-OF-ACTIVITY

Les étapes suivantes doivent être réalisées après l'émission par la DLE d'une demande PH-DATA END-OF-ACTIVITY:

a) transférer le paquet réservé à la sous-couche MAC.

#### 9.6.3.3 Réception

##### 9.6.3.3.1 START-OF-ACTIVITY

Après la réception d'un paquet de la sous-couche MAC, émettre une indication PH-DATA de classe START-OF-ACTIVITY. Le paramètre de données correspondant doit détenir le premier octet du paquet reçu. La valeur du paramètre d'état correspondant doit être établie sur SUCCESS (Succès).

##### 9.6.3.3.2 DATA

Les données suivantes dans le paquet reçu doivent entraîner l'émission par la MDS d'indications PH-DATA de classe DATA. Les paramètres de données correspondants doivent détenir les valeurs reçues. La valeur du paramètre d'état correspondant doit indiquer SUCCESS.

### 9.7 Vide

NOTE Dans la présente édition, le 9.7 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

### 9.8 Type 8: MDS: Supports câblés et optiques

#### 9.8.1 Fonction

La MDS (sous-couche dépendante du support) échange des séquences PhSDU par l'interface MIS-MDS, comme cela est décrit au 6.5 et transmet la PhPDU par l'interface MDS-MAU comme cela est décrit à l'Article 9. La MDS code et décode la PhSDU, ajoute et retire la trame de transmission (en-tête et bit d'arrêt) des sous-séquences de PhSDU à émettre et à recevoir, elle synchronise l'interface MIS-MDS avec l'interface MDS-MAU et avec les PhPDU ainsi qu'avec les fonctions temporelles et émet directement une PhPDU entre les MAU par l'interface MDS-MAU (couplage MAU).

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La MDS peut être constituée de plusieurs canaux. La PhPDU doit générer un canal de la MDS correspondant aux séquences de PhSDU transmises par l'interface MIS-MDS et code les séquences de PhSDU en conséquence. En revanche, ce canal doit reconnaître le format de la PhPDU reçue et transmet à la MIS la séquence de PhSDU décodée par l'interface MIS-MDS. Tous les autres canaux sont utilisés pour transférer directement une PhSDU entre deux MAU.

Le canal de la MDS d'un esclave qui a une interface avec la MIS doit avoir la relation suivante entre les sens de transmission et de réception: Si le signal RTS de l'interface MIS-MDS est à 0, le contenu du DI est transmis sur le signal DO de l'interface MDS-MAU avec un temps de retard d'exactement un temps binaire. Si RTS est à 1, DO est couplé à TxD (applicable uniquement lorsqu'il n'y a aucun couplage MDS).

Dans la MDS d'un maître, il est possible qu'une séquence de 8 PhSDU soit d'abord mise en tampon et ensuite une PhPDU de séquence de données ou de séquence de contrôle correspondante est générée.

### 9.8.2 Formats de PhPDU

#### 9.8.2.1 Généralités

La MDS peut reconnaître et générer les formats de PhPDU suivants: **PhPDU de séquence de données, PhPDU de séquence de contrôle, PhPDU d'état** et **PhPDU de réinitialisation**

#### 9.8.2.2 PhPDU de séquence de données

La MDS génère la PhPDU de séquence de données par l'ajout d'un bit de départ, d'un en-tête et d'un bit d'arrêt à l'unité de données. L'unité de données proprement dite est constituée de huit PhSDU qui, en tant que séquence PhSDU, ont été transmises comme partie de la DLPDU de séquence de données par l'interface MIS-MDS, au moyen du service de transmission de messages. La Figure 54 représente la structure de la PhPDU de séquence de données.

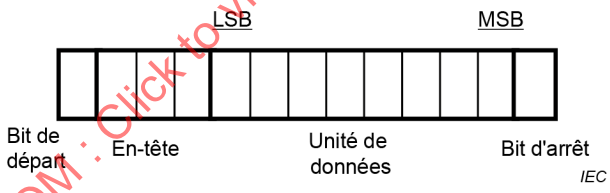


**Figure 54 – PhPDU de séquence de données**

La PhPDU de séquence de données ainsi générée est transmise de gauche à droite, par l'interface MDS-MAU dans l'ordre suivant: bit de départ, en-tête, unité de données, bit d'arrêt. Les PhSDU de l'unité de données sont transmises par l'interface MDS-MAU dans l'ordre dans lequel elles ont été émises à travers l'interface MIS-MDS.

Conformément à la Figure 54, une PhPDU de séquence de données est reçue de gauche à droite et dans l'ordre suivant: bit de départ, en-tête, unité de données, bit d'arrêt. La MDS retire le bit de départ, le bit d'arrêt et l'en-tête et transmet à la MIS la séquence de PhSDU contenue dans l'unité de données avec le service de réception de messages, comme partie d'une DLPDU de séquence de données, par l'intermédiaire de l'interface MIS-MDS. La transmission commence par la première PhSDU qui suit l'en-tête et se termine par la dernière PhSDU avant le bit d'arrêt.

NOTE 1 Chaque PhPDU de séquence de données commence par un bit de départ et se termine par un bit d'arrêt.

NOTE 2 Une DLPDU de séquence de données est transmise par une séquence de PhPDU de séquence de données.

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La structure de l'en-tête dans une PhPDU de séquence de données est représentée à la Figure 55.

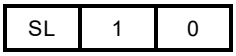


**Figure 55 – Structure de l'en-tête dans une PhPDU de séquence de données**

L'en-tête de la PhPDU de séquence de données est transmis et reçu de gauche à droite, par l'interface MDS-MAU, en commençant par le bit SL.

Pour qu'une PhPDU de séquence de données soit envoyée, le symbole logique transféré dans le bit SL équivaut à l'état logique inversé du signal TxSL de l'interface MIS-MDS au moment auquel la PhPDU de séquence de données doit être transmise à la MAU par l'interface MDS-MAU (voir le Tableau 56):

**Tableau 56 – Attribution du bit SL et du signal TxSL**

| Signal TxSL | Bit SL |
|---|---|
| Niveau logique 1 | 0 |
| Niveau logique 0 | 1 |

Pour une PhPDU de séquence de données reçue, l'état logique du signal RxSL de l'interface MIS-MDS équivaut au symbole logique inversé qui est transmis dans le bit SL (voir le Tableau 57).

**Tableau 57 – Attribution du bit SL et du signal RxSL**

| Bit SL | Signal RxSL |
|---|---|
| 0 | Niveau logique 1 |
| 1 | Niveau logique 0 |

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### 9.8.2.3 PhPDU de séquence de contrôle

La MDS génère la PhPDU de séquence de contrôle par l'ajout d'un bit de départ, d'un en-tête et d'un bit d'arrêt à l'unité de données. L'unité de données proprement dite est constituée de huit PhSDU qui ont été transmises en tant que séquence PhSDU au moyen du service de transmission de messages, comme partie de la DLPDU de séquence de contrôle par l'interface MIS-MDS. La Figure 56 représente la structure de la PhPDU de séquence de contrôle.

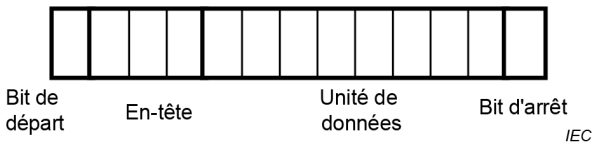


**Figure 56 – PhPDU de séquence de contrôle**

Une PhPDU de séquence de contrôle ainsi générée est transmise de gauche à droite, par l'interface MDS-MAU dans l'ordre suivant: bit de départ, en-tête, unité de données, bit d'arrêt. Les PhSDU de l'unité de données sont transmises par l'interface MDS-MAU dans l'ordre dans lequel elles ont été émises à travers l'interface MIS-MDS.

Une PhPDU de séquence de contrôle est reçue, conformément à la Figure 56, de gauche à droite et dans l'ordre suivant: bit de départ, en-tête, unité de données, bit d'arrêt. La MDS retire le bit de départ, le bit d'arrêt et l'en-tête et transmet à la MIS la séquence de PhSDU contenue dans l'unité de données avec le service de réception de messages, comme partie d'une DLPDU de séquence de contrôle, par l'intermédiaire de l'interface MIS-MDS. La transmission commence par la première PhSDU qui suit l'en-tête et se termine par la dernière PhSDU avant le bit d'arrêt.

NOTE 1 Chaque PhPDU de séquence de contrôle commence par le bit de départ et se termine par le bit d'arrêt.

NOTE 2 Une DLPDU de séquence de contrôle est transmise avec une série de quatre PhPDU de séquence de contrôle.

La structure de l'en-tête dans une PhPDU de séquence de contrôle est représentée à la Figure 57.

| | | |
|---|---|---|
| SL | 0 | 0 |

**Figure 57 – Structure de l'en-tête dans une PhPDU de séquence de contrôle**

L'en-tête de la PhPDU de séquence de contrôle est transmis et reçu de gauche à droite, par l'interface MDS-MAU, en commençant par le bit SL.

Pour qu'une PhPDU de séquence de contrôle soit envoyée, le symbole logique à transférer dans le bit SL équivaut à l'état logique inversé du signal TxSL de l'interface MIS-MDS au moment auquel la PhPDU de séquence de contrôle doit être transmise à la MAU par l'interface MDS-MAU (voir le Tableau 58):

**Tableau 58 – Attribution du bit SL et du signal TxSL**

| Signal TxSL | Bit SL |
|---|---|
| Niveau logique 1 | 0 |
| Niveau logique 0 | 1 |

Pour une PhPDU de séquence de contrôle reçue, l'état logique du signal RxSL de l'interface MIS-MDS équivaut au symbole logique inversé qui est transmis dans le bit SL (voir le Tableau 59).

**Tableau 59 – Attribution du bit SL et du signal RxSL**

| Bit SL | Signal RxSL |
|---|---|
| 0 | Niveau logique 1 |
| 1 | Niveau logique 0 |

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### 9.8.2.4 PhPDU d'état

La PhPDU d'état qui est formée par la MDS est constituée d'un bit de départ, de l'en-tête et d'un bit d'arrêt. La structure de la PhPDU d'état est représentée à la Figure 58.

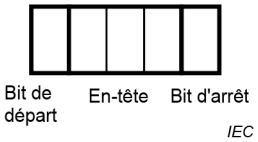


**Figure 58 – Structure de la PhPDU d'état**

La PhPDU d'état est transmise et reçue de gauche à droite, par l'interface MDS-MAU, en commençant par le bit de départ, suivi par l'en-tête et se terminant par le bit d'arrêt.

La structure de l'en-tête d'une PhPDU d'état est représentée à la Figure 59.

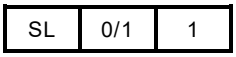


**Figure 59 – Structure de l'en-tête dans une PhPDU d'état**

Conformément à la Figure 59, l'en-tête est transmis et reçu de gauche à droite, par l'interface MDS-MAU, en commençant par le bit SL. L'état du bit qui suit le bit SL n'est pas défini et peut prendre par hypothèse les valeurs "0" ou "1".

Pour qu'une PhPDU d'état soit envoyée, le symbole logique à transférer dans le bit SL équivaut à l'état logique inversé des signaux TxSL de l'interface MIS-MDS au moment auquel la PhPDU d'état doit être transmise à la MAU par l'interface MDS-MAU (voir le Tableau 60).

**Tableau 60 – Attribution du bit SL et du signal TxSL**

| Signal TxSL | Bit SL |
|---|---|
| Niveau logique 1 | 0 |
| Niveau logique 0 | 1 |

Pour une PhPDU d'état reçue, l'état logique du signal RxSL de l'interface MIS-MDS équivaut au symbole logique inversé qui est transmis dans le bit SL (voir le Tableau 61).

**Tableau 61 – Attribution du bit SL et du signal RxSL**

| Bit SL | Signal RxSL |
|---|---|
| 0 | Niveau logique 1 |
| 1 | Niveau logique 0 |

Chaque PhPDU d'état commence par un bit de départ et se termine par un bit d'arrêt.

Si aucune des séquences de PhSDU n'est transmise à la MDS par l'interface MIS-MDS, la MDS commence automatiquement à transmettre des PhPDU d'état successives. Des états de repos peuvent être générés entre deux PhPDU d'état successives. La transmission des PhPDU d'état se termine de manière synchrone avec le message dès que la première PhSDU d'une PhPDU de séquence de données ou de séquence de contrôle a été transmise de la MIS à la MDS.

Les PhPDU d'état sont transmises après une PhPDU de réinitialisation si aucune PhPDU de séquence de contrôle ou de séquence de données ne doit être transmise.

NOTE La réception d'une PhPDU d'état ne modifie pas l'état logique du signal RxCR de l'interface MIS-MDS.

#### 9.8.2.5 PhPDU d'état d'activité du support

La PhPDU d'état d'activité du support qui est formée par la MDS est constituée d'un bit de départ, de l'en-tête et d'un bit d'arrêt. La structure de la PhPDU d'état d'activité du support est représentée à la Figure 60.

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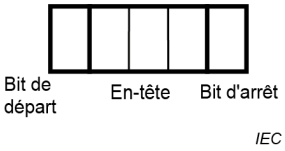


**Figure 60 – Structure de la PhPDU d'état d'activité du support**

La structure de l'en-tête d'une PhPDU d'état d'activité du support est représentée à la Figure 61.

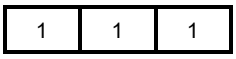


**Figure 61 – Structure de l'en-tête d'une PhPDU d'état d'activité du support**

Conformément à la Figure 61, l'en-tête est transmis et reçu de gauche à droite, par l'interface MDS-MAU. La PhPDU d'état d'activité du support n'est transmise par une MAU passive de départ (mode de rebouclage = désactivé) que si la Gestion systèmes établit la variable "sélection de données" = activé.

### 9.8.2.6 Codage et décodage

Le codage et le décodage sont effectués conformément aux règles du Tableau 62.

**Tableau 62 – Règles de codage et de décodage**

| Bit de symbole logique | Codage DO, DI |
|---|---|
| 1 | Niveau haut |
| 0 | Niveau bas |

Les niveaux haut et bas doivent être prélevés du début d'un bit pendant la durée d'un temps binaire.

NOTE 1 Pour le codage, les symboles logiques sont convertis en l'état correspondant du signal DO de l'interface MDS-MAU.

NOTE 2 Pour le décodage, l'état du signal DI de l'interface MDS-MAU est converti en symbole logique correspondant.

### 9.8.2.7 Bit de départ

Le bit de départ correspond au symbole logique "1".

La MDS doit synchroniser son horloge de réception avec le début des bits de départ (transitions bas-haut).

### 9.8.2.8 Bit d'arrêt

Le bit d'arrêt correspond au symbole logique "0".

NOTE La MDS ne peut synchroniser son horloge de réception sur un bit de départ nouvel arrivant qu'après un bit d'arrêt (transitions bas-haut).

### 9.8.3 États de repos

L'émetteur du maître bus peut générer des états de repos au cours des transitions des PhPDU d'état en PhPDU de séquence de données ou en PhPDU de séquence de contrôle. Les états de repos ont toujours un niveau bas sur DO. La longueur maximale des états de repos ne doit pas dépasser 26 temps binaires. Les règles de décodage pour les états de repos reconnus sur le support sont données dans le Tableau 63.

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**Tableau 63 – Règles de décodage pour les états de repos**

| État de repos | État RxCR | Décodage DI |
|---|---|---|
| Data_Idle | Niveau logique 0 | Niveau bas |
| CRC_Idle | Niveau logique 1 | Niveau bas |
| CRC_Status_Idle | Niveau logique 1 | Niveau bas |

### 9.8.4 PhPDU de réinitialisation

#### 9.8.4.1 Structure de la PhPDU de réinitialisation

La PhPDU de réinitialisation transmet les symboles logiques "réinitialisation courte" ou "réinitialisation longue". La Figure 62 représente la structure de la PhPDU de réinitialisation.

**Figure 62 – PhPDU de réinitialisation**

NOTE Les symboles "réinitialisation courte" et "réinitialisation longue" ne diffèrent qu'en matière de durée de transmission d'un niveau bas par les signaux DO ou DI de l'interface MDS-MAU.

#### 9.8.4.2 Codage et décodage

Les règles de codage de la PhPDU de réinitialisation sont données dans le Tableau 64 et le Tableau 65.

**Tableau 64 – Règles de codage de la PhPDU de réinitialisation**

| Symbole logique | Intervalle de temps | Codage DO |
|---|---|---|
| Réinitialisation courte du bus | 2 ms ≤ TRst < 25,6 ms | Niveau bas |
| Réinitialisation longue du bus | TRst ≥ 25,6 ms | Niveau bas |

**Tableau 65 – Règles de décodage de la PhPDU de réinitialisation**

| DI | Intervalle de temps | Symbole logique |
|---|---|---|
| Niveau bas | 2 ms ≤ TRst < 25,6 ms | Réinitialisation courte du bus |
| Niveau bas | TRst ≥ 25,6 ms | Réinitialisation longue du bus |

NOTE 1 Une PhPDU de réinitialisation se termine par le bit de départ d'une PhPDU de séquence de données, d'une PhPDU de séquence de contrôle ou d'une PhPDU d'état.

NOTE 2 Au cours du codage, les symboles logiques sont convertis en l'état correspondant du signal DO de l'interface MDS-MAU pendant le temps TRst.

NOTE 3 Au cours du décodage, pendant le temps TRst, l'état du signal DI de l'interface MDS-MAU est converti en symbole logique correspondant.

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Les temps donnés dans le Tableau 64 et le Tableau 65 ne s'appliquent pas à l'émetteur du maître. Pour l'émetteur du maître du bus, la PhPDU de réinitialisation correspondante doit être générée sur demande du service RO, conformément aux définitions spécifiées dans les variables PhL *"durée de réinitialisation courte du bus"* et *"durée de réinitialisation longue du bus"*.

NOTE 4 Les règles de codage pour la PhPDU de réinitialisation s'appliquent uniquement à un couplage MDS dans la MIS.

### 9.8.5 Couplage des MAU

Lorsque des MAU du même type ont des paires couplées, chaque PhPDU ainsi que tous les états au repos sont transmis sans aucune modification entre deux MAU. La Figure 63, la Figure 64 et la Figure 65 présentent des configurations possibles des appareils de bus lorsque le support câblé à 2 conducteurs est utilisé.

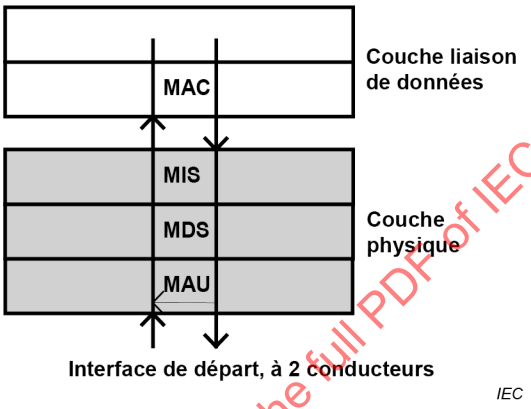


**Figure 63 – Configuration d'un maître**

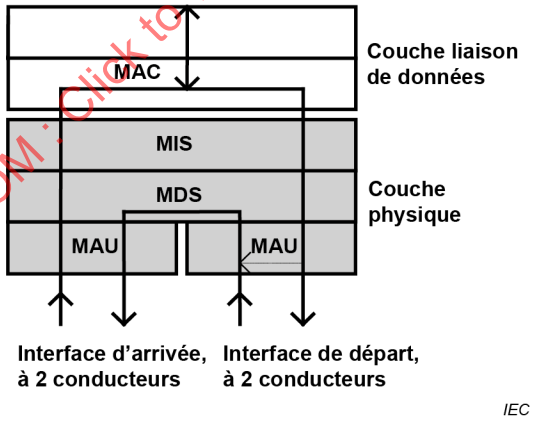


**Figure 64 – Configuration d'un esclave**

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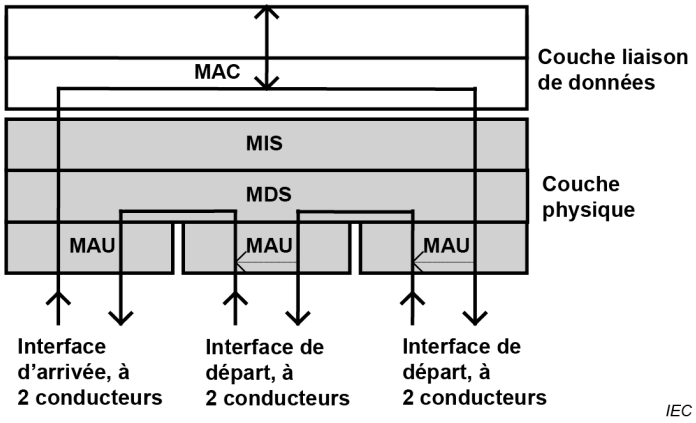


**Figure 65 – Configuration d'un coupleur de bus**

Lorsque deux MAU sont directement couplées, des répéteurs transparents au code peuvent être utilisés pour la régénération temporelle.

### 9.9 Type 12: MDS: Support câblé

Cette sous-couche est conforme à la sous-couche PHY du 100BASE-TX décrit à l'Article 25 de l'ISO/IEC/IEEE 8802-3:2021.

### 9.10 Type 16: MDS: Supports optiques

#### 9.10.1 Règles de codage de données

Les signaux sur les lignes de transmission doivent être codés NRZI. Les variations des signaux sont uniquement possibles en synchronisation avec l'horloge de transmission. Dès lors qu'un "0" est transmis, le signal doit modifier son état en synchronisation avec l'horloge de transmission, tandis qu'il doit rester inchangé lorsqu'un "1" est transmis.

L'émetteur doit vérifier, par une méthode appropriée (c'est-à-dire insertion binaire) qu'un nombre suffisant de zéros est présent dans le flux binaire transmis. Cela engendre des variations supplémentaires du signal. De cette manière, des conditions sont créées rendant possible l'extraction d'une horloge de réception à partir du signal reçu. L'horloge de réception récupérée doit également avoir une position de phase fixe par rapport à l'horloge de l'émetteur. L'horloge doit pouvoir être récupérée au moyen d'une boucle numérique à verrouillage de phase (DPLL) qui doit être synchronisée sur la variation du signal reçu transformé en signal électrique. La Figure 66 d) donne un exemple de signal codé NRZI. Par conséquent, l'horloge de transmission fournit la configuration de synchronisation du système par l'intermédiaire des transitions du signal.

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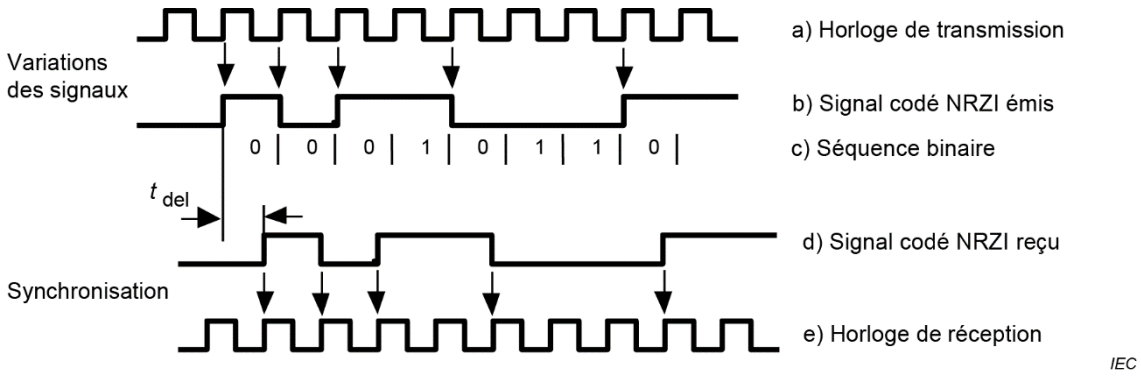


**Figure 66 – Exemple de signal codé en NRZI**

### 9.10.2 Télégrammes et caractères de remplissage

Au niveau physique, il suffit de savoir qu'un télégramme doit commencer et se terminer par la séquence binaire 0111 1110. Cette séquence binaire est également connue sous le nom de délimiteur. En raison de l'insertion binaire, cette séquence binaire ne peut pas se produire à l'intérieur du télégramme.

D'autres zones du télégramme appartiennent à des couches de protocole supérieures et font l'objet d'un traitement différent.

Lorsqu'une unité ne dispose pas son propre télégramme sur le réseau, deux possibilités se présentent:

a) le maître doit émettre un signal dit "de remplissage" (bits de remplissage) entre ses propres télégrammes. Il doit être composé d'une séquence de un "0" binaire et de 7 "1" binaires (c'est-à-dire 0111 1111). Cela génère un signal de remplissage symétrique dont la période est égale à 16 fois la période de l'horloge de transmission, en raison du codage NRZI (voir Figure 67);

b) entre ses propres télégrammes, un esclave doit transmettre, avec l'horloge locale synchronisée, des signaux reçus, régénérés physiquement (mode répéteur).

Pendant la transition d'un télégramme à un signal de remplissage (maître) ou d'un télégramme au mode répéteur (esclave), les variations du signal doivent suivre la configuration de l'horloge en cours.

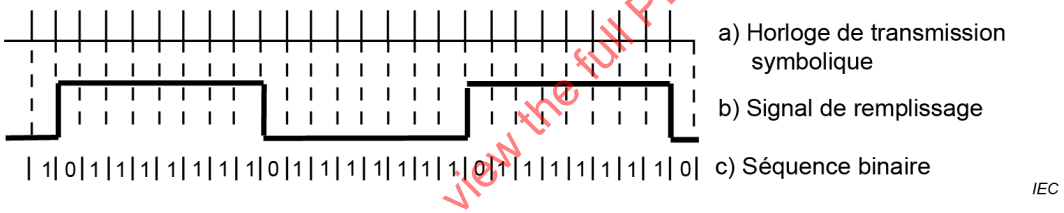


**Figure 67 – Signal de remplissage**

NOTE En raison de l'insertion binaire et de a), l'esclave situé physiquement en premier sur le réseau est capable, à tout instant, de déduire son horloge locale à partir de son signal reçu. En raison de b), c'est également le cas pour toutes les unités suivantes, et ainsi de suite jusqu'au récepteur du maître. De cette manière, les boucles numériques à verrouillage de phase, qui sont en fin de compte utilisées pour obtenir l'horloge locale, restent verrouillées, empêchant ainsi une perte de temps liée à la synchronisation avant le début du message réel.

## 9.11 Type 18: MDS: Supports câblés

### 9.11.1 Vue d'ensemble

La MDS de Type 18 doit pouvoir détecter le lancement et l'achèvement ultérieur d'une réception de données, dont les moyens ne relèvent pas du domaine d'application de la présente spécification.

### 9.11.2 Transmission

La transmission de données commence dès réception d'une demande PH-DATA (START-OF-ACTIVITY) provenant de l'utilisateur DL. Cette demande est traduite par la MDS en une affirmation de signal TRANSMIT-ENABLE, avec la valeur spécifiée dans le champ DATA transmis sur le DATA.

La MDS doit émettre une confirmation PH-DATA (SUCCESS) et doit recevoir la demande PH-DATA (DATA) suivante avant l'expiration du compteur de temps binaire de débit en bauds de la MDS. La confirmation PH-DATA (SUCCESS) qui en résulte ne se produit qu'après réaction à cette demande. De cette manière, le compteur de temps de débit en bauds de la MDS régule le débit de données.

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À la réception d'une demande PH-DATA (END-OF-ACTIVITY) de la part de l'utilisateur DL, la MDS achève la transmission en cours et conclut par une infirmation du signal TRANSMIT-ENABLE.

### 9.11.3 Réception

À la réception d'une activité de données, la MDS émet une indication PH-DATA (START-OF-ACTIVITY) avec la valeur de DATA reçue. Chaque donnée suivante reçue donne lieu à une indication PH-DATA (DATA) avec la valeur de DATA reçue. Lorsque la réception des données est terminée, la MDS émet une indication PH-DATA (END-OF-ACTIVITY) à l'utilisateur DL.

## 9.12 Type 24: MDS: Câble à paire torsadée

### 9.12.1 Généralités

La sous-couche dépendante du support (MDS) fait partie de l'équipement de transmission de données (DCE). Elle communique des bits codés par le biais de l'interface MDS-MAU spécifiée au 10.8.

### 9.12.2 Exactitude d'horloge

Les spécifications temporelles de la signalisation PhL doivent être telles qu'elles sont définies dans le Tableau 66, le Tableau 67 et le Tableau 68.

**Tableau 66 – Caractéristiques temporelles de la MDS de Type 24-1**

| Spécification | Limites / caractéristiques | Commentaires |
|---|---|---|
| Débit binaire | 10 Mbit/s avec une tolérance de ± CA | Également appelé débit de DL-symbol, données 'zéro' ou 'un' |
| Temps binaire | 100 ns avec une tolérance de ± CA | Également appelé durée de DL-symbol, données 'zéro' ou 'un' |
| Durée de symbole PhL | 50 ns avec une tolérance de ± CA | Également appelée durée de Ph-symbol, voir les règles de codage de données |
| Exactitude d'horloge (CA) | ± 100 µHz/Hz max. | Tenant compte de la température, ainsi que de la stabilité à long et à court termes |

**Tableau 67 – Caractéristiques temporelles de la MDS de codage de Manchester de Type 24-3**

| Spécification | Limites / caractéristiques | | Commentaires |
|---|---|---|---|
| Débit binaire | 4 Mbit/s avec une tolérance de ± CA | 8 Mbit/s avec une tolérance de ± CA | Également appelé débit de DL-symbol, données 'zéro' ou 'un' |
| Temps binaire | 250 ns avec une tolérance de ± CA | 125 ns avec une tolérance de ± CA | Également appelé durée de DL-symbol, données 'zéro' ou 'un' |
| Durée de symbole PhL | 125 ns avec une tolérance de ± CA | 62,5 ns avec une tolérance de ± CA | Également appelée durée de Ph-symbol, voir les règles de codage de données |
| Exactitude d'horloge (CA) | ± 100 ppm max. | | Tenant compte de la température, ainsi que de la stabilité à long et à court termes |

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**Tableau 68 – Caractéristiques temporelles de la MDS de codage NRZI de Type 24-3**

| Spécification | Limites / caractéristiques | | | Commentaires |
|---|---|---|---|---|
| Débit binaire | 16 Mbit/s avec une tolérance de ± CA | 24 Mbit/s avec une tolérance de ± CA | 32 Mbit/s avec une tolérance de ± CA | Également appelé débit de DL-symbol, données ‘zéro’ ou ‘un’ |
| Temps binaire | 62,5 ns avec une tolérance de ± CA | 41,66 ns avec une tolérance de ± CA | 31,25 ns avec une tolérance de ± CA | Également appelé durée de DL-symbol, données ‘zéro’ ou ‘un’ |
| Durée de symbole PhL | 62,5 ns avec une tolérance de ± CA | 41,66 ns avec une tolérance de ± CA | 31,25 ns avec une tolérance de ± CA | Également appelée durée de Ph-symbol, voir les règles de codage de données |
| Exactitude d’horloge (CA) | ± 100 ppm max. | | | Tenant compte de la température, ainsi que de la stabilité à long et à court termes |

### 9.12.3 Régénération de données

Selon le Type utilisé et le codage de données, les signaux à l'interface DLL-PhL doivent être synchronisés sur le débit binaire local, comme cela est présenté dans le Tableau 66, le Tableau 67 ou le Tableau 68. Chaque application PhL doit prévoir un mécanisme de régénération des données qui récupère ou reconstruit les données reçues à partir du support approprié, de manière à satisfaire aux exigences de temporisation du Tableau 66, du Tableau 67 ou du Tableau 68. Lorsque la synchronisation des données a été atteinte par la MDS, l'indication de PH-LOCK doit être "vrai".

Une partie de la trame des données reçue peut être perdue ou ignorée lors du processus d'obtention de la synchronisation des données. La spécification de temporisation des données présentée dans le Tableau 66, le Tableau 67 ou le Tableau 68 doit être atteinte avant le commencement de l'indicateur de début.

### 9.12.4 Règles de codage de données

Les DL-symbols présents à l'interface DLL-PhL doivent être codés en Ph-symbols appropriés comme cela est indiqué dans le Tableau 69 et à la Figure 68, et dans le Tableau 70 et à la Figure 69. Les symboles ZÉRO et ONE doivent être codés en Ph-symbols qui représentent les règles de codage de données Manchester Biphase L, comme cela est indiqué dans le Tableau 69. La forme d'onde de tension du signal (provenant de la MAU) est présentée sous forme théorique à la Figure 68 de manière à fournir un exemple des règles de codage de données du Tableau 69.

**Tableau 69 – Règles de codage des données MDS du codage de Manchester**

| Bits de données (nom commun) | Représentation DL_symbol | Codage Ph-symbol | codé Manchester |
|---|---|---|---|
| données "ZÉRO" | ZÉRO ou {0} | {L,H} | 0 |
| données "one" | ONE ou {1} | {H,L} | 1 |

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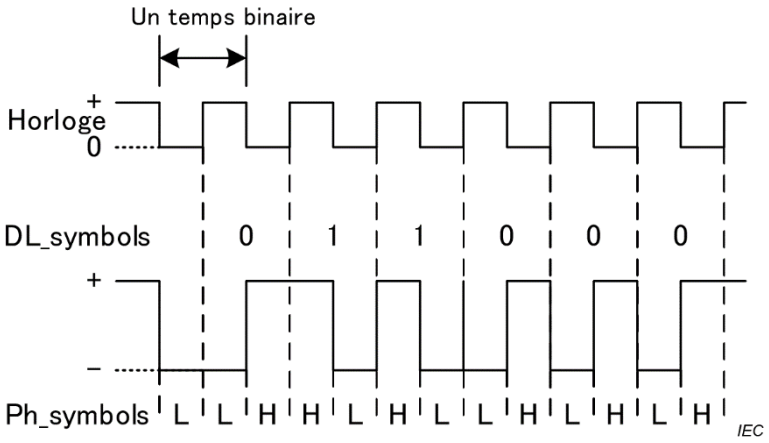


**Figure 68 – Symboles codés Manchester**

**Tableau 70 – Règles de codage des données MDS du codage de NRZI**

| Bits de données (nom commun) | Représentation DL_symbol | Codage Ph-symbol | Codé NRZI |
|---|---|---|---|
| données "ZÉRO" | ZÉRO ou {0} | inverser le précédent niveau de symbole binaire | 0 |
| données "one" | ONE ou {1} | maintenir le précédent niveau de symbole binaire | 1 |

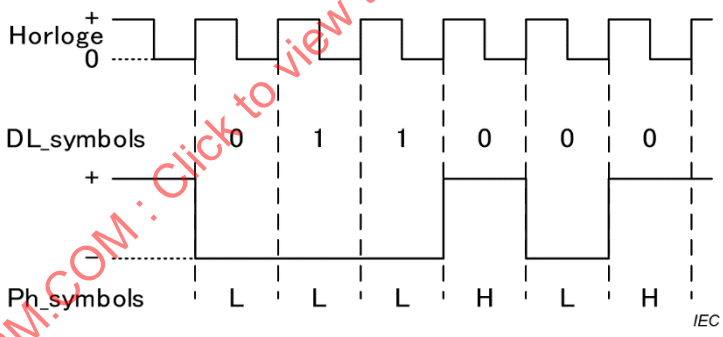


**Figure 69 – Symboles codés NRZI**

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## 9.13 Type 28: MDS: Supports câblés et coaxiaux à paire torsadée

### 9.13.1 Généralités

La MDS fait partie intégrante du DCE. Elle échange la PhSDU par l'intermédiaire d'une interface ETTD-DCE et transmet les symboles mappés à la MAU par l'intermédiaire de l'interface MDS-MAU. Le signal est reçu au niveau de la MDS homologue après démodulation et décodage. Il convient que la PhSDU soit récupérée et transmise à la DIS par l'interface ETTD-DCE pour un traitement ultérieur.

La MDS de la PhL spécifie le processus de canal physique du DCE, y compris le brouillage, le codage, le décodage, l'entrelacement, le mapping, la modulation et la démodulation.

### 9.13.2 Spécification de la MDS

#### 9.13.2.1 Processus de canal physique

La Figure 70 représente le processus de canal PhL de la transmission et de la réception. Lors du processus de transmission, les flux de données sont entrelacés après le brouillage (codage RS et codage convolutif, respectivement), puis modulés par 16QAM, 64QAM ou 256QAM (voir 9.13.2.5) pour former un signal OFDM. En fonction du mode de transmission, les données sont combinées en SF, puis transmises sur la ligne câblée. Le système de réception mène le processus inverse du système de transmission qui est utilisé pour récupérer correctement le flux de données qui provient du signal physique codé.

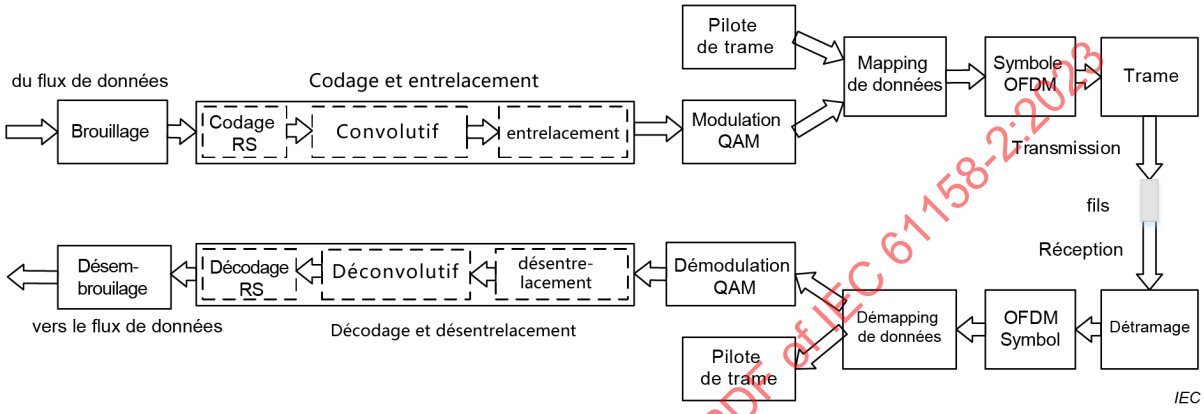


**Figure 70 – Processus de canal PhL**

#### 9.13.2.2 Configuration des paramètres système

Le signal PhL est transmis par modulation OFDM. Le processus central de génération du signal OFDM est IFFT (*Inverse Fast Fourier Transform* – transformée de Fourier rapide inverse), le processus de récupération du signal OFDM reposant sur FFT (*Fast Fourier Transform* – transformée de Fourier rapide). Sur la base d'une largeur de bande donnée et d'une condition d'intervalle d'échantillonnage, il convient que différents points d'échantillonnage FFT/IFFT permettent d'obtenir un intervalle de sous-porteuse et une longueur de symbole OFDM différents. Le système prend en charge 0, 1, 2 et 3, soit au total quatre modes de transmission différents, correspondant respectivement à 4 096, 2 048, 1 024 et 512 points d'échantillonnage. Voir le Tableau 50 pour une configuration de paramètres spécifique.

#### 9.13.2.3 Brouillage

Pour éviter les longues séquences de "0" ou de "1", il convient que le CB à transmettre soit brouillé avant le codage. La séquence de brouillage est une séquence m de longueur 11, et le polynôme de génération est $x^{11} + x^2 + 1$.

La phase d'initialisation est 0b11111111111. Le générateur de séquence de brouillage est réinitialisé lorsque chaque CB commence le traitement. La Figure 71 représente le processus de génération de séquence de brouillage. L'élément "enable" (activer) indique l'auxiliaire de commande, et l'élément "data" (données) représente la séquence d'octets en entrée à brouiller. L'élément "output" (sortie) est la séquence d'octets brouillée.

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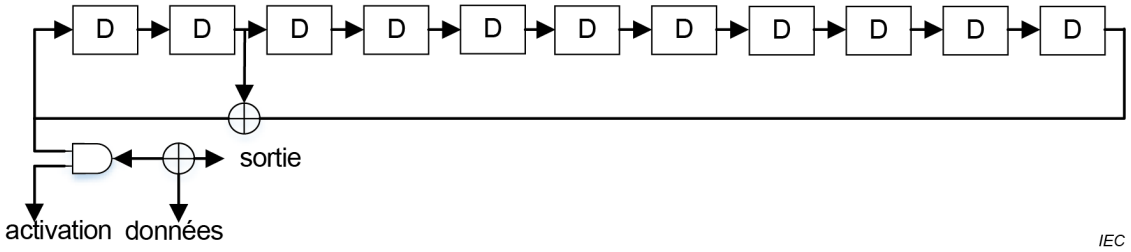


**Figure 71 – Génération de la séquence de brouillage**

#### 9.13.2.4 Codage et entrelacement

##### 9.13.2.4.1 Généralités

Le code RS utilise le code le plus court de la RS d'origine (255, 247), RS (255, 239) et le code système RS (255, 223). Le code RS d'origine contient 255 octets. La longueur de contrôle est de 8, 16 ou 32 octets, qui est le code cyclique reposant sur le domaine fini GF(256). Le polynôme de génération dans le domaine est donné par la Formule (2)

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \tag{2}$$

Le polynôme de génération du code RS est donné par la Formule (3).

$$g(x) = \sum_{i=0}^{i=L-1} g_i x^i \tag{3}$$

où

$L$ est la longueur du bit de contrôle.

Le polynôme de séquence d'informations en entrée est donné par la Formule (4).

$$m(x) = \sum_{i=0}^{i=K-1} m_i x^i \tag{4}$$

où

$K$ est la longueur du bit d'informations.

Le polynôme de sortie du code système est donné par la Formule (5).

$$C(x) = \sum_{i=0}^{i=N-1} c_i x^i = x^{N-K} m(x) + r(x) \tag{5}$$

où

$r(x)$ est défini par la Formule (6).

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$$r(x) = \frac{x^{N-K} m(x)}{g(x)} \quad (6)$$

Les informations détaillées relatives au polynôme de génération RS (255, 247), RS (255, 239), RS (255, 223) $g^0(x)$, $g^1(x)$, $g^2(x)$ sont données à l'Annexe W.

Le mode de code RS utilisé est présenté dans le Tableau 71.

**Tableau 71 – Mode de code RS**

| Mode de code RS | Code RS |
|---|---|
| 0 | (239, 207) |
| 1 | (159, 127) |
| 2 | (119, 103) |
| 3 | (79, 63) |
| 4 | (59, 51) |
| 5 | (39, 31) |
| 6 | (109, 177) |
| 7 | (139, 107) |
| 8 | (104, 88) |
| 9 | (69, 61) |
| 10 | (51, 43) |
| 11 | (34, 26) |

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#### 9.13.2.4.2 Codage convolutif

Chaque octet des données de transmission codé par RS est mappé dans le flux de 8 bits selon le principe de transmission prioritaire du bit élevé, puis envoyé dans le codeur de code convolutif. Les bits sont codés à un débit de 1/2, 2/3 et 3/4 respectivement (voir le Tableau 72).

**Tableau 72 – Mode de code convolutif**

| Code convolutif | Taux de code convolutif |
|---|---|
| 0 | 1/2 |
| 1 | 2/3 |
| 2 | 3/4 |

La longueur de contrainte du codeur convolutif est de 7, le taux de code étant de 1/2. Le polynôme de génération est $G_1 = 171_8$ et $G_0 = 133_8$. La Figure 72 représente un codeur convolutif avec un taux de code de 1/2.

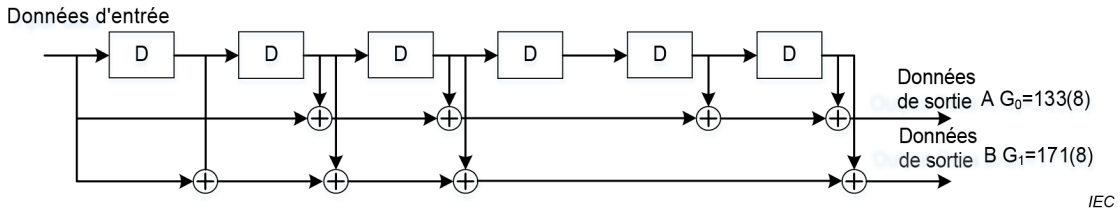


**Figure 72 – Codeur convolutif avec taux de code de 1/2**

La valeur initiale des registres de décalage est définie sur la valeur correspondante des 6 derniers bits dans le flux d'entrée, de sorte que l'état initial et l'état final du registre de décalage soient les mêmes. Selon la Figure 72, les flux de bits codés sont produits dans l'ordre A et l'ordre B. La suppression des bits de codage permet d'obtenir le code convolutif avec les taux de code 2/3 et 3/4. Le processus de suppression de bit est représenté à la Figure 73.

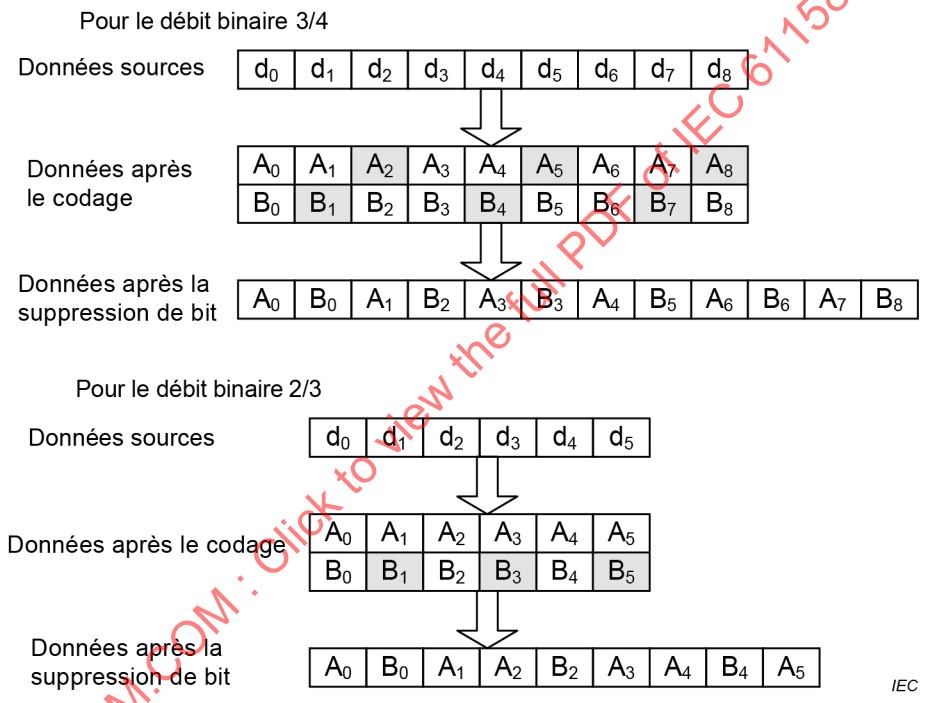


**Figure 73 – Processus de suppression de bit avec les taux de code 2/3 et 3/4**

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#### 9.13.2.4.3 Entrelacement de bits

Il est nécessaire que le flux binaire codé fasse l'objet d'un entrelacement par regroupement d'un flux binaire avec $N_{CBIB}$ en tant que bloc d'entrelacement. Tous les bits de données codés sont entrelacés à l'intérieur d'un bloc de ressource d'un symbole OFDM. L'entrelacement est subdivisé en deux étapes: en premier lieu, les bits de codage adjacents sont mappés aux sous-porteuses non adjacentes; en second lieu, les bits de codage adjacents sont mappés aux bits de poids fort et de poids faible de la constellation. Les règles d'entrelacement spécifiques sont les suivantes:

La première permutation est donnée par la Formule (7):

$$i = \left(\frac{N_{CBIB}}{N_{COL}}\right)(k \bmod N_{COL}) + floor\left(\frac{k}{N_{COL}}\right) \quad (7)$$

où

$N_{CBIB}$ est la longueur de bloc entrelacé;

$k$ est le numéro de séquence de bit codé avant la première permutation;

$i$ est le numéro de séquence de bit codé après la première permutation.

La seconde permutation est donnée par la Formule (8):

$$j = s \times floor\left(\frac{i}{s}\right) + \left[i + N_{CBIB} - floor\left(i \times \frac{N_{COL}}{N_{CBIB}}\right)\right] \bmod s \quad (8)$$

où

$i$ = 0,1, …$N_{CBIB}$

$$s = \max\left(\frac{N_{BPS}}{2,1}\right)$$

$j$ est le numéro de séquence de bit codé après la seconde permutation;

$N_{BPS}$ est le nombre de bits correspondant à un symbole de modulation.

Le Tableau 73 présente les paramètres d'entrelacement de bits. Il convient que le mode de porteuse A utilise les modes d'entrelacement 3 et 4. Il convient que le mode de porteuse B utilise les modes d'entrelacement 0, 1 et 2.

**Tableau 73 – Paramètres d'entrelacement de bits**

| Mode d'entrelacement | Mode de modulation | Numéro de bit de symbole ($N_{BPS}$) | Numéro de colonne ($N_{COL}$) | Longueur de bloc d'entrelacement ($N_{CBIB}$) |
|---|---|---|---|---|
| 0 | 16QAM | 4 | 16 | 320 |
| 1 | 64QAM | 6 | 16 | 480 |
| 2 | 256QAM | 8 | 16 | 640 |
| 3 | 64QAM | 6 | 14 | 420 |
| 4 | 256QAM | 8 | 14 | 560 |

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#### 9.13.2.5 Mapping QAM

Le mappeur de modulation utilise le nombre binaire 0, 1 en entrée pour générer un symbole x de sortie de modulation complexe. Le schéma de mapping de modulation est 16QAM, 64QAM et 256QAM. Le point de constellation z est obtenu à partir d'un nombre binaire en fonction du mode de modulation, puis fait l'objet d'une normalisation de manière à obtenir le symbole de modulation complexe correct.

#### 9.13.2.6 Mapping de ressource

Un signal de référence est déduit de la séquence m avec un polynôme de génération de $x^{11}$ + $x^8$ + $x^5$ + $x^2$ + 1. La Figure 74 représente le circuit de génération de la séquence m.

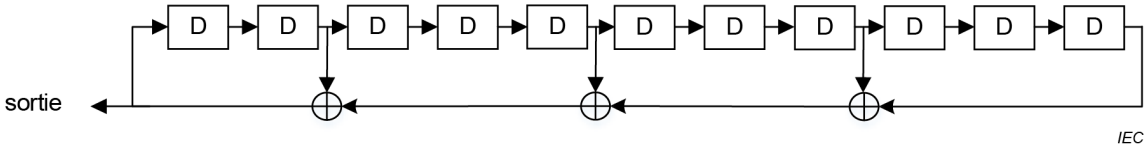


**Figure 74 – Génération de la séquence m**

La séquence m de la Figure 74 est modulée par BPSK de manière à obtenir la séquence de génération de signal de référence $r(m)$. Pour le mapping de ressource physique du pilote, il convient que le signal de référence $r(m)$ soit mappé à la ressource de symbole OFDM. Le pilote SynS est mappé au 0e et au 1er symboles OFDM de la SF et, pour le symbole pilote 0, uniquement aux sous-porteuses paires. Il convient que le pilote diffusé soit mappé à la bande latérale supérieure ou à la bande latérale inférieure d'un symbole OFDM, et que le pilote contigu soit mappé à une sous-porteuse partielle dans la mi-bande latérale du symbole OFDM spécifié. Pour le mapping de ressource physique, il convient que le bloc de symbole complexe modulé soit mappé à la ressource à mi-bande latérale du symbole OFDM correspondant, la ressource de sous-porteuse égale à la répartition d'intervalle étant mise en œuvre dans le domaine fréquentiel.

### 9.13.2.7 Génération de signal OFDM

Le signal temporel continu du symbole OFDM $l$ d'une SF est défini par la Formule (9).

$$s_l(t) = \left[ \sum_{k=N_S}^{N_S+N_{SD}-1} a_{k^{(-)},l} \times e^{j2\pi k\Delta f\left(t-N_{CP,l}T_s\right)} \right] \tag{9}$$

où

$k^{(-)} = k - N_s$

Le Tableau 74 présente les paramètres de configuration OFDM.

**Tableau 74 – Paramètres de configuration OFDM**

| | $\Delta f$ | $N$ | $N_{SD}$ | $N_{CP}$ | $N_S$ |
|---|---|---|---|---|---|
| **Mode de transmission** | **Intervalle de sous-porteuse, kHz** | **Numéro FFT** | **Numéro de sous-porteuse valide** | **Longueur de préfixe cyclique** | **Numéro de sous-porteuse de départ** |
| 0 | 24 | 4 096 | 1 280 | 2 048 | 64 |
| 1 | 48 | 2 048 | 640 | 1 024 | 32 |
| 2 | 96 | 1 024 | 320 | 512 | 16 |
| 3 | 192 | 512 | 160 | 256 | 8 |

En utilisant la fonction réelle à partir de la formule ci-dessus, la fonction de transmission peut être obtenue comme cela est indiqué dans la Formule (10).

$$S_l(t) = \mathrm{Re}\left[s_l(t)\right] \tag{10}$$

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#### 9.13.2.8 Verrouillage de trame

Pour chaque symbole dans la SF, il existe une structure représentée à la Figure 75, 64 symboles formant une SF.

Le signal est donné par la Formule (11).

$$S(t) = \sum_{l=0}^{63} S_l(t - T_l) \tag{11}$$

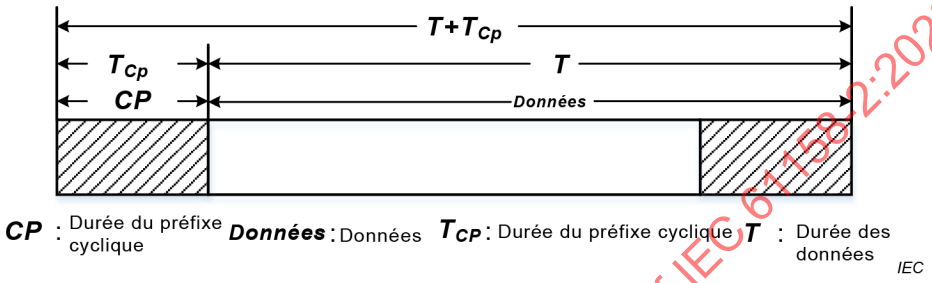


**Figure 75 – Schéma d'une structure de symbole OFDM**

#### 9.13.2.9 Schéma de codage de modulation (MCS)

La PhL prend en charge différents modes de modulation de codage, et le MCS du mode de porteuse A et du mode de porteuse B est présenté dans le Tableau 75 et le Tableau 76.

**Tableau 75 – Schéma de codage de modulation dans le mode de porteuse A**

| Mode de fonctionnement | Mode de transmission | Codage RS | Codage convolutif | Mode de modulation |
|---|---|---|---|---|
| A0 | 0 | (209, 177) | 1/2 | 64QAM |
| A1 | 0 | (139, 107) | 2/3 | 64QAM |
| A2 | 0 | (209, 177) | 3/4 | 256QAM |
| A3 | 1 | (104, 88) | 1/2 | 64QAM |
| A4 | 1 | (139, 107) | 2/3 | 64QAM |
| A5 | 1 | (209, 177) | 3/4 | 256QAM |
| A6 | 2 | (69, 61) | 2/3 | 64QAM |
| A7 | 2 | (104, 88) | 3/4 | 256QAM |
| A8 | 3 | (34, 26) | 2/3 | 64QAM |
| A9 | 3 | (51, 43) | 3/4 | 256QAM |

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**Tableau 76 – Schéma de codage de modulation dans le mode de porteuse B**

| Mode de fonctionnement | Mode de transmission | Codage RS | Codage convolutif | Mode de modulation |
|---|---|---|---|---|
| B0 | 0 | (159, 127) | 1/2 | 16QAM |
| B1 | 0 | (239, 207) | 1/2 | 64QAM |
| B2 | 0 | (159, 127) | 2/3 | 64QAM |
| B3 | 0 | (239, 207) | 3/4 | 256QAM |
| B4 | 1 | (79, 63) | 1/2 | 16QAM |
| B5 | 1 | (119, 103) | 1/2 | 64QAM |
| B6 | 1 | (159, 127) | 2/3 | 64QAM |
| B7 | 1 | (239, 207) | 3/4 | 256QAM |
| B10 | 2 | (79, 63) | 2/3 | 64QAM |
| B11 | 2 | (119, 103) | 3/4 | 256QAM |
| B14 | 3 | (39, 31) | 2/3 | 64QAM |
| B15 | 3 | (59, 51) | 3/4 | 256QAM |

# 10 Interface MDS – MAU

## 10.1 Généralités

La MAU (unité de liaison au support) est une partie facultativement séparée d'un élément de communication qui relie le support directement ou par l'intermédiaire de composants passifs (voir la Figure 1). Pour des variantes de signalisation électrique, la MAU est l'émetteur-récepteur qui fournit le décalage de niveau et la forme d'onde des signaux émis et reçus. L'interface MDS – MAU relie la MAU à la MDS. Les services sont définis comme des signaux physiques afin de faciliter l'éventuelle exposition facultative de cette interface. Les paragraphes ci-après spécifient pour chaque type l'ensemble minimal de services exigés au niveau de l'interface MDS – MAU. Pour les services de gestion, voir l'Article 6.

NOTE Un certain nombre d'interfaces MDS – MAU différentes sont spécifiées, sur la base des pratiques industrielles en la matière.

## 10.2 Type 1: Interface MDS – MAU: Supports câblés et optiques

### 10.2.1 Services

Si l'interface MDS – MAU est exposée, elle doit prendre en charge au moins l'ensemble des services exigés indiqués dans le Tableau 77 et spécifiés au 10.2.2.

**Tableau 77 – Ensemble minimal de services à l'interface MDS – MAU**

| Service | Abréviation | Direction |
|---|---|---|
| **Exigé:** | | |
| Signal de transmission | TxS | Vers la MAU |
| Signal de réception | RxS | De la MAU |
| Activation de transmission | TxE | Vers la MAU |
| **Facultatif:** | | |
| Activation du rebouclage | LbE | Vers la MAU |

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### 10.2.2 Spécifications de services

#### 10.2.2.1 Signal de transmission (TxS)

Le service de signal de transmission (TxS) doit transférer à la MAU la séquence de signaux PhPDU codée à travers l'interface MDS – MAU, et la séquence doit être transmise sur le support si TxE (activation de la transmission) est mis au niveau logique "1" (niveau haut).

#### 10.2.2.2 Signal de réception (RxS)

Le service de signal de réception (RxS) doit transférer à la MDS la séquence de signaux PhPDU codée ou un silence, à travers l'interface MAU – MDS. Le signal RxS doit renvoyer en écho le signal transmis par TxS par la réception simultanée des émissions en provenance du support.

#### 10.2.2.3 Activation de la transmission (TxE)

Le service TxE (activation de la transmission) doit fournir à la MDS la fonction qui permet d'activer la MAU pour qu'elle émette. TxE doit être mis au niveau logique "1" (niveau haut) au début de la transmission du préambule puis au niveau logique "0" (niveau bas) après la transmission du dernier bit du délimiteur de fin.

Si des supports redondants sont utilisés et si la méthode de mise en œuvre de la redondance consiste à recevoir sur tous les canaux, mais à ne transmettre que sur un seul, alors le canal (câble) qui est en cours d'utilisation pour la transmission doit être sélectionné en mettant son signal TxE au niveau logique "1" (niveau haut). Tous les canaux qui ne sont pas en cours d'utilisation pour la transmission doivent être désactivés par l'établissement du signal TxE au niveau logique "0" (niveau bas).

#### 10.2.2.4 Activation du rebouclage (LbE)

Si le service facultatif LbE (activation du rebouclage) présenté dans le Tableau 77 est utilisé, il doit désactiver l'étage de sortie finale du circuit de transmission de la MAU, connecter la sortie de l'étage précédent du circuit de transmission de la MAU au circuit de réception de la MAU et déconnecter le circuit de réception de la MAU du support. L'état du service Activation du rebouclage ne doit pas être modifié pendant que la MAU émet ou reçoit.

NOTE Ce service de confirmation n'a qu'une importance locale et permet à un appareil de vérifier par des essais l'intégrité et la fonctionnalité des circuits de la PhL, à l'exception du support.

### 10.2.3 Caractéristiques des signaux

Les caractéristiques temporelles doivent être compatibles avec celles spécifiées dans les exigences du présent document pour la MDS correspondante.

Si l'interface MDS – MAU est exposée, elle doit fonctionner avec des niveaux de signaux numériques, comme cela est présenté dans le Tableau 78. Les deux côtés de l'interface doivent fonctionner à la même valeur de $V_{DD}$.

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**Tableau 78 – Niveaux de signaux pour une interface MDS – MAU exposée**

| Symbole | Paramètre | Conditions | Limites | Unités | Remarques |
|---|---|---|---|---|---|
| VOL | Tension de sortie de niveau bas maximale | Iout = ±100 µA | 0,1 | V | Voir Note 1 |
| | | Iout = +1,6 mA | 0,4 | V | |
| VOH | Tension de sortie de niveau haut minimale | Iout = ±100 µA | $V_{DD}$ – 0,1 | V | Voir Note 1 |
| | | Iout = -0,8 mA | $V_{DD}$ – 0,8 | V | Voir Note 2 |
| VIL | Tension d'entrée de niveau bas maximale | | 0,2 $V_{DD}$ | V | |
| VIH | Tension d'entrée de niveau haut minimale | | 0,7 $V_{DD}$ | V | Voir Note 3 |

NOTE 1 Donne la capacité d'entraîner deux charges CMOS typiques.

NOTE 2 La compatibilité d'une entrée CMOS avec une sortie TTL exige une résistance de polarisation de l'entrée du signal vers VDD.

NOTE 3 La compatibilité d'une sortie CMOS pour 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. La compatibilité d'une sortie TTL (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) exige une résistance de polarisation de l'entrée du signal vers $V_{DD}$.

#### 10.2.4 Mode de communication

À cette interface, le mode de communication doit permettre une transmission et une réception simultanées.

#### 10.2.5 Caractéristiques de temporisation

L'interface MDS – MAU doit fonctionner correctement à un débit binaire de PhSDU compris entre 1 kbit/s et 1,1 fois le débit binaire MAU déclaré le plus élevé.

NOTE Les débits binaires disponibles dans une mise en œuvre donnée sont fournis dans la déclaration de conformité de mise en œuvre du protocole (PICS).

### 10.3 Vide

NOTE Dans la présente édition, le 10.3 est destiné à maintenir la numérotation des articles et à réduire le plus possible la rupture avec des normes nationales et multinationales ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

### 10.4 Type 2: Interface MDS – MAU: Supports câblés et optiques

#### 10.4.1 Interface MDS-MAU: Généralités

##### 10.4.1.1 Conformité

Un nœud peut inclure toute (ou plusieurs) variantes de PhL mais, pour chaque variante de PhL mise en œuvre, l'interface de support appropriée doit être fournie.

Il n'est pas nécessaire d'exposer l'interface MDS-MAU lors de la mise en œuvre de toute variante de PhL. Cette interface peut être interne au nœud et peut être interne à un appareil à semi-conducteur. Cependant, si une conformité à l'interface MDS-MAU est revendiquée, la mise en œuvre doit satisfaire aux exigences du 10.4.

##### 10.4.1.2 Délai du support à l'interface MDS-MAU

Pour toutes les mises en œuvre conformes à l'interface MDS-MAU, le délai de réception du support à l'interface MDS-MAU doit être inférieur à 200 ns et le délai de transmission de l'interface MDS-MAU au support doit être inférieur à 200 ns.

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### 10.4.2 Interface MDS – MAU: Câble coaxial de 5 Mbit/s en mode tension

#### 10.4.2.1 Définitions des signaux

Le paragraphe 10.4.2 énumère les signaux définis pour l'interface MDS-MAU à support à câble coaxial de 5 Mbit/s en mode tension, comme cela est présenté dans le Tableau 79.

**Tableau 79 – Définitions de l'interface MDS-MAU: Câble coaxial de 5 Mbit/s en mode tension**

| TxDataOut | TxDataBar | NetEnable | RxData | RxCarrier | Ph-symbol |
|---|---|---|---|---|---|
| x | x | 0 | indéfini | 0 | Pas de transmission<br>MAU_FRAME_REQUEST = faux |
| 0 | 0 | 1 | indéfini | 0 | Pas de transmission<br>MAU_FRAME_REQUEST = faux |
| 1 | 0 | 1 | 1 | 1 | H |
| 0 | 1 | 1 | 0 | 0 | L |
| 1 | 1 | 1 | - | - | Non autorisé, l'émetteur peut être endommagé |

#### 10.4.2.2 TxDataOut

TxDataOut doit être "vrai" pour représenter le niveau haut (H) à partir de la MAU et doit être "faux" pour représenter le niveau bas (L), comme cela est présenté dans le Tableau 79. TxDataOut doit être "faux" lorsqu'aucune donnée de Ph-symbol ne doit être transmise (MAU_FRAME_REQUEST = = false).

#### 10.4.2.3 TxDataBar

TxDataBar doit être "vrai" pour représenter L à partir de la MAU et doit être "faux" pour représenter H, comme cela est présenté dans le Tableau 79. TxDataBar doit être "faux" lorsqu'aucune donnée de Ph-symbol ne doit être transmise (MAU_FRAME_REQUEST = false).

#### 10.4.2.4 NetEnable

NetEnable doit être "vrai" pour permettre à la MAU d'émettre les données de Ph-symbol TxDataOut et TxDataBar sur le support à câble coaxial. NetEnable sur "faux" doit empêcher la transmission de données de Ph-symbol TxataOut et TxDataBar, comme cela est présenté dans le Tableau 79.

#### 10.4.2.5 RxData

RxData doit représenter les Ph-symbols (H ou L) bruts, déformés et non synchronisés, tels qu'ils sont récupérés du support à câble coaxial. Ce signal doit être "vrai" ou "faux" selon les exigences du Tableau 121. Après récupération des données et resynchronisation pour répondre aux exigences de temporisation de la MDS (du Tableau 54), ces Ph-symbols doivent être décodés en M_symbols appropriés de la MDS, comme cela est présenté dans le Tableau 55.

#### 10.4.2.6 RxCarrier

RxCarrier doit être "vrai" lorsque le niveau du signal sur le support à câble coaxial dépasse la tension du seuil de détection de porteuse, comme cela est présenté dans le Tableau 122; dans le cas contraire, il doit être "faux". Ce signal doit être utilisé pour générer l'indication de Ph-Carrier à l'interface DLL-PhL définie au 5.3.5.

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### 10.4.3 Support optique 5 Mbit/s d'interface MDS – MAU

#### 10.4.3.1 Définitions des signaux

Le paragraphe 10.4.3 énumère les signaux définis pour l'interface MDS – MAU à support à fibre optique de 5 Mbit/s, comme cela est présenté dans le Tableau 80.

**Tableau 80 – Support à fibre optique 5 Mbit/s d'interface MDS – MAU**

| TXDATAOUT | NETENABLE | RXDATA | RXCARRIER | Ph-symbol |
|---|---|---|---|---|
| Sans effet | 0 | 0 | 0 | L (bas) ou "lumière inactive'' |
| 1 | 1 | 1 | 1 | H (haut) ou ''lumière active'' |
| 0 | 1 | 0 | 0 | L (bas) ou "lumière inactive'' |

#### 10.4.3.2 TxDataOut

TXDATAOUT doit être "vrai" pour représenter H à partir de la MAU et doit être "faux" pour représenter L, comme cela est présenté dans le Tableau 129. Un signal "vrai" doit être représenté sur le support à fibre optique comme "lumière active". Un signal "faux" doit être représenté sur le support à fibre optique comme "lumière inactive". Les exigences de niveau de transmission de la fibre qui définissent "lumière active" (ou puissance couplée, PT on) et "lumière inactive" (ou puissance couplée, PT off) doivent être telles qu'elles sont définies au 19.6.

#### 10.4.3.3 NetEnable

NETENABLE doit être "vrai" pour indiquer que la sous-couche MDS a des Ph-symbol valides à transmettre sur le support à fibre optique. NETENABLE doit permettre à la MAU d'émettre des niveaux de lumière TXDATAOUT sur le support à fibre optique. NETENABLE sur "faux" doit empêcher l'émission de signaux TXDATAOUT, comme cela est présenté dans le Tableau 80.

#### 10.4.3.4 RxData

RXDATA doit représenter les Ph-symbols (H ou L) bruts, déformés et non synchronisés, tels qu'ils sont récupérés du support à fibre optique. Ce signal doit être "vrai" lorsque le niveau de lumière sur le support satisfait aux exigences de "lumière active" définies au 19.6; autrement ce signal doit être "faux". Après récupération des données et resynchronisation pour répondre aux exigences de temporisation de la MDS (du Tableau 54), ces Ph-symbols doivent être décodés en PLS_DATA_INDICATION appropriés de la MDS, comme cela est présenté dans le Tableau 55. RXDATA doit indiquer "faux" si le support est défectueux, manquant ou si l'alimentation est retirée de l'extrémité émission de la fibre.

#### 10.4.3.5 RxCarrier

RXCARRIER doit être "vrai" lorsque le niveau de lumière sur le support satisfait aux exigences de "lumière active" définies au 19.6; autrement ce signal doit être "faux". Ce signal doit être directement utilisé pour générer l'indication PLS_CARRIER_INDICATION à l'interface DLL-PhL. Si l'émetteur-récepteur à fibre optique ne prend pas en charge un mécanisme d'indication de porteuse, ce signal d'interface doit être connecté au signal d'interface RXDATA. RXCARRIER doit indiquer "faux" si le support est défectueux, manquant ou si l'alimentation est retirée de l'extrémité émission de la fibre.

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#### 10.4.4 Port d'accès au réseau (NAP) de l'interface MDS – MAU

Les signaux suivants doivent être exigés pour l'interface MDS-MAU du port NAP:

a) /TxPTC doit être "faux" pour représenter H des données de transmission à partir de la MAU, et doit être "vrai" pour représenter L;

b) /RxPTC doit être "faux" pour représenter H des données de réception à partir de la MDS, et doit être "vrai" pour représenter L. Ce signal doit être "vrai" si le support NAP est retiré, défectueux, en court-circuit ou si l'émetteur d'origine est désactivé.

### 10.5 Type 3: Interface MDS – MAU: Supports câblés et optiques

#### 10.5.1 Transmission synchrone

L'interface MDS – MAU spécifiée pour le Type 1 doit être utilisée (voir 10.2).

#### 10.5.2 Transmission asynchrone

L'interface DL-Ph pour la transmission asynchrone doit être utilisée en lieu et place de l'interface MDS – MAU décrite au 10.2 (voir 5.1 et 5.4.2).

### 10.6 Type 8: Interface MDS – MAU: Supports câblés et optiques

#### 10.6.1 Vue d'ensemble des services

L'interface MDS-MAU met à disposition des services qui permettent de connecter la MDS à une MAU correspondante. Les services sont définis comme des signaux logiques que la sous-couche MAU convertit directement en signaux physiques (voir le Tableau 81).

**Tableau 81 – Services de l'interface MDS-MAU**

| Service | Mnémonique | Direction |
|---|---|---|
| Données sortantes | DO | De la MDS |
| Données entrantes | DI | De la MAU |
| Connecteur de bus | BC | De la MAU |
| Activation du rebouclage | LbE | De la MDS |
| Sélection de données | DS | De la MDS |
| Activité du support | MA | De la MDS |
| NOTE Les services connecteur de bus, activation du rebouclage, sélection de données et activité du support sont uniquement pris en charge par la MAU d'une interface de départ. | | |

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#### 10.6.2 Description des services

##### 10.6.2.1 Données sortantes (DO)

Ce service transmet la PhPDU de la MDS à la MAU.

##### 10.6.2.2 Données entrantes (DI)

Ce service transmet la PhPDU de la MAU à la MDS.

#### 10.6.2.3 Connecteur de bus (BC)

Ce service indique à une MDS si le support de transmission est connecté à la MAU d'une interface de départ. Si le support de transmission n'est pas connecté à la MAU d'une interface de départ, la Gestion systèmes doit, pour cette MAU, déconnecter le circuit de réception du support au moyen du service activation du rebouclage (LbE) et connecter le circuit de transmission au circuit de réception.

NOTE 1 Le service Connecteur de bus est uniquement pris en charge par la MAU d'une interface de départ. Il n'est pas lié aux autres services de l'interface MDS-MAU.

NOTE 2 Il s'agit d'un service de gestion local qui indique si un autre appareil de bus est connecté à l'interface de départ de la MAU, ce qui permet à la Gestion systèmes de fermer ou d'ouvrir l'anneau de transmission au moyen du service Activation du rebouclage.

NOTE 3 La détection d'un autre appareil de bus connecté est réalisée par un signal qui est conduit par l'intermédiaire d'un pont dans le connecteur du câble de départ (voir la définition du câble).

#### 10.6.2.4 Activation du rebouclage (LbE)

Ce service permet à la Gestion systèmes de désaccoupler le circuit de réception du support de transmission pour une MAU d'interface de départ et de connecter le circuit de transmission au circuit d'entrée.

NOTE 1 Le service activation du rebouclage est uniquement pris en charge par la MAU d'une interface de départ et n'est pas lié aux autres services de l'interface MDS-MAU.

NOTE 2 Il s'agit d'un service de gestion local qui permet à la Gestion systèmes de fermer l'anneau de transmission si aucun autre esclave de bus n'est connecté à la MAU d'une interface de départ.

#### 10.6.2.5 Activité du support (MA)

Ce service émet une PhPDU d'état spécial de la MDS à la MAU si l'anneau actif a été désaccouplé du support et si les circuits de transmission et de réception ont été connectés, mais une activité contrôlée doit être générée sur le support.

NOTE 1 Ce service est utilisé par un esclave uniquement.

NOTE 2 Le service Activité du support est uniquement pris en charge par la MAU d'une interface de départ et n'a aucune relation temporelle avec les autres services de l'interface MDS-MAU.

#### 10.6.2.6 Sélection de données (DS)

La Gestion systèmes utilise ce service pour émettre sur le support désaccouplé d'une MAU de départ soit une PhPDU de réinitialisation soit, au moyen du service activité du support, certaines PhPDU d'état.

NOTE 1 Ce service est utilisé par un esclave uniquement.

NOTE 2 Le service Sélection des données est uniquement pris en charge par la MAU d'une interface de départ et n'est pas lié aux autres services de l'interface MDS-MAU.

### 10.6.3 Réponse temporelle

La MDS doit pouvoir décoder clairement un bit qui présente une instabilité du signal binaire, comme cela est spécifié à la Figure 76. La variation de l'horloge d'échantillonnage doit s'inscrire dans une plage de ± 0,1 %.

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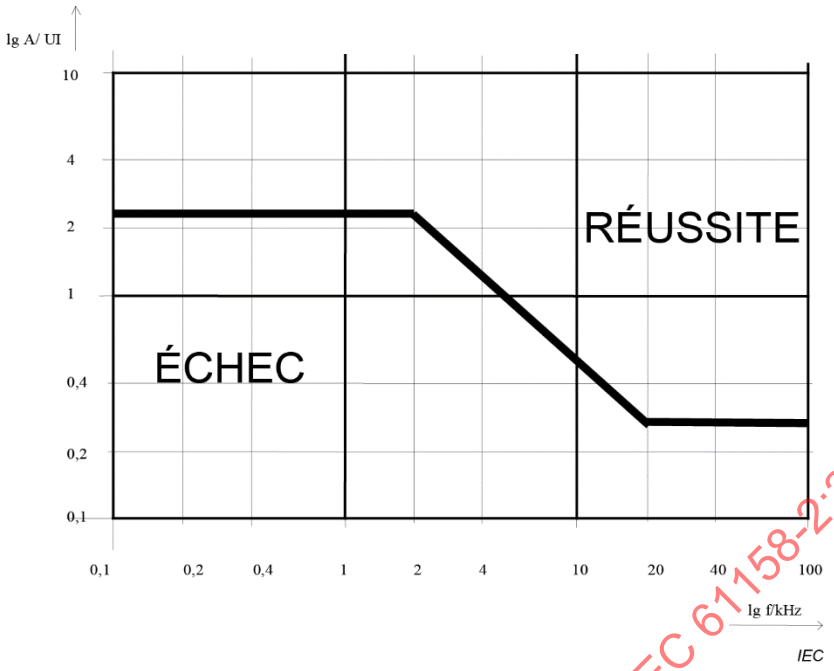


**Figure 76 – Tolérance à l'instabilité (gigue)**

### 10.6.4 Mode de transmission

L'interface MDS-MAU doit permettre une émission et une réception simultanées et indépendantes.

## 10.7 Type 18: Interface MDS – MAU: Supports câblés

### 10.7.1 Généralités

La granularité des PhPDU échangées au niveau de l'interface MAU est d'un bit.

### 10.7.2 Services

Si l'interface MAU est exposée, elle doit prendre en charge au moins l'ensemble des services exigés indiqués dans le Tableau 82 et spécifiés au 10.7.3.

**Tableau 82 – Ensemble minimal de services à l'interface MAU**

| Service | Abréviation | Direction |
|---|---|---|
| Signal de transmission | TxS | Vers la MAU |
| Signal de réception | RxS | De la MAU |
| Activation de transmission | TxE | Vers la MAU |

### 10.7.3 Spécifications de services

#### 10.7.3.1 Signal de transmission (TxS)

Le service de signal de transmission (TxS) doit transférer la séquence de signaux PhPDU codée à travers l'interface vers la MAU, dans laquelle la séquence doit être transmise sur le support si TxE (activation de la transmission) est mis au niveau logique "1" (niveau haut).

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#### 10.7.3.2 Signal de réception (RxS)

Le service de signal de réception (RxS) doit transférer la séquence de signaux PhPDU codée ou un silence, à travers l'interface vers la MDS. Le signal RxS doit renvoyer en écho le signal transmis par TxS par la réception simultanée des émissions en provenance du support.

#### 10.7.3.3 Activation de la transmission (TxE)

Le service TxE (activation de la transmission) doit fournir la fonction qui permet d'activer la MAU pour qu'elle émette. TxE doit être mis au niveau logique "1" (niveau haut) au début de la transmission du préambule, puis au niveau logique "0" (niveau bas) après la transmission du dernier bit du délimiteur de fin.

### 10.7.4 Caractéristiques des signaux

Si l'interface MAU est exposée, elle doit fonctionner avec des niveaux de signaux numériques, comme cela est présenté dans le Tableau 83. Les deux côtés de l'interface doivent fonctionner à la même valeur de $V_{DD}$.

**Tableau 83 – Niveaux de signaux pour une interface MAU exposée**

| Symbole | Paramètre | Conditions | Limites | Unités | Remarques |
|---|---|---|---|---|---|
| $V_{OL}$ | Tension de sortie de niveau bas maximale | Iout = ±100 µA | 0,1 | V | Voir Note 1 |
| | | Iout = +1,6 mA | 0,4 | V | |
| $V_{OH}$ | Tension de sortie de niveau haut minimale | Iout = ±100 µA | $V_{DD}$ – 0,1 | V | Voir Note 1 |
| | | Iout = -0,8 mA | $V_{DD}$ – 0,8 | V | Voir Note 2 |
| $V_{IL}$ | Tension d'entrée de niveau bas maximale | | 0,2 $V_{DD}$ | V | |
| $V_{IH}$ | Tension d'entrée de niveau haut minimale | | 0,7 $V_{DD}$ | V | Voir Note 3 |

NOTE 1 Donne la capacité d'entraîner deux charges CMOS typiques.

NOTE 2 La compatibilité d'une entrée CMOS avec une sortie TTL exige une résistance de polarisation de l'entrée du signal vers $V_{DD}$.

NOTE 3 La compatibilité d'une sortie CMOS pour 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. La compatibilité d'une sortie TTL (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) exige une résistance de polarisation de l'entrée du signal vers $V_{DD}$.

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### 10.7.5 Mode de communication

À cette interface, le mode de communication doit permettre une transmission et une réception simultanées.

### 10.7.6 Caractéristiques de temporisation

L'interface MAU doit fonctionner correctement à un débit binaire de PhSDU compris entre 1 kbit/s et 1,1 fois le débit binaire MAU déclaré le plus élevé. L'exactitude de la fréquence de synchronisation doit être autour de 150 µHz/Hz du taux spécifié.

## 10.8 Type 24: Interface MDS – MAU: Support câblé à paire torsadée

### 10.8.1 Vue d'ensemble du service

Si l'interface MDS – MAU est exposée, elle doit prendre en charge au moins l'ensemble des services exigés indiqués dans le Tableau 84 et spécifiés au 10.8.2.

**Tableau 84 – Services minimaux de l'interface MDS-MAU**

| Désignation du signal | Mnémonique | Direction |
|---|---|---|
| Signal de transmission | TxS | Vers la MAU |
| Activation de transmission | TxE | Vers la MAU |
| Signal de réception | RxS | De la MAU |

### 10.8.2 Description des services

#### 10.8.2.1 Signal de transmission (TxS)

Ce service transmet la PhPDU de la MDS à la MAU; la transmission doit être effectuée sur le support si TxE (activation de la transmission) est mis au niveau logique "1" (niveau haut).

#### 10.8.2.2 Activation de la transmission (TxE)

Le service TxE (activation de la transmission) doit fournir à la MDS la fonction qui permet d'activer la MAU pour qu'elle émette. TxE doit être mis au niveau logique "1" (niveau haut) par la MDS, immédiatement avant que l'émission ne commence, et au niveau logique "0" (niveau bas) après la fin de la transmission.

#### 10.8.2.3 Signal de réception (RxS)

Ce service transmet la PhPDU de la MAU à la MDS.

#### 10.8.2.4 Caractéristiques des signaux

Si l'interface MDS – MAU est exposée, elle doit fonctionner avec des niveaux de signaux numériques, comme cela est présenté dans le Tableau 85. Les deux côtés de l'interface doivent fonctionner à la même valeur de $V_{DD}$.

**Tableau 85 – Niveaux de signaux pour une interface MDS – MAU exposée ($V_{DD}$=5V)**

| Symbole | Paramètre | Conditions | Limites | Unités | Remarques |
|---|---|---|---|---|---|
| $V_{OL}$ | Tension de sortie de niveau bas maximale | Iout = ±100 µA | 0,1 | V | Voir Note 1 |
| $V_{OH}$ | Tension de sortie de niveau haut minimale | Iout = ±100 µA<br>Iout = -0,8 mA | $V_{DD}$ – 0,1<br>$V_{DD}$ – 0,8 | V | Voir Note 2 |
| $V_{IL}$ | Tension d'entrée de niveau bas maximale | | 0,2 $V_{DD}$ | V | |
| $V_{IH}$ | Tension d'entrée de niveau haut minimale | | 0,7 $V_{DD}$ | V | Voir Note 3 |

NOTE 1 Donne la capacité d'entraîner deux charges CMOS typiques.

NOTE 2 La compatibilité d'une entrée CMOS avec une sortie TTL exige une résistance de polarisation de l'entrée du signal vers $V_{DD}$.

NOTE 3 La compatibilité d'une sortie CMOS pour 3,0 V ≤ $V_{DD}$ ≤ 5,5 V. La compatibilité d'une sortie TTL (4,75 V ≤ $V_{DD}$ ≤ 5,25 V) exige une résistance de polarisation de l'entrée du signal vers $V_{DD}$.

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#### 10.8.2.5 Caractéristiques de temporisation

Les caractéristiques temporelles doivent être compatibles avec celles spécifiées dans les exigences du présent document pour la MDS correspondante. L'interface MDS – MAU doit fonctionner correctement à un débit binaire de PhSDU jusqu'à 32 Mbit/s.

### 10.9 Type 28: Interface MDS – MAU: Supports câblés et coaxiaux à paire torsadée

#### 10.9.1 Généralités

L'unité de liaison au support (MAU) est une partie facultativement séparée d'un élément de communication qui relie le support directement ou par l'intermédiaire de composants passifs. L'interface MDS-MAU de la PhL fournit la fonction de conversion de signal et de connexion. Il convient que l'interface convertisse le signal numérique produit par le MDS en signal analogique et l'envoie par l'intermédiaire de la MAU, ou qu'elle convertisse le signal analogique reçu de la MAU en signal numérique qui peut être traité par le MDS.

#### 10.9.2 Services

L'interface MDS-MAU de la PhL prend en charge au moins un ensemble des services exigés indiqués dans le Tableau 86 et spécifiés au 10.9.4.

**Tableau 86 – Ensemble minimal de services à l'interface MDS – MAU**

| Service | Abréviation | Direction |
|---|---|---|
| **Exigé:** | | |
| Signal de transmission | TxS | Vers la MAU |
| Signal de réception | RxS | De la MAU |
| Activation de transmission | TxE | Vers la MAU |
| **Facultatif:** | | |
| Activation du rebouclage | LbE | Vers la MAU |

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#### 10.9.3 Processus du service

La Figure 77 représente le processus de service de l'interface MDS-MAU de la PhL.

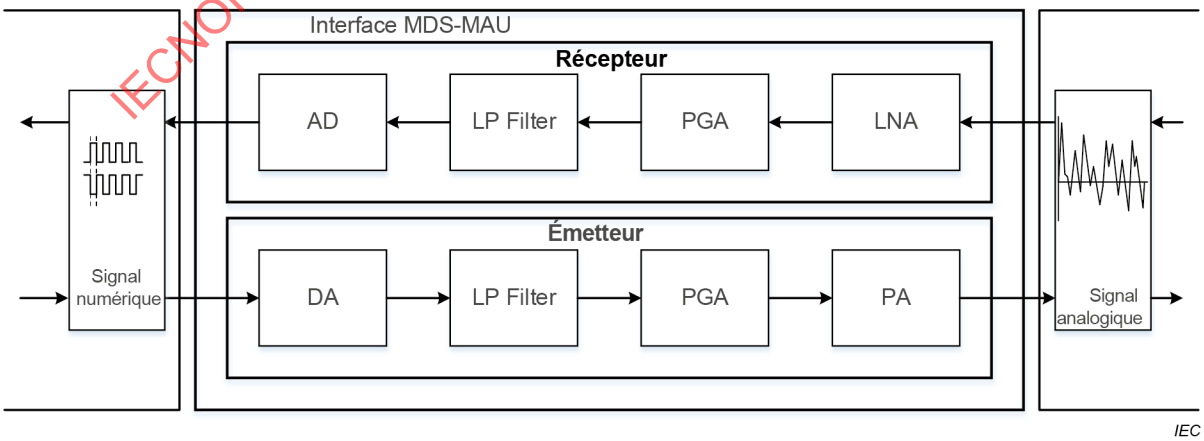


**Figure 77 – Diagramme du processus de service de l'interface MDS-MAU**

Le MDS de la PhL met en œuvre le codage et la modulation en fonction d'OFDM et génère le signal numérique vers l'interface MDS-MAU pour transmettre le signal. L'interface inclut un émetteur et un récepteur. Au niveau de l'émetteur, le signal numérique est converti en signal analogique par le module N/A. Après filtrage, amplification de gain et amplification de puissance, le signal analogique est transmis au support, puis envoyé au réseau. Au niveau du récepteur, le signal analogique est récupéré vers le signal numérique correspondant par le module A/N après amplification à faible bruit, amplification de puissance et filtrage. Ensuite, le signal numérique est transmis au MDS pour un traitement supplémentaire (démodulation et décodage, par exemple).

### 10.9.4 Spécifications de services

#### 10.9.4.1 Signal de transmission (TxS)

Le service de signal de transmission (TxS) transfère la séquence de signaux PhPDU codée à la MAU sur l'interface MDS-MAU. Si Activation de la transmission (TxE) est défini sur niveau logique 0 (niveau bas), il convient que la séquence de signaux analogiques en sortie soit envoyée au support.

#### 10.9.4.2 Signal de réception (RxS)

Le signal de réception (RxS) transfère la séquence de signaux PhPDU codée au MDS sur l'interface MDS-MAU. Il convient que la séquence de signaux en sortie soit une PhPDU décodable. Lorsque la PhL fonctionne, le service RxS est toujours valide par défaut et il n'est pas nécessaire de confirmer son activation. Il convient que le signal RxS renvoie en écho le signal transmis par TxS par la réception simultanée des émissions en provenance du support.

#### 10.9.4.3 Activation de la transmission (TxE)

Le service TxE (activation de la transmission fournit à la MDS la fonction qui permet d'activer la MAU pour qu'elle émette. Il convient que TxE soit défini sur le niveau logique 0 (niveau bas) lorsque la séquence de signaux PhPDU est prête a être envoyée, puis défini sur le niveau logique 1 (niveau haut) après que l'interface MDS-MAU a traité la séquence et l'a transmise au support. Dès que l'appareil physique est sous tension, TxE est défini sur le niveau logique 0 (niveau bas) par défaut, c'est-à-dire que l'utilisateur est toujours autorisé à envoyer.

#### 10.9.4.4 Activation du rebouclage (LbE)

Lorsque l'interface MDS-MAU fournit le service d'activation de rebouclage (LbE), le signal envoyé par la MAU est renvoyé à la MAU en tant que signal reçu pour un traitement supplémentaire. LbE renvoie tous les signaux vers le rebouclage local, ce qui n'a aucun effet sur les signaux reçus par la MAU de la part du support. Il convient que l'état du service de LbE ne varie pas lorsque la MAU émet ou reçoit.

NOTE Ce service de confirmation est valide en local. Il permet à un appareil de vérifier par des essais l'intégrité et la fonctionnalité des circuits de la PhL, à l'exception du support.

### 10.9.5 Spécifications de transmission

#### 10.9.5.1 Niveau de transmission

La PhL spécifie que la puissance de sortie maximale admissible est de 100 mW.

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#### 10.9.5.2 Spécification du spectre de fréquence de transmission

La plage de fréquences de transmission mise en œuvre dans l'interface MDS-MAU de la PhL est comprise entre 1,536 MHz et 32,256 MHz. Pour réduire la puissance hors bande du signal RF, il convient d'utiliser le filtre pour filtrer le signal RF. La Figure 78 représente le modèle de signal pour une éventuelle mise en œuvre du filtre dans la largeur de bande du signal.

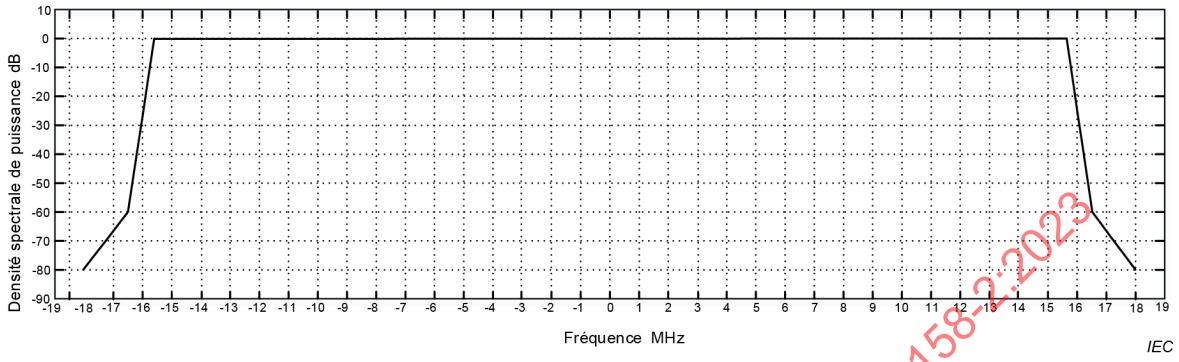


**Figure 78 – Modèle de spectre de signal**

#### 10.9.5.3 Tolérance de fréquence de sous-porteuse de transmission

La plage de fréquences d'horloge de la PhL doit être de 100 MHz avec une précision de ±150 ppm. Pendant la transmission, la fréquence de sous-porteuse est synchronisée avec la fréquence d'horloge.

#### 10.9.5.4 Exactitude de la modulation

Il convient que le diagramme de constellation après moyennage de la sous-porteuse, de la trame OFDM et du groupement pour RMS satisfasse au Tableau 87.

**Tableau 87 – Erreurs admissibles du diagramme de constellation dans différents modes de modulation**

| Mode de modulation | Erreur de constellation relative (dB) |
|---|---|
| 16QAM | 45 |
| 64QAM | 45 |
| 256QAM | 45 |

#### 10.9.5.5 Paramètres de transmission du système

La puissance d'émission maximale du système est de 20 dBmW, et la sensibilité de réception minimale est de −82 dBmW.

La distance de transmission maximale est de 500 m.

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Le Tableau 88 présente les spécifications de paramètres pour différents taux de transmission.

**Tableau 88 – Paramètres de transmission du système**

| Paramètre | Valeur | | | Unité |
|---|---|---|---|---|
| Débit binaire de charge nette | 14 | 57 | 103 | Mbit/s |
| SNR | 13,4 | 18 | 23 | dB |

## 11 Type 1 et Type 7: Unité de liaison au support: mode tension, topologie de bus linéaire, support câblé à paire torsadée 150 Ω

### 11.1 Généralités

NOTE Ces exigences applicables à la MAU ne sont pas spécifiquement destinées à faciliter les options de distribution de l'alimentation par le biais des conducteurs de signaux et à permettre la certification de la sécurité intrinsèque.

Le support de réseau est composé d'un câble à paire torsadée blindé. Indépendamment de la topologie, tous les appareils connectés, sauf éventuellement l'appareil de transmission, présentent une impédance élevée pour éviter une surcharge importante du réseau. Des formes d'onde trapézoïdales sont utilisées pour réduire les émissions électromagnétiques et la distorsion des signaux.

Une topologie de bus linéaire est prise en charge, comme le sont également certaines topologies acycliques à dérivations. Un réseau comporte un câble de ligne principale, disposant de terminaisons à ses extrémités.

### 11.2 Grandeurs dépendantes du débit binaire

Six débits binaires sont définis pour une unité de liaison au support (MAU) à paire torsadée en mode tension. Une MAU donnée doit prendre en charge au moins un de ces débits binaires.

Le Tableau 89 indique les débits binaires pris en charge et définit les symboles relatifs aux grandeurs dépendantes du débit binaire utilisés tout au long de l'Article 11.

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**Tableau 89 – Grandeurs dépendantes du débit binaire de réseaux en mode tension**

| Grandeur | | Symbole | Unité | Valeur | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Débit binaire nominal | | BR | Mbit/s | 0,031 25 | 1 | 2,5 | 5 | 10 | 25 |
| Écart maximal par rapport à BR | | ΔBR | | 0,2 % | 0,01 % | | | | |
| Durée binaire nominale | | $T_{bit}$ | µs | 32 | 1,0 | 0,4 | 0,2 | 0,1 | 0,04 |
| Écart maximal par rapport à Tbit | | $\Delta T_{bit}$ | - | 0,9 µs | 0,025 % | | | | |
| Fréquences de signalisation | Nominale pour une répétition de bit | $f_r$ | MHz | 0,031 25 | 1 | 2,5 | 5 | 10 | 25 |
| | Nominale minimale = 0,25 fr | $f_{min}$ | MHz | 0,007 8 | 0,25 | 0,625 | 1,25 | 2,5 | 6,25 |
| | Nominale maximale = 1,25 fr | $f_{max}$ | MHz | 0,039 | 1,25 | 3,125 | 6,25 | 12,5 | 31,25 |
| Nombre maximal d'appareils | | $N_{max}$ | | 32 | | | | 16 | |
| Distance maximale entre appareils | | $L_{max}$ | m | 4 000 | 750 | 500 | 400 | 200 | 100 |
| Affaiblissement maximal entre appareils | | $A_{max}$ | dB | 15 | 17 | 18 | | | |
| Distorsion d'affaiblissement maximale entre appareils | | $AD_{max}$ | dB | 8 | | 10 | | | |
| Distorsion de désadaptation maximale entre appareils | | $MD_{max}$ | dB | 0,2 | | | 0,4 | 0,6 | |
| Temps de croissance ou de décroissance de signal maximal | | $T_{rf}$ | ns | 8 000 | 200 | 80 | 40 | 20 | 8 |
| Espacement maximal des coupleurs pour former une grappe | | $CS_{max}$ | m | 4 | | 2 | 1 | 0,5 | 0,25 |
| Impédance d'entrée minimale d'un appareil | | $Din_{min}$ | kΩ | 8 | | | 4 | 2 | 1 |
| Sortie maximale d'émetteur passif | | $QTO_{max}$ | mV rms | 1 | 5 | 10 | 20 | 40 | 80 |
| Fréquence maximale pour le mesurage de QTOmax | | $f_{QTOmax}$ | MHz | 0,1 | 4 fr | | | | |

Le débit binaire moyen doit être BR avec une tolérance de ± ΔBR, moyenné sur une trame d'une longueur minimale de 16 octets.

Le temps binaire instantané doit être $T_{bit}$ avec une tolérance de ± $\Delta T_{bit}$.

## 11.3 Spécifications du réseau

### 11.3.1 Composants

Une MAU en mode tension fonctionne sur un réseau constitué des composants suivants:

a) un câble à paire torsadée;
b) des appareils (qui comportent au moins un élément de communication);
c) des connecteurs;
d) des coupleurs;
e) des terminateurs.

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### 11.3.2 Topologies

Une MAU câblée doit fonctionner sur un réseau de topologie de bus linéaire nominalement acyclique, constitué d'une ligne principale, terminée à chaque extrémité comme cela est spécifié au 11.8.5 et à laquelle des éléments de communication sont connectés par l'intermédiaire de coupleurs. Chaque élément de communication doit être connecté en parallèle au câble de ligne principale.

NOTE Le coupleur et l'élément de communication sont en général intégrés dans un appareil.

Des répéteurs actifs peuvent être utilisés pour constituer des dérivations ou étendre la longueur de la ligne principale au-delà d'un segment unique si cela est admis par les règles de configuration du réseau. Les dérivations doivent être considérées comme des segments, et peuvent rendre le bus non linéaire. Les cycles (boucles fermées) ne sont jamais admis.

### 11.3.3 Règles de configuration du réseau

Une MAU qui revendique la conformité à l'Article 11 doit satisfaire aux exigences de l'Article 11 lorsqu'elle est utilisée sur un réseau qui satisfait à ces règles.

**Règle 1:** Un bus de terrain doit être capable d'assurer la communication entre deux et $N_{max}$ appareils, qui fonctionnent tous au même débit binaire.

NOTE 1 Cette règle n'exclut pas l'utilisation d'un nombre d'appareils supérieur à Nmax dans un système installé.

**Règle 2:** Un segment de bus de terrain à pleine charge (qui comporte le nombre maximal d'appareils connectés) doit avoir une longueur totale de câble, y compris les dérivations, entre deux appareils quelconques, jusqu'à $L_{max}$.

NOTE 3 La prise en charge de cette longueur maximale de câble est une exigence de conformité MAQU à l'Article 11, mais n'exclut pas l'utilisation de longueurs supérieures dans un système installé.

**Règle 3:** Le nombre total de régénérations de forme d'onde par des répéteurs et des coupleurs actifs entre deux appareils quelconques dépend de la mise en œuvre du répéteur concerné.

NOTE 3 Ce nombre total était limité à quatre dans les éditions précédentes du présent document.

**Règle 4:** Le délai maximal de propagation entre deux appareils quelconques ne doit pas dépasser 40 $T_{bit}$. Pour que le réseau fonctionne efficacement, il convient que cette partie du temps de retournement de tout appareil du réseau, générée par une PhE entre la fin d'une trame reçue et le début d'une trame émise qui contient une réponse immédiate associée, ne dépasse pas 30 temps binaires, dont il convient que 2 temps binaires au plus soient dus à la MAU.

NOTE 4 Sachant qu'il n'est pas obligatoire d'exposer l'interface DLL – PhL ou l'interface MDS – MAU, cette partie du temps de retournement d'un appareil de bus de terrain due à la PhL ou à la MAU n'est pas spécifiée et donc non disponible pour des essais de conformité.

**Règle 5:** Le bus de terrain doit pouvoir fonctionner en continu lorsqu'un appareil y est connecté ou déconnecté. Les erreurs de données générées lors de la connexion ou de la déconnexion doivent être détectées.

**Règle 6:** Pour un bus de terrain qui n'est pas alimenté par l'intermédiaire de conducteurs de signaux, la défaillance unique de tout élément de communication (y compris un court circuit mais à l'exception des bavardages) ne doit pas interférer avec les transactions entre d'autres éléments de communication pendant plus de 1 ms.

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**Règle 7:** Dans des systèmes polarisés, les paires de conducteurs du support doivent être distinctement repérées afin d'identifier de manière unique chaque conducteur individuel. Une polarisation homogène doit être maintenue en tout point de raccordement.

**Règle 8:** La dégradation des caractéristiques électriques du signal, entre deux appareils quelconques, due à l'affaiblissement, à la distorsion d'affaiblissement et à la distorsion de désadaptation doit être limitée aux valeurs indiquées ci-dessous.

a) Affaiblissement du signal: La configuration du bus (la longueur de ligne principale, le nombre d'appareils et les éventuels appareils d'adaptation) doit être telle que l'affaiblissement entre deux appareils quelconques, à une fréquence $f_r$, ne doit pas dépasser $A_{max}$;

b) Distorsion d'affaiblissement: La configuration du bus (les longueurs de la ligne principale et des lignes secondaires ainsi que le nombre d'appareils) doit être telle qu'entre deux appareils quelconques:

c) Distorsion de désadaptation: La désadaptation (due à un effet quelconque) sur le bus, en tout point sur la ligne principale et dans la bande de fréquence $f_{min}$ à $f_{max}$, doit être:

$$0 \leq [\text{Affaiblissement } (f_{max}) - \text{Affaiblissement } (f_{min})] \leq AD_{max}$$

L'affaiblissement doit être monotonique, non décroissant, pour toutes les fréquences de $f_{min}$ à $f_{max}$;

$$|Z - Zf_r| / |Z + Zf_r| \leq MD_{max}$$

où $Zf_r$ est l'impédance caractéristique du câble de ligne principale à la fréquence $f_r$ et Z est la combinaison parallèle de $Zf_r$ et de l'impédance de charge au niveau du coupleur.

NOTE 5 Cette règle permet de réduire le plus possible les restrictions, en matière de longueurs de la ligne principale et des lignes secondaires, ainsi qu'en matière de nombre d'appareils, etc. en ne spécifiant que les limites de transmission imposées par des combinaisons de ces facteurs. Il est possible d'utiliser différentes combinaisons en fonction des besoins de l'application.

NOTE 6 En général, la cause d'une désadaptation importante est la concentration de plusieurs coupleurs sur une courte longueur de ligne principale.

Si la distance entre deux coupleurs consécutifs est inférieure à CSmax, alors le délai de propagation entre ces deux coupleurs est inférieur à *T*rf et la concentration apparaît comme un seul élément désadapté, qui induit des réflexions importantes des transitions de signaux.

Une concentration de coupleurs dont la distance entre deux coupleurs consécutifs est inférieure à $_{CS}$max est définie comme une grappe. Afin de satisfaire à la Règle 8c lorsque des appareils avec une impédance d'entrée de valeur minimale $Din_{min}$ et des lignes secondaires de longueur zéro sont utilisés, il est recommandé qu'une grappe ne comprenne pas plus de 4 coupleurs.

L'utilisation d'appareils avec une impédance d'entrée notablement plus élevée que la valeur minimale $Din_{min}$ permet d'utiliser des grappes constituées d'un plus grand nombre de coupleurs. L'utilisation de lignes secondaires de longueur non égale à zéro peut exiger que les grappes soient constituées de moins de 4 coupleurs.

NOTE 4 Il est possible de réduire la désadaptation due à une grappe de la manière suivante:

– au moyen de coupleurs multivoies actifs,

– par insertion d'appareils d'adaptation (atténuateurs passifs) de chaque côté de la grappe tout en satisfaisant à la Règle 8.

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**Règle 9:** Les règles suivantes doivent s'appliquer aux systèmes mis en œuvre avec des supports redondants:

a) chaque canal (câble) doit satisfaire aux règles de configuration du réseau;

b) il ne doit pas y avoir de segment non redondant entre deux segments redondants;

c) les répéteurs doivent également être redondants;

d) si les appareils du système sont configurés (par la Gestion systèmes) pour émettre sur plusieurs canaux simultanément, alors la différence de délai de propagation entre deux appareils quelconques sur deux canaux quelconques ne doit pas dépasser cinq temps binaires;

   Cette période peut être étendue, mais non réduite, par la Gestion systèmes, comme cela est indiqué dans le Tableau 13 (voir 6.2.2.2 et 9.2.9).

e) les numéros de canaux et leur association aux supports de transmission physiques doivent être maintenus de manière cohérente sur l'ensemble des bus de terrain, c'est-à-dire que les canaux 1, 2, 3… en provenance de la gestion systèmes doivent toujours être connectés aux canaux physiques 1, 2, 3…;

### 11.3.4 Règles de distribution de l'alimentation pour la configuration du réseau

Le blindage du câble ne doit pas être utilisé comme conducteur de l'alimentation.

## 11.4 Spécification du circuit de transmission de la MAU

### 11.4.1 Récapitulatif

Le Tableau 90, le Tableau 91 et le Tableau 92 résument les exigences applicables à la MAU.

**Tableau 90 – Récapitulatif de la spécification du niveau de transmission de la MAU**

| Caractéristiques du niveau de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 79) | Limites |
|---|---|
| Niveau de sortie (crête à crête, voir la Figure 80)<br>Avec charge d'essai (0,5 de $Z_o$ nominale du câble de ligne principale à la fréquence fr) | 5,5 V à 9,0 V<br>75 Ω ± 1 % |
| Différence d'amplitude positive et négative maximale (biais de la signalisation) telle qu'elle est représentée à la Figure 81 | ± 0,45 V |
| Niveau de sortie, un terminateur retiré (crête à crête)<br>avec charge d'essai (impédance nominale du câble de ligne principale à la fréquence fr) | 5,5 V à 11,0 V<br>150 Ω ± 1 % |
| Niveau maximal de sortie; circuit ouvert (crête à crête) | 5,5 V à 30,0 V |
| Distorsion maximale du signal de sortie; c'est-à-dire surtension, suroscillation et statisme (voir la Figure 80) | ±10 % |
| Sortie d'émetteur passif, c'est-à-dire bruit de l'émetteur (mesuré sur la bande de fréquence de 1 kHz à $f_{QTO^{max}}$) | ≤ QTOmax (eff.) |

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**Tableau 91 – Récapitulatif de la spécification de temporisation de transmission de la MAU pour un fonctionnement à 31,25 kbit/s**

| Caractéristiques de temporisation de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 79) | Limites |
|---|---|
| Débit binaire de transmission | BR ± ΔBR |
| Temps binaire instantané | Tbit ± ΔTbit |
| Temps de croissance et de décroissance (10 % à 90 % du signal crête à crête, voir la Figure 80) | ≤ 25 % Tbit |
| Taux de dérive (en tout point de 10 % à 90 % du signal crête à crête) | ≤ 0,2 V/µs |
| Instabilité maximale de bit élémentaire émis (écart du point de passage par zéro, voir la Figure 81) | ± 2,5 % Tbit |
| Délai d'activation/désactivation de transmission (c'est-à-dire durée pendant laquelle la forme d'onde de sortie peut ou non satisfaire aux exigences de transmission) | ≤ 2,0 Tbit |

**Tableau 92 – Récapitulatif de la spécification de temporisation de transmission de la MAU pour un fonctionnement ≥ 1 Mbit/s**

| Caractéristiques de temporisation de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 79) | Limites |
|---|---|
| Débit binaire de transmission | BR ± ΔBR |
| Temps binaire instantané | Tbit ± ΔTbit |
| Temps de croissance et de décroissance (10 % à 90 % du signal crête à crête, voir la Figure 80) | ≤ 20 % Tbit |
| Taux de dérive (en tout point de 10 % à 90 % du signal crête à crête) | ≤ 100 V/µs × (fr/MHz) |
| Instabilité maximale de bit élémentaire émis (écart du point de passage par zéro, voir la Figure 81) | ± 2,5 % Tbit |
| Délai d'activation/désactivation de transmission (c'est-à-dire durée pendant laquelle la forme d'onde de sortie peut ou non satisfaire aux exigences de transmission) | ≤ 2,0 Tbit |

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### 11.4.2 Configuration d'essai de la MAU

La Figure 79 représente la configuration qui doit être utilisée pour les essais de MAU, comme suit.

- Tension de signal en mode différentiel: $V_d = V_a - V_b$.
- Résistance de la charge d'essai R = 75 Ω (0,5 impédance nominale du câble de ligne principale à $f_r$) et C = 0,15 µF, sauf spécification contraire dans une exigence particulière.
- Borne "+" des données raccordée à la borne "+" de l'alimentation et borne "-" des données raccordée à la borne "-" de l'alimentation.

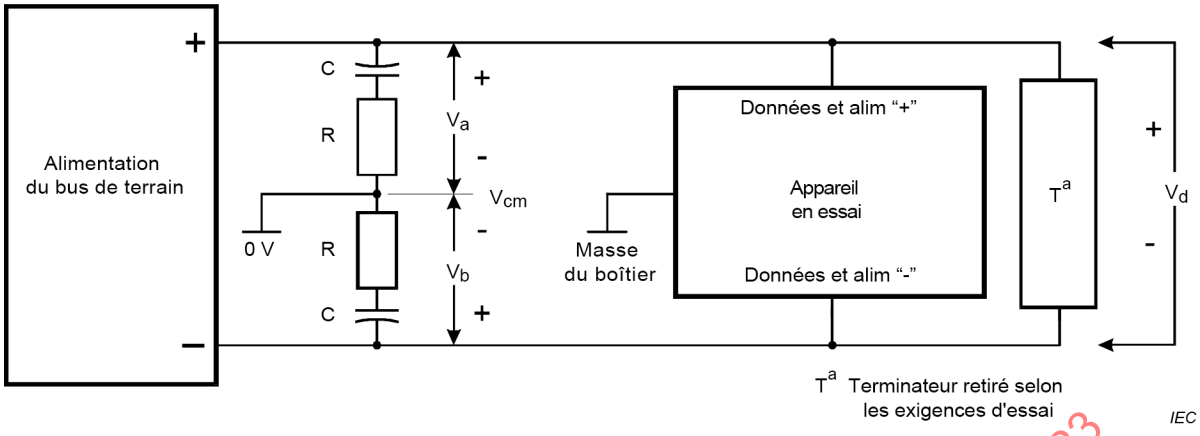


**Figure 79 – Configuration d'essai du circuit de transmission**

### 11.4.3 Exigences de niveau de sortie de la MAU

La Figure 80 décrit la forme de sortie du signal compte tenu des exigences de niveau de sortie en tension de la paire torsadée.

NOTE La Figure 80 présente un exemple de la composante alternative d'un cycle de forme d'onde de bus de terrain, qui représente certains éléments-clés de la spécification du circuit de transmission. Seules les tensions des signaux sont indiquées; ce schéma ne tient aucunement compte des tensions d'alimentation.

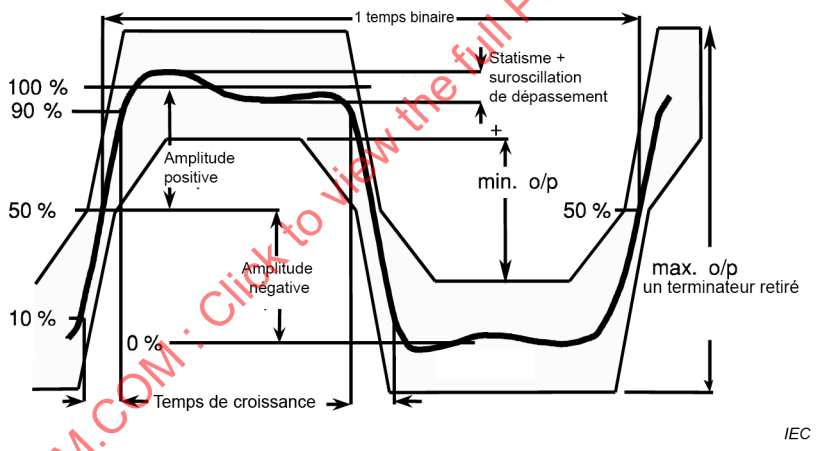


**Figure 80 – Forme d'onde de sortie**

Le circuit de transmission de la MAU doit être conforme aux exigences de niveau de sortie suivantes, toutes les amplitudes étant mesurées au point médian estimé entre toute crête ou creux en haut et en bas de la forme d'onde ("point médian" à la Figure 80):

a) la tension de sortie sur la charge d'essai après élévation/abaissement par le transformateur (le cas échéant), doit être comprise entre 5,5 V et 9,0 V crête à crête avec une résistance de charge de 75 Ω avec une tolérance de ± 1 % ("min. o/p" à la Figure 80);

b) la tension de sortie au niveau de la ligne principale ou aux bornes de transmission, avec une résistance de charge de 150 Ω avec une tolérance de ± 1 % (c'est-à-dire l'un des terminateurs de la ligne principale étant retiré) doit être comprise entre 5,5 V et 11,0 V crête à crête ("max. o/p un terminateur retiré" à la Figure 80);

c) la tension de sortie au niveau de la ligne principale ou aux bornes de transmission, avec toute charge comprenant un circuit ouvert, doit être comprise entre 5,5 V et 30,0 V crête à crête. A des fins d'essai, un circuit ouvert doit être défini comme une charge qui présente une résistance de 100 k Ω en parallèle avec une capacité de 15 pF;

d) au cours d'une émission, un appareil ne doit pas subir de défaillance permanente lorsqu'une résistance de charge de ≤1 Ω est appliquée pendant 1 s;

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e) la différence entre amplitude positive et amplitude négative, mesurée comme cela est représenté à la Figure 80, ne doit pas dépasser ± 0,45 V crête;

f) le bruit en sortie d'une MAU en réception ou non alimentée ne doit pas dépasser $QTO_{max}$ eff., mesuré de manière différentielle sur la bande de fréquence de 1 kHz à $f_{QTOmax}$, en référence à la ligne principale;

g) la tension différentielle sur la charge d'essai doit donner une modification monotonique de la tension, entre 10 % et 90 % de la valeur crête à crête. Par la suite, la tension du signal ne doit pas varier de plus de ±10 % de la valeur crête à crête jusqu'à ce que la transition suivante ait lieu. Cette variation admise doit inclure toutes les formes de distorsion de signal de sortie, c'est-à-dire la surtension, la suroscillation et le statisme.

### 11.4.4 Exigences de temporisation des sorties de la MAU

#### 11.4.4.1 Exigences communes de temporisation des sorties pour tous les débits de données

Le circuit de transmission d'une MAU doit satisfaire aux exigences suivantes de temporisation des sorties:

a) l'instabilité de bit élémentaire transmis ne doit pas dépasser $\Delta T_{bit}$ par rapport au point de passage par zéro théorique, mesuré en fonction du point de passage par zéro précédent (voir la Figure 81);

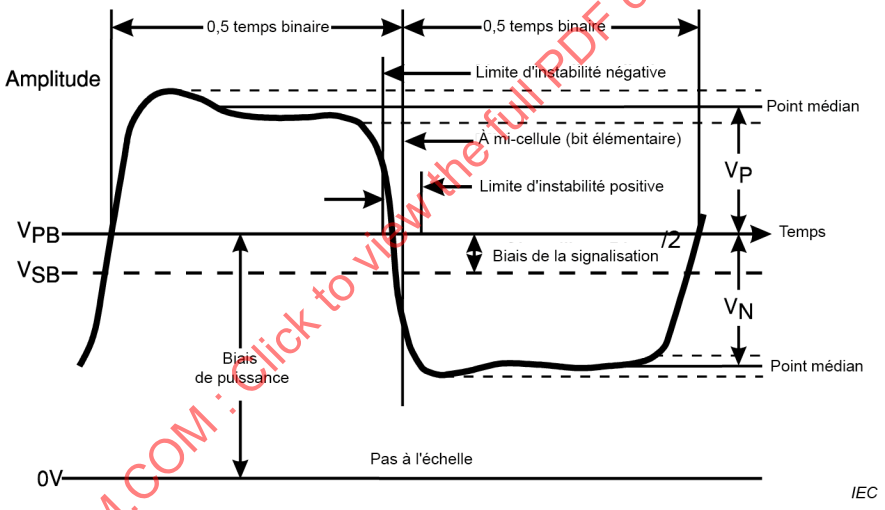


**Figure 81 – Instabilité de bit élémentaire transmis et reçu (écart du point de passage par zéro)**

b) le circuit de transmission doit s'activer, ce qui signifie que le signal doit monter d'un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 11.4.3 f), jusqu'au niveau de pleine puissance, en moins de 2,0 $T_{bit}$. La forme d'onde correspondant au troisième temps binaire et au-delà, doit être telle qu'elle est représentée à la Figure 80;

c) le circuit de transmission doit se désactiver, ce qui signifie que le signal doit tomber depuis le niveau de pleine puissance jusqu'à un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 11.4.3 f), en moins de 2,0 $T_{bit}$. La durée nécessaire pour que le circuit de transmission revienne à son impédance d'état "non actif" ne doit pas dépasser 4,0 $T_{bit}$. A des fins d'essai, cette exigence doit être satisfaite dans la configuration d'essai du circuit de transmission de la Figure 79, avec la capacité équivalente d'une longueur de câble maximale entre les bornes de l'appareil en essai.

NOTE Cette exigence permet d'assurer que la capacité de la ligne a été pleinement déchargée lors de la transition du circuit de transmission de l'état actif à l'état passif.

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#### 11.4.4.2 Exigences supplémentaires de temporisation des sorties pour un fonctionnement à 31,25 kbit/s

Le circuit de transmission de la MAU doit satisfaire aux exigences supplémentaires suivantes de temporisation des sorties:

a) les temps de croissance et de décroissance, mesurés de 10 % à 90 % de l'amplitude du signal crête à crête, ne doivent pas dépasser 0,25 $T_{bit}$ (voir la Figure 80);

b) le taux de dérive, mesuré en tout point dans une plage de 10 % à 90 % de l'amplitude du signal crête à crête, ne doit pas dépasser 0,2 V/ µs (voir la Figure 80).

NOTE Les exigences a) et b) génèrent une forme d'onde trapézoïdale à la sortie du circuit de transmission. L'exigence b) limite le niveau des émissions de perturbation qui peuvent être couplées aux circuits adjacents, etc. L'exigence b) est calculée à partir de la formule suivante:

$$\text{taux de dérive max.} = 2 \text{ x taux de dérive min} = 2 \times 0{,}8\ V_o / 0{,}25\ \text{Tbit} = 6{,}4 \times V_o / \text{Tbit},$$

où $V_o$ est la tension de sortie maximale crête à crête (9,0 V) avec une charge normalisée.

#### 11.4.4.3 Exigences supplémentaires de temporisation des sorties pour un fonctionnement à ≥ 1 Mbit/s

Le circuit de transmission de la MAU doit satisfaire aux exigences supplémentaires suivantes de temporisation des sorties:

a) les temps de croissance et de décroissance, mesurés de 10 % à 90 % de l'amplitude du signal crête à crête, ne doivent pas dépasser 0,2 $T_{bit}$ (voir la Figure 80);

b) le taux de dérive, mesuré en tout point dans une plage de 10 % à 90 % de l'amplitude du signal crête à crête, ne doit pas dépasser 100 V/ µs × ($f_{r/MHz}$) (voir la Figure 80).

NOTE Les exigences a) et b) génèrent une forme d'onde trapézoïdale à la sortie du circuit de transmission. L'exigence b) limite le niveau des émissions de perturbation qui peuvent être couplées aux circuits adjacents, etc. L'exigence b) est calculée à partir de la formule suivante:

$$\text{taux de dérive max.} = 36 \text{ x taux de dérive min} = 3 \times 0{,}8\ V_o / 0{,}2\ \text{Tbit} = 12 \times V_o / \text{Tbit},$$

où $V_o$ est la tension de sortie maximale crête à crête (9,0 V) avec une charge normalisée.

### 11.4.5 Polarité du signal

Pour un appareil alimenté par le bus, la borne "+" des données doit être connectée à la borne "+" de l'alimentation et la borne "–" des données doit être connectée à la borne "–" de l'alimentation. Voir la Figure 79.

Lorsque la transmission est activée, une transition du haut vers le bas du signal codé Manchester doit entraîner une transition du haut vers le bas de la tension $V_d$ sur le bus. Une transition du bas vers le haut du signal codé Manchester doit entraîner une transition du bas vers le haut de la tension $V_d$ sur le bus. La polarité du signal est définie à la Figure 82.

Pendant la réception, une transition du haut vers le bas de la tension $V_d$ sur le bus, doit entraîner une transition du haut vers le bas du signal codé Manchester. Une transition du bas vers le haut de la tension $V_d$ sur le bus doit entraîner une transition du bas vers le haut du signal codé Manchester.

NOTE 1 Le codage Manchester est défini au 9.2.2.

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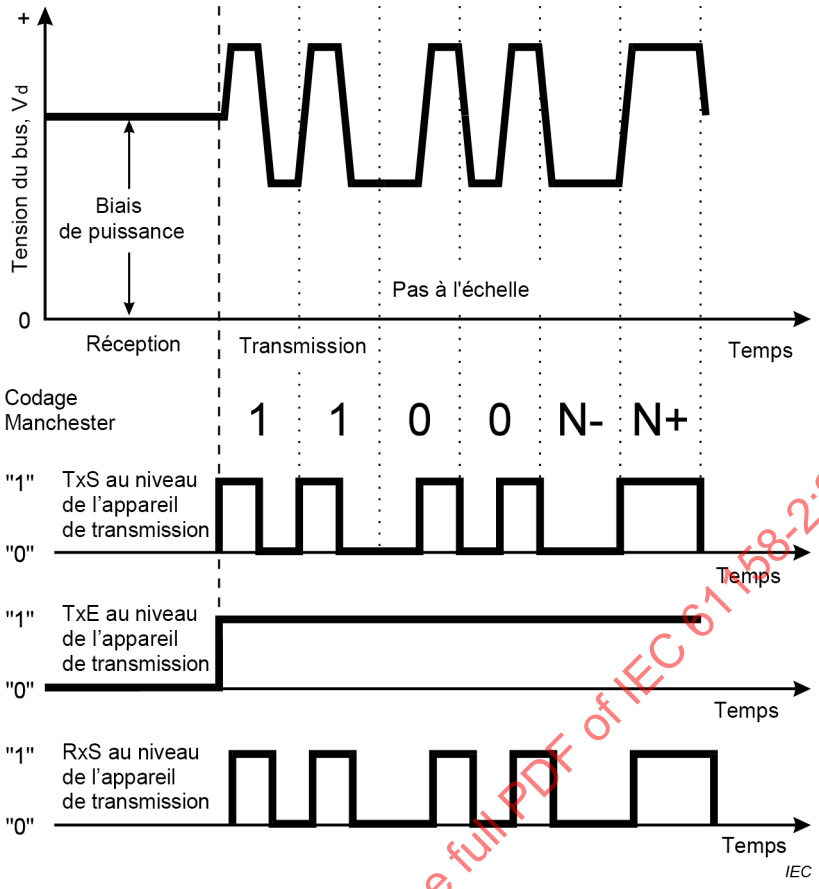


**Figure 82 – Polarité du signal**

NOTE 2 La forme d'onde de la Figure 82 donne un exemple des symboles "1", "0", "N+" et "N-". Cette forme d'onde ne représente pas une PhPDU réelle. Voir 9.2.2 pour les règles de codage.

NOTE 3 Les formes d'onde TxS et RxS de la Figure 82 sont indéterminées au cours de la période marquée "réception".

NOTE 4 Les signaux à l'interface MDS-MAU sont définis à l'Article 10. Les signaux TxS, TxE et RxS de la Figure 82 sont uniquement accessibles si l'interface MDS-MAU est exposée.

## 11.5 Spécification du circuit de réception de la MAU

### 11.5.1 Récapitulatif

Le Tableau 93 résume la spécification.

**Tableau 93 – Récapitulatif de la spécification du circuit de réception de la MAU**

| Caractéristiques du circuit de réception (valeurs en référence à la ligne principale) | Limites |
|---|---|
| Impédance d'entrée, mesurée sur la plage de fréquences $f_{min}$ à $f_{max}$ | ≥8 kΩ |
| Sensibilité; signal minimal crête à crête dont l'acceptation est exigée (voir la Figure 83) | 700 mV |
| Suppression du bruit; bruit maximal crête à crête dont le rejet est exigé (voir la Figure 83) | 280 mV |
| Instabilité maximale de bit élémentaire reçu (écart du point de passage par zéro (voir la Figure 81) | ±0,10 Tbit |

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### 11.5.2 Impédance d'entrée

L'impédance d'entrée différentielle du circuit de réception d'une MAU ne doit pas être inférieure à Din $_{min}$ sur la plage de fréquences $f_{min}$ à $f_{max}$. Cette exigence doit être satisfaite à l'état hors tension et sous tension (sans émission), ainsi que pendant la transition entre ces états. Cette impédance doit être mesurée aux bornes de l'élément de communication à l'aide d'une onde sinusoïdale d'une amplitude de signal supérieure au seuil de sensibilité du récepteur et inférieure à 9,0 V crête à crête.

NOTE L'exigence d'une impédance d'entrée ≥$Din_{min}$ pendant la mise sous tension et hors tension peut être satisfaite par désactivation automatique de l'émetteur au cours de ces périodes.

### 11.5.3 Sensibilité du récepteur et suppression du bruit

Un circuit de réception de MAU doit être capable d'accepter un signal d'entrée d'une amplitude d'au moins 700 mV crête à crête, y compris la surtension et l'oscillation (voir "niveau du signal" ainsi que "amplitude positive" et "amplitude négative" à la Figure 83).

Le circuit de réception de MAU ne doit pas répondre à un signal d'entrée d'amplitude crête à crête non supérieur à 280 mV (voir "suppression du bruit" à la Figure 83).

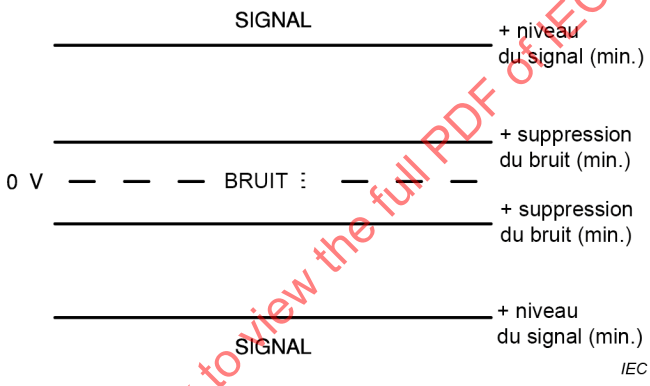


**Figure 83 – Sensibilité du récepteur et suppression du bruit**

### 11.5.4 Instabilité de bit élémentaire reçu

Le circuit de réception doit accepter un signal codé Manchester transmis conformément au 11.2 et au 11.4. En outre, le récepteur doit fonctionner correctement à des signaux avec une variation temporelle, entre deux points adjacents quelconques de transition des signaux (passage par zéro) de 0,10 $T_{bit}$t, au plus. Voir la Figure 81.

NOTE 1 Cette spécification n'exclut pas l'utilisation de récepteurs dont les performances sont supérieures à la présente spécification.

NOTE 2 En fonction de la configuration du symbole, la durée nominale entre passages par zéro peut être de 0,5 Tbit ou 1,0 Tbit.

NOTE 2 Il n'y a aucune exigence quant au rejet d'un signal donné avec une valeur de variation temporelle spécifiée. Le récepteur rend compte d'une erreur lorsque l'instabilité de bit élémentaire reçu dépasse l'aptitude du récepteur à décoder la signalisation de manière fiable.

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### 11.5.5 Susceptibilité au brouillage et taux d'erreurs

Lorsqu'un bus de terrain fonctionne dans différents environnements de bruit normalisés, il convient que la probabilité qu'une unité de données utilisateur de couche Application contienne une erreur non détectée, du fait du fonctionnement des entités physiques et DLL d'acheminement, soit inférieure à 1 sur $10^{12}$ (1 erreur en 20 années à 1 600 messages/s).

Un élément de communication est réputé conforme à cette exigence théorique lorsqu'il satisfait aux exigences suivantes de susceptibilité au brouillage. Ces exigences sont spécifiées sur la base d'un taux d'erreur de trame détecté obtenu au moyen d'un rapport d'erreurs détectées/non détectées de $10^6$.

NOTE 1 Cela est réalisable au moyen d'une séquence de contrôle de trame de 16 bits au niveau de la DLL.

Un élément de communication qui inclut une MAU, utilisant des trames qui contiennent 64 bits de données utilisateur aléatoires, à un débit de trame maximal et avec des signaux d'une amplitude de 1,4 V crête à crête, ne doit pas produire plus de trois erreurs de trame détectées sur 3 x $10^6$ trames pendant son fonctionnement en présence d'une tension en mode commun ou de bruit gaussien comme suit:

a) un signal sinusoïdal en mode commun à toute fréquence de 63 Hz à 2 $f_r$, d'une amplitude de 4 V eff. et de 47 Hz à 63 Hz avec une amplitude de 250 V eff.;

b) un signal DC en mode commun de ±10 V;

c) un bruit blanc gaussien différentiel additionnel dans la bande de fréquence de 1 kHz à 4 $f_r$, avec une densité de bruit de 30 µV/√Hz eff.

NOTE 3 Les valeurs spécifiées pour la tension en mode commun et le bruit gaussien correspondent à des essais de conformité de circuit de réception avec des charges symétriques et ne sont pas représentatives d'une pratique d'installation de système.

Un élément de communication qui inclut une MAU, utilisant des trames qui contiennent 64 bits de données utilisateur aléatoires, à une moyenne de 1 600 messages/s, avec des signaux d'une amplitude de 1,4 V crête à crête, ne doit pas produire plus de six erreurs de trame détectées sur 100 000 trames, lorsqu'il est utilisé dans des environnements de perturbations électromagnétiques ou électriques comme suit:

1) champ électromagnétique de 10 V/m, comme cela est spécifié dans l'IEC 61000-4-3 au niveau de sévérité 3;

2) transitoires électriques rapides, comme cela est spécifié dans l'IEC 61000-4-4 au niveau de sévérité 3.

Le taux d'erreur spécifié ci-dessus doit également être satisfait après, mais non pendant le fonctionnement dans les environnements de bruit suivants:

i) décharge électrostatique de 8 kV sur une structure métallique exposée, comme cela est spécifié dans l'IEC 61000-4-2, au niveau de sévérité 3. Si l'appareil subit une perte temporaire de fonctions ou de performances par suite de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai;

ii) essais de perturbation à haute fréquence, comme cela est spécifié dans l'IEC 60255-22-1:1988, classe III de tension d'essai (2,5 kV et 1 kV de valeurs crêtes de la première demi-alternance, respectivement en mode longitudinal et transversal). Si l'appareil subit une perte temporaire de fonctions ou de performances du fait de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai.

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### 11.6 Inhibition du bavardage

La MAU doit comporter une capacité d'interruption automatique pour empêcher les signaux émis d'atteindre le support. Le matériel dans la MAU (sans message extérieur autre que la détection des signaux de sortie ou de fuite par la fonction de transmission) doit fournir une fenêtre d'une durée comprise entre 5 000 $T_{bit}$ et 15 000 $T_{bit}$ au cours de laquelle une trame normale peut être émise. Si la longueur de trame dépasse cette durée, la fonction d'inhibition du bavardage doit empêcher d'autres signaux en sortie d'atteindre le support et doit désactiver l'écho sur la ligne RxS (voir 10.2.2.2) pour indiquer à la MDS la détection de bavardage.

Pour un débit binaire de 31,25 kbit/s, la MAU doit réinitialiser la fonction d'interruption automatique après une période de 3 s avec une tolérance de ± 50 %.

NOTE 1 Cette disposition inhibe le trafic sur le bus pendant 8 % (≈ 1/12,5) du temps disponible au plus.

Pour un débit binaire de 1 Mbit/s ou plus, la MAU doit réinitialiser la fonction d'interruption automatique après une période de 500 000 $T_{bit}$ avec une tolérance de ± 50 %.

NOTE 2 Cette disposition inhibe le trafic sur le bus pendant 3 % (≈ 1/32) du temps disponible au plus.

### 11.7 Distribution de l'alimentation

#### 11.7.1 Vue d'ensemble

Les MAU en mode tension qui fonctionnent à un débit binaire de ≤ 2,5 Mbit/s peuvent, au choix, recevoir leur alimentation par l'intermédiaire de conducteurs de signaux ou être alimentées séparément. Les MAU en mode tension qui fonctionnent à un débit binaire de > 2,5 Mbit/s sont alimentées séparément. Un appareil à alimentation séparée peut être connecté à un bus de terrain alimenté.

Pour faciliter le renvoi aux textes correspondants, les exigences du 11.7 pour les appareils alimentés par le réseau et les alimentations du réseau sont résumées dans le Tableau 94 et dans le Tableau 95, respectivement.

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**Tableau 94 – Caractéristiques des appareils alimentés par le réseau**

| Caractéristiques des appareils alimentés par le réseau | Limites | | |
|---|---|---|---|
| | 31,25 kbit/s | 1 Mbit/s | > 1 Mbit/s |
| Taux de variation maximal du courant passif (pas de transmission) | 1 mA/µs | 0,05 mA/µs | 0,1 mA/µs |
| Tension de service | 9,0 V à 32,0 V d.c. | | |
| Tension de tenue minimale, quelle que soit la polarité, sans dommage | 35 V | | |

**Tableau 95 – Exigences d'alimentation réseau**

| Exigences d'alimentation réseau | Limites |
|---|---|
| Tension de sortie | ≤ 32 VDC |
| Ondulation de sortie et bruit | Voir Figure 84. |
| Impédance de sortie, mesurée sur la plage de fréquences fmin à fmax | ≥ Dinmin |

### 11.7.2 Tension d'alimentation

Un appareil de bus de terrain qui revendique la conformité à l'Article 11 doit pouvoir fonctionner dans une plage de tension de 9 V à 32 V DC entre les deux conducteurs, y compris l'ondulation. L'appareil doit résister à une tension minimale de ±35 V DC sans aucun dommage.

Un appareil de bus de terrain qui revendique la conformité à l'Article 11 doit satisfaire aux exigences de l'Article 11 lorsqu'il est alimenté par une source qui présente les spécifications suivantes:

a) la tension de sortie maximale de l'alimentation doit être de 32 V DC, y compris l'ondulation.

   Il convient que la tension de l'alimentation ajoutée à la tension de sortie de l'émetteur en circuit ouvert soit inférieure à la limite spécifiée par l'organisme de réglementation local pour la mise en œuvre particulière;

b) l'impédance de sortie de l'alimentation doit être ≥ 8 kΩ sur la plage de fréquences $f_{min}$ à $f_{max}$;

c) les exigences de claquage de l'isolation du circuit de signaux et du circuit de distribution de l'alimentation par rapport à la masse et par rapport à l'autre circuit doivent être conformes à l'IEC 61131-2.

   La tension d'essai équivalente doit être appliquée entre circuits isolés indépendants ou entre circuits isolés et parties conductrices accessibles. Pour des circuits de tension nominale ≤ 50 V DC ou efficace, les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 444 V eff., 635 V DC et 635 V crête. Pour des circuits de tension nominale comprise entre 150 V et 300 V eff., les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 2 260 V eff., 3 175 V DC et 3 175 V crête;

d) lorsqu'une source donnée alimente au moins deux segments, l'impédance de l'isolation de chaque segment doit être partagée à ±10 % entre les deux conducteurs de signaux du segment.

### 11.7.3 Alimentation par l'intermédiaire de conducteurs de signaux

Un appareil de bus de terrain qui revendique la conformité à l'Article 11 qui est alimenté par les conducteurs de signaux doit satisfaire aux exigences de l'Article 11 lorsqu'il fonctionne à des valeurs maximales d'ondulation et de bruit de l'alimentation, de la manière suivante:

a) 30 mV crête à crête sur la plage de fréquences $f_{min}$ à $f_{max}$;

b) 2 V crête à crête sur la plage de fréquences de 47 Hz à 63 Hz;

c) 300 mV crête à crête à des fréquences supérieures à 12,5 $f_r$, jusqu'à une fréquence maximale de 50 MHz;

d) des niveaux à des fréquences intermédiaires généralement conformes à la Figure 84, qui donnent le niveau et les fréquences pour une alimentation par des conducteurs de signaux.

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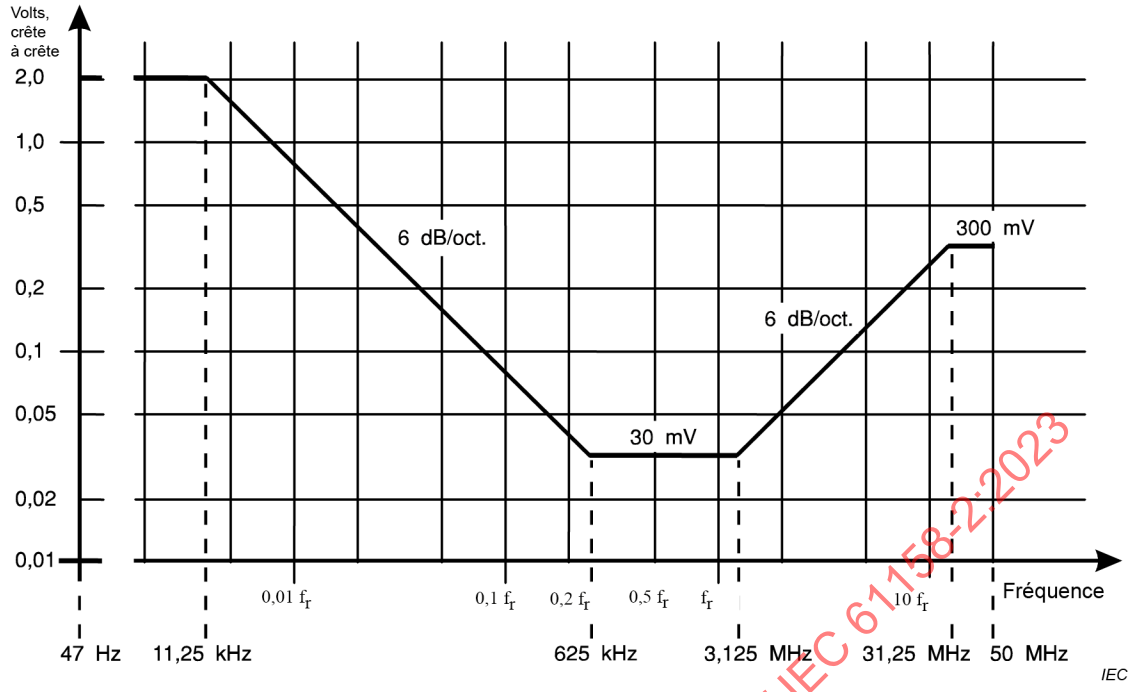


**Figure 84 – Ondulation et bruit de l'alimentation**

L'appareil doit avoir un taux de variation maximal du courant passif, à l'état de non émission, de 0,1 mA/ µs.

NOTE Cette exigence limite les effets des transitoires d'alimentation sur les signaux.

### 11.7.4 Alimentation séparée à partir des conducteurs de signaux

NOTE La distribution de l'alimentation pour des appareils de bus de terrain non alimentés par le bus s'effectue au moyen de conducteurs séparés qui fournissent l'énergie à des alimentations locales ou des régulateurs. Il est possible que ces conducteurs soient contenus dans un câble séparé ou dans le même câble que les conducteurs de signaux.

Un appareil de bus de terrain alimenté séparément, qui revendique la conformité à l'Article 11, ne doit pas prélever plus de 100 µA en courant continu sur les conducteurs de signaux et ne doit pas fournir plus de 100 µA en courant continu aux conducteurs de signaux, lorsqu'il n'y a pas de transmission.

### 11.7.5 Isolation électrique

Tous les appareils de bus de terrain, alimentés séparément ou par l'intermédiaire des conducteurs de signaux, doivent assurer une isolation basse fréquence entre la masse et le câble de ligne principale du bus de terrain.

NOTE 1 Cette isolation peut s'effectuer par isolation de l'ensemble de l'appareil de la masse ou au moyen d'un transformateur, d'un optocoupleur ou de tout autre organe d'isolation entre le câble de ligne principale et l'appareil.

Une alimentation et un élément de communication combinés ne doivent pas exiger d'isolation électrique.

Pour les installations électriques qui sont équipées de mises à la terre différentes, l'impédance d'isolation mesurée entre le blindage du câble de bus de terrain et la masse de l'appareil de bus de terrain doit être supérieure à 250 kΩ à toutes les fréquences inférieures à 63 Hz.

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L'isolation doit être contournée par une capacité à des fréquences élevées, de sorte que l'impédance mesurée entre le blindage du câble du bus de terrain et la masse de l'appareil de bus de terrain soit inférieure à 15 Ω entre 3 MHz et 100 MHz.

NOTE 2 La capacité entre la masse et le blindage du câble de ligne principale nécessaire pour satisfaire à ces exigences peut prendre toute valeur comprise entre 3,5 nF et 10,6 nF.

Pour des installations électriques qui sont équipées d'une masse commune, conformément à l'IEC 60364-4-41 et à l'IEC 60364-5-54, le blindage du câble de bus de terrain et la masse de l'appareil de bus de terrain peuvent être directement connectés.

La capacité dissymétrique maximale par rapport à la masse de toute borne d'entrée d'un appareil ne doit pas dépasser 250 pF.

Les exigences de claquage de l'isolation du circuit de signaux et du circuit de distribution de l'alimentation par rapport à la masse et par rapport à l'autre circuit doivent être conformes à l'IEC 61131-2.

NOTE 3 La tension d'essai équivalente est appliquée entre circuits isolés indépendants ou entre circuits isolés et parties conductrices accessibles. Pour des circuits alimentés à partir d'une source de tension assignée ≤ 50 V DC ou efficace, les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 444 V eff., 635 V DC et 635 V crête. Pour un appareil alimenté à partir d'une source de tension assignée comprise entre 150 V et 300 V eff., les tensions d'essai équivalentes au niveau de la mer correspondent à des tensions d'essais de choc de 2 260 V eff., 3 175 V DC et 3 175 V crête.

### 11.8 Spécifications du support

#### 11.8.1 Connecteur

Si des connecteurs de câbles sont utilisés, ils doivent être conformes au présent document (voir l'Annexe A). Des techniques de terminaison sur le terrain, comme les bornes à vis ou à lames, ainsi que les terminaisons permanentes (épissures), peuvent également être utilisées.

#### 11.8.2 Câble d'essai normalisé

Le câble utilisé pour les essais d'appareils de bus de terrain avec une MAU de 150 Ω en mode tension, destinés à vérifier la satisfaction aux exigences de l'Article 11, doit être un câble unique à paire torsadée, à blindage global, qui satisfait aux exigences minimales suivantes, à une température de 25 °C:

a) $Z_o$ = 150 Ω avec une tolérance de ± 10 % sur la plage comprise entre 0,25 $f_r$ et 1,25 $f_r$;

b) affaiblissement maximal à une fréquence de 0,25 $f_r$ à 1,25 $f_r$, comme cela est spécifié dans le Tableau 96;

c) déséquilibre capacitif maximal par rapport au blindage = 1,5 nF/km;

d) résistance maximale en courant continu (par conducteur) = 57,1 Ω/km;

e) section du conducteur (dimension des fils) = 0,33 $mm^2$, valeur nominale;

f) résistivité minimale entre chaque conducteur et le blindage = 16 GΩ km;

g) la couverture minimale du blindage doit être de 95 %.

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**Tableau 96 – Limites d'affaiblissement du câble d'essai**

| Débit binaire | Affaiblissement maximal à | |
|---|---|---|
| | $0,25\ f_r$ | $1,25\ f_r$ |
| 31,25 kbit/s | 1,5 dB | 3 dB |
| 1 Mbit/s | 6,5 dB | 13 dB |
| 2,5 Mbit/s | 10 B | 20 dB |
| 5 Mbit/s | 13 dB | 26 dB |
| 10 Mbit/s | 17 dB | 37 dB |
| 25 Mbit/s | 26 dB | 60 dB |

La spécification ci-dessus concerne les essais de conformité d'une MAU. D'autres types de câbles peuvent être utilisés dans les installations réelles (voir l'Annexe B.) Les câbles à spécifications améliorées peuvent permettre de plus grandes longueurs de lignes principales ou une meilleure immunité aux perturbations, ou encore il peut être exigé qu'ils satisfassent à des conditions d'environnement ou d'installation. En revanche, les câbles qui présentent des spécifications inférieures peuvent être utilisés, sous réserve d'une limitation des longueurs utilisées, tant pour les lignes principales que secondaires, à laquelle s'ajoute une éventuelle non-conformité aux exigences de susceptibilité aux perturbations radioélectriques (RFI) et électromagnétiques (EMI).

### 11.8.3 Coupleur

Le coupleur représenté à la Figure 85 doit fournir un ou plusieurs points de connexion à la ligne principale. Il est en général intégré à un appareil de bus de terrain.

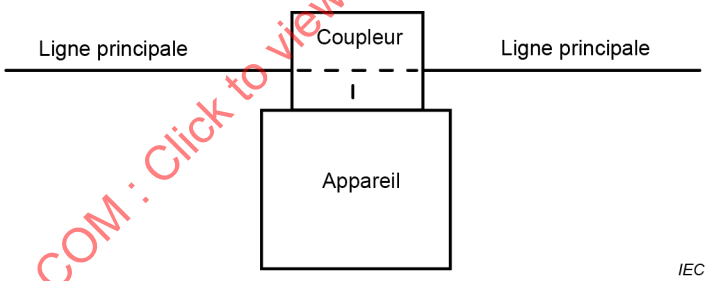


**Figure 85 – Coupleur de bus de terrain**

Un coupleur passif peut inclure un ou tous les éléments facultatifs décrits ci-dessous:

a) un transformateur qui assure l'isolation galvanique et la transformation de l'impédance entre la ligne principale et l'appareil;

b) des connecteurs qui facilitent le branchement à la ligne principale.

Les coupleurs actifs qui exigent une alimentation externe, comportent des composantes d'amplification et de réémission des signaux. Le niveau de transmission et les exigences de temporisation doivent être conformes au 11.4.

### 11.8.4 Épissures

NOTE Une épissure est toute partie du réseau dans laquelle l'impédance caractéristique du câble de réseau n'est pas maintenue. Cela peut être dû à la séparation des conducteurs du câble, au retrait de blindage du câble, à la modification de calibre ou de type de fil, à la fixation à des barrettes à bornes, etc. Une définition pratique d'une épissure est par conséquent toute partie du réseau qui n'est pas une longueur continue du support spécifié.

La continuité de tous les conducteurs du câble doit être maintenue dans une épissure.

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### 11.8.5 Terminateur

Un terminateur doit être placé aux deux extrémités du câble de ligne principale et connecté d'un conducteur de signal à l'autre. Il ne doit y avoir aucune connexion entre terminateur et blindage du câble.

A des fins d'essai, en utilisant le câble spécifié au 11.8.2, le terminateur doit avoir une valeur d'impédance de 150 Ω avec une tolérance de ± 2 % sur l'ensemble de la plage de fréquences comprise entre 625 kHz et 31,25 MHz.

NOTE Dans des applications pratiques, la valeur choisie est environ égale à la valeur de l'impédance caractéristique moyenne du câble aux fréquences pertinentes afin de réduire le plus possible les réflexions de la ligne de transmission.

Le courant continu de fuite à travers le terminateur ne doit pas dépasser 100 µA. Le terminateur doit être non polarisé.

### 11.8.6 Règles de blindage

Pour une entière satisfaction aux exigences d'immunité au bruit du 11.5.3, il est nécessaire d'assurer l'intégrité du blindage sur toute la longueur du câblage, dans les connecteurs et dans les coupleurs, de la manière suivante:

a) la couverture du blindage doit être supérieure à 95 % de la longueur totale du câble;

b) le blindage doit couvrir complètement les circuits électriques des connecteurs, des coupleurs et des épissures.

NOTE Toute dérogation à ces règles de blindage peut dégrader l'immunité au bruit.

### 11.8.7 Règles de mise à la masse (mise à la terre)

NOTE Mise à la masse (à la terre) signifie une connexion permanente à la terre par l'intermédiaire d'une impédance suffisamment basse et ayant un courant admissible suffisant pour prévenir un amorçage en tension qui peut entraîner un danger excessif pour le matériel connecté ou les personnes.

Les lignes de tension zéro (commun) peuvent être reliées à la masse où elles sont galvaniquement isolées de la ligne principale du bus de terrain.

Les appareils de bus de terrain doivent fonctionner conformément aux exigences de l'Article 11, le point médian d'un terminateur ou d'un coupleur inductif étant directement connecté à la masse.

Les appareils de bus de terrain ne doivent pas raccorder l'un des conducteurs de la paire torsadée à la masse, quel que soit le point du réseau. Les signaux doivent être appliqués et préservés de manière différentielle sur l'ensemble du réseau.

Il est habituel dans la pratique de mettre effectivement à la masse le blindage du câble de ligne principale de bus de terrain (le cas échéant) en un point sur la longueur du câble. De ce fait, il convient que les appareils de bus de terrain permettent une isolation en courant continu du blindage du câble par rapport à la masse.

La pratique courante est également de raccorder les conducteurs de signaux à la masse de manière symétrique, au même point, au moyen, par exemple, de la prise médiane d'un terminateur ou d'un transformateur de couplage.

Pour des systèmes alimentés par le bus, il convient que la mise à la masse du blindage et des conducteurs de signaux équilibrés soit proche de l'unité d'alimentation. Il est admis de prévoir un couplage capacitif entre le blindage ou les conducteurs de signaux équilibrés et la mise à la masse locale de l'appareil pour une meilleure immunité aux interférences électromagnétiques.

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### 11.8.8 Code de couleur des câbles

Il convient que le choix des couleurs de câble tienne compte des pratiques régionales.

En Amérique du Nord, il convient d'attribuer les couleurs des conducteurs intérieurs du câble et de la gaine extérieure (enveloppe) du câble, comme cela est spécifié dans le Tableau 97.

**Tableau 97 – Code de couleur recommandé pour les câbles en Amérique du Nord**

| **Couleur des conducteurs intérieurs** | |
|---|---|
| Conducteur intérieur "+" (tension positive) | Orange ou rouge/orange/marron, à l'extrémité du spectre |
| Conducteur intérieur "-" (tension négative) | Bleu ou bleu/violet, à l'extrémité du spectre |
| Conducteur du blindage (qui peut être relié à la terre) | Nu, incolore ou vert |
| **Couleur de la gaine extérieure (enveloppe)** | |
| Règles de construction d'usage général | Orange |
| Règles de construction non incendiaire | Bande orange/bleue |
| Règles de construction en sécurité intrinsèque (IS) | Bande bleue ou bleue/orange ou bande bleue/noire |

## 12 Type 1 et Type 3: Unité de liaison au support: 31,25 kbit/s, mode tension avec option basse puissance, topologie bus et arborescente, support câblé 100 Ω

### 12.1 Généralités

NOTE Le Type 3 utilise cette MAU uniquement pour la transmission synchrone.

La MAU 31,25 kbit/s en mode tension de 100 Ω fournit simultanément l'accès à un réseau de communication et à un réseau de distribution d'énergie facultatif. Les appareils raccordés au réseau communiquent par l'intermédiaire du support et peuvent ou non être alimentés par ce support. Si l'alimentation s'effectue par le bus, elle est distribuée en tension et en courant continus et des signaux de communication sont superposés sur l'alimentation en courant continu. Dans les applications de sécurité intrinsèque, la puissance disponible peut limiter le nombre d'appareils.

Le support du réseau est constitué d'un câble d'une seule paire, qui est en général mais pas toujours, une paire torsadée. Indépendamment de la topologie, tous les appareils connectés, sauf éventuellement l'appareil de transmission, présentent une impédance élevée pour éviter une surcharge importante du réseau. Les formes d'onde trapézoïdales sont utilisées pour réduire les émissions électromagnétiques.

Des topologies en bus et arborescentes sont prises en charge. Quelle que soit la topologie, un réseau comporte un câble de ligne principale qui comporte des terminaisons à ses extrémités. Dans la topologie de bus, les lignes secondaires sont réparties sur la longueur de la ligne principale. Dans la topologie arborescente, les lignes secondaires sont concentrées à une extrémité de la ligne principale. Une ligne secondaire peut connecter plusieurs appareils au réseau et le nombre maximal d'appareils sur une ligne secondaire donnée dépend de la longueur de cette ligne.

À fréquence industrielle (courant continu), les appareils apparaissent pour le réseau comme des absorbeurs de courant avec un taux de variation limité du courant d'alimentation prélevé du support. Cela permet d'éviter que les modifications transitoires du courant de charge n'interfèrent avec les signaux de communication.

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L'Article 12 spécifie une option à faible puissance qui permet de réduire le courant prélevé du réseau par les appareils lorsqu'ils ne sont pas en émission.

Pour réduire le plus possible les oscillations et les suroscillations sur le réseau, l'impédance de l'alimentation est spécifiée en fonction de l'impédance du terminateur de bus, de sorte que la réactance totale du réseau soit réduite le plus possible sur la plage de fréquences de 50 Hz à 39 kHz.

### 12.2 Débit binaire de transmission

Le débit binaire moyen, BR, doit être de 31,25 kbit/s avec une tolérance de ± 0,2 %, moyenné sur une trame d'une longueur minimale de 16 octets. Le temps binaire instantané, $T_{bit}$, doit être de 32 µs ± 0,9 µs.

### 12.3 Spécifications du réseau

#### 12.3.1 Composants

Une MAU fonctionne sur un réseau constitué des composants suivants:

a) un câble à conducteurs;
b) des appareils (qui comportent au moins un élément de communication);
c) des coupleurs;
d) des terminateurs.

Le réseau peut inclure les composants facultatifs suivants:

a) des connecteurs;
b) des alimentations;
c) des appareils qui comprennent les alimentations;
d) des barrières de sécurité intrinsèque.

#### 12.3.2 Topologies

Une MAU câblée doit fonctionner sur un réseau de topologie de bus linéaire ou arborescente nominalement acyclique constituée d'une ligne principale, terminée à chaque extrémité comme cela est spécifié au 12.8.5 et à laquelle des éléments de communication sont connectés par l'intermédiaire de coupleurs et de lignes secondaires. Une topologie arborescente dont tous les éléments de communication sont placés aux extrémités de la ligne principale est considérée comme un cas particulier de bus aux fins de l'Article 12. Chaque élément de communication doit être connecté en parallèle au câble de ligne principale.

Le coupleur et l'élément de communication peuvent être intégrés dans un seul appareil (c'est-à-dire une ligne secondaire de longueur zéro). Plusieurs éléments de communication peuvent être connectés à la ligne principale en un point donné, au moyen d'un coupleur multivoies. Un coupleur actif peut être utilisé pour étendre une ligne secondaire sur une longueur qui exige une terminaison afin d'éviter les réflexions et distorsions. Des répéteurs actifs peuvent être utilisés pour étendre la longueur de la ligne principale au-delà d'un segment unique si cela est admis par les règles de configuration du réseau. Les dérivations doivent être considérées comme des segments, et peuvent rendre le bus non linéaire. Les cycles (boucles fermées) ne sont jamais admis.

#### 12.3.3 Règles de configuration du réseau

Une MAU qui revendique la conformité à l'Article 12 doit satisfaire aux exigences de l'Article 12 lorsqu'elle est utilisée sur un réseau qui satisfait à ces règles.

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**Règle 1:** Un bus de terrain doit être capable d'assurer la communication entre les nombres d'appareils indiqués ci-après, qui fonctionnent tous au même débit binaire:

a) pour un bus de terrain non IS sans alimentation par les conducteurs de signaux: entre deux et 32 appareils;

b) pour un bus de terrain non IS avec alimentation par l'intermédiaire de conducteurs de signaux: entre deux et le nombre d'appareils qui peuvent être alimentés par l'intermédiaire des conducteurs de signaux, en prenant pour hypothèse qu'au moins 120 mA (au total) doivent être mis à la disposition des appareils à l'extrémité distante de l'alimentation et en sachant que la communication avec un appareil à l'extrémité de l'alimentation consomme 10 mA;

c) pour un bus de terrain IS: entre deux et le nombre d'appareils qui peuvent être alimentés par l'intermédiaire des conducteurs de signaux, en prenant pour hypothèse qu'au moins 40 mA (au total) doivent être mis à la disposition des appareils dans la zone dangereuse.

NOTE 1 Cette règle n'exclut pas l'utilisation d'un nombre d'appareils supérieur à celui spécifié dans un système installé. Étant donné que la consommation d'énergie de l'appareil n'est pas spécifiée, le nombre d'appareils alimentés par le bus ne peut pas être spécifié.

Le point b) prend pour hypothèse que la tension minimale d'alimentation est de 20 V DC.

Le point c) prend pour hypothèse que la barrière IS fonctionne avec une sortie de 19 V en courant continu.

**Règle 2:** Un segment de bus de terrain à pleine charge (qui comporte le nombre maximal d'appareils connectés) doit avoir une longueur totale de câble, y compris les lignes secondaires, entre deux appareils quelconques, jusqu'à 1 900 m.

NOTE 2 La prise en charge de cette longueur maximale de câble est une exigence de conformité à l'Article 12, mais n'exclut pas l'utilisation de longueurs supérieures dans un système installé.

**Règle 3:** Le nombre total de régénérations de forme d'onde par des répéteurs et des coupleurs actifs entre deux appareils quelconques dépend de la mise en œuvre du répéteur concerné.

NOTE 3 Ce nombre total était limité à quatre dans les éditions précédentes du présent document.

**Règle 4:** Le délai maximal de propagation entre deux appareils quelconques ne doit pas dépasser 20 $T_{bit}$.

Pour que le réseau fonctionne efficacement, il convient que cette partie du temps de retournement de tout appareil du réseau, générée par une PhE entre la fin d'une trame reçue et le début d'une trame émise qui contient une réponse immédiate associée, ne dépasse pas 30 temps binaires, dont il convient que 2 temps binaires au plus soient dus à la MAU.

NOTE 4 Sachant qu'il n'est pas obligatoire d'exposer l'interface DLL – PhL ou l'interface MDS – MAU, cette partie du temps de retournement d'un appareil de bus de terrain due à la PhL ou à la MAU n'est pas spécifiée et donc non disponible pour des essais de conformité.

**Règle 5:** Le bus de terrain doit pouvoir fonctionner en continu lorsqu'un appareil y est connecté ou déconnecté. Les erreurs de données générées lors de la connexion ou de la déconnexion doivent être détectées.

**Règle 6:** La défaillance d'un quelconque élément de communication ou d'une ligne secondaire (à l'exception d'un court-circuit, d'une faible impédance ou d'un bavardage) ne doit pas interférer avec des transactions entre d'autres éléments de communication pendant plus de 1 ms.

**Règle 7:** Dans des systèmes polarisés, les paires de conducteurs du support doivent être distinctement repérées afin d'identifier de manière unique chaque conducteur individuel. Une polarisation homogène doit être maintenue en tout point de raccordement.

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**Règle 8:** La dégradation des caractéristiques électriques du signal, entre deux appareils quelconques, due à l'affaiblissement, à la distorsion d'affaiblissement et à la distorsion de désadaptation doit être limitée aux valeurs indiquées ci-dessous.

a) Affaiblissement du signal: La configuration du bus (les longueurs de la ligne principale et des lignes secondaires, ainsi que le nombre d'appareils, les barrières IS, les sectionneurs galvaniques, et les éventuels appareils d'adaptation) doit être telle que l'affaiblissement entre deux appareils quelconques, à une fréquence $f_r$ (31,25 kHz), ne doit pas dépasser 10,5 dB.

b) Distorsion d'affaiblissement: La configuration du bus (longueurs de ligne principale et de lignes secondaires, nombre d'appareils, barrières IS et sectionneurs galvaniques) doit être telle qu'entre deux appareils quelconques:

   $0 \leq [\text{Affaiblissement } (1{,}25\ f_r) - \text{Affaiblissement } (0{,}25\ f_r)] \leq 6 \text{ dB}$

   L'affaiblissement doit être monotonique, non décroissant pour toutes les fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz).

c) Distorsion de désadaptation: La désadaptation (due à n'importe quel effet, y compris une ligne secondaire en circuit ouvert de longueur maximale) sur le bus doit être telle qu'en tout point sur la ligne principale dans la bande de fréquence comprise entre 0,25 $f_r$ et 1,25 $f_r$ (7,8 kHz à 39 kHz):

   $|Z - Zf_r| / |Z + Zf_r| \leq 0{,}2$

   où $Zf_r$ est l'impédance du câble de ligne principale à la fréquence $f_r$ (31,25 kHz) et Z est la combinaison parallèle de $Zf_r$ et de l'impédance de charge au niveau du coupleur.

La concentration des coupleurs doit être inférieure à 15 pour 250 m.

NOTE 3 Cette règle permet de réduire le plus possible les restrictions, en matière de longueurs de la ligne principale et des lignes secondaires ainsi qu'en matière de nombre d'appareils, etc. en ne spécifiant que les limites de transmission imposées par des combinaisons de ces facteurs. Il est possible d'utiliser différentes combinaisons en fonction des besoins de l'application.

**Règle 9:** Les règles suivantes doivent s'appliquer aux systèmes mis en œuvre avec des supports redondants:

a) chaque canal (câble) doit satisfaire aux règles de configuration du réseau;

b) il ne doit pas y avoir de segment non redondant entre deux segments redondants;

c) les répéteurs doivent également être redondants;

d) si les appareils du système sont configurés (par la Gestion systèmes) pour émettre sur plusieurs canaux simultanément, alors la différence de délai de propagation entre deux appareils quelconques sur deux canaux quelconques ne doit pas dépasser cinq temps binaires.

   Cette période peut être étendue, mais non réduite, par la Gestion systèmes, comme cela est indiqué dans le Tableau 13 (voir 6.2.2.2 et 9.2.9);

e) les numéros de canaux et leur association aux supports de transmission physiques doivent être maintenus de manière cohérente sur l'ensemble des bus de terrain, c'est-à-dire que les canaux 1, 2, 3… en provenance de la gestion systèmes doivent toujours être connectés aux canaux physiques 1, 2, 3…;

**Règle 10:** Pour un segment de bus de terrain alimenté par le bus, la tension mise à la disposition de tous les appareils, y compris l'ondulation et la composante continue de la chute de tension due à la signalisation, doit s'inscrire dans une plage de 9,0 V à 32,0 V en courant continu.

NOTE 6 La composante continue de la chute de tension due à la signalisation dépend de la configuration du réseau. La composante continue est due à une variation d'échelon du courant de l'appareil à travers la résistance du réseau (résistance du câble, résistance de la barrière IS, etc.).

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### 12.3.4 Règles de distribution de l'alimentation pour la configuration du réseau

Voir 11.3.4.

## 12.4 Spécification du circuit de transmission de la MAU

### 12.4.1 Récapitulatif

Pour faciliter le renvoi aux textes correspondants, les exigences définies au 12.2 et 12.4 sont résumées dans le Tableau 98 et le Tableau 99.

**Tableau 98 – Récapitulatif de la spécification du niveau de transmission de la MAU**

| Caractéristiques du niveau de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 79) | Limites |
|---|---|
| Niveau de sortie (crête à crête, voir la Figure 80)<br>Avec charge d'essai (0,5 de l'impédance nominale du câble de ligne principale à la fréquence fr (31,25 kHz)) | 0,75 V à 1 V<br>50 Ω ± 0,5 Ω |
| Différence d'amplitude positive et négative maximale (biais de la signalisation) telle qu'elle est représentée à la | ±50 mV |
| Niveau de sortie, un terminateur retiré (crête à crête)<br>avec charge d'essai (impédance nominale du câble de ligne principale à la fréquence fr (31,25 kHz)) | 0,75 V à 2,0 V<br>100 Ω ± 1 Ω |
| Niveau maximal de sortie; circuit ouvert (crête à crête) | 35 V |
| Distorsion maximale du signal de sortie; c'est-à-dire surtension suroscillation et statisme (voir la Figure 80) | ±10 % |
| Sortie d'émetteur passif, c'est-à-dire bruit de l'émetteur (mesuré sur la bande de fréquence de 1 kHz à 100 kHz) | ≤ 1 mV (RMS) |

**Tableau 99 – Récapitulatif de la spécification de temporisation de transmission de la MAU**

| Caractéristiques de temporisation de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 79) | Limites pour 31,25 kbit/s (alimenté par bus et/ou IS) |
|---|---|
| Débit binaire de transmission | 31,25 kbit/s ± 0,2 % |
| Temps binaire instantané | 32 µs ± 0,9 µs |
| Temps de croissance et de décroissance (10 % à 90 % du signal crête à crête, voir la Figure 80) | ≤ 25 % Tbit |
| Taux de dérive (en tout point de 10 % à 90 % du signal crête à crête) | ≤ 0,2 V/µs |
| Instabilité maximale de bit élémentaire émis (écart du point de passage par zéro, voir la Figure 81) | ± 2,5 % Tbit |
| Délai d'activation/désactivation de transmission (c'est-à-dire durée pendant laquelle il est admis que la forme d'onde de sortie ne satisfasse pas aux exigences de transmission) | ≤ 2,0 Tbit |

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### 12.4.2 Configuration d'essai de la MAU

La Figure 79 représente la configuration qui doit être utilisée pour les essais de MAU.

Tension de signal en mode différentiel: $V_d = V_a – V_b$.

Sauf spécification contraire dans une exigence particulière, la résistance de la charge d'essai R = 50 Ω (0,5 de l'impédance nominale du câble de ligne principale à une fréquence $f_r$ de 31,25 kHz) et C = 2 µF (2 x la capacité d'un terminateur).

Borne "+" des données raccordée à la borne "+" de l'alimentation et borne "-" des données raccordée à la borne "-" de l'alimentation.

NOTE Voir 12.7 concernant la spécification de l'alimentation et 12.8.5 concernant la spécification du terminateur.

### 12.4.3 Exigences de niveau de sortie de la MAU

La Figure 80 décrit la forme de sortie du signal compte tenu des exigences de niveau de sortie en tension de la paire torsadée.

NOTE 1 La Figure 80 représente un exemple de la composante alternative d'un cycle de forme d'onde de bus de terrain, qui représente certains éléments-clés de la spécification du circuit de transmission. Seules les tensions des signaux sont indiquées; ce schéma ne tient aucunement compte des tensions d'alimentation.

Le circuit de transmission de la MAU doit être conforme aux exigences de niveau de sortie suivantes, et toutes les amplitudes sont mesurées au point médian estimé entre toute crête ou creux en haut et en bas de la forme d'onde ("point médian" à la Figure 80):

a) la tension de sortie sur la charge d'essai après élévation/abaissement par le transformateur (le cas échéant), doit être comprise entre 0,75 V et 1,0 V crête à crête avec une résistance de charge de 50 Ω avec une tolérance de ± 1 % ("min o/p" à la Figure 80);

b) la tension de sortie au niveau de la ligne principale ou aux bornes de transmission, avec une résistance de charge de 100 Ω avec une tolérance de ± 1 % (c'est-à-dire avec l'un des terminateurs de la ligne principale retiré) doit être comprise entre 0,75 V et 2,0 V crête à crête ("max. o/p un terminateur retiré" à la Figure 80);

c) la tension de sortie au niveau de la ligne principale ou aux bornes de transmission, avec toute charge comprenant un circuit ouvert, ne doit pas dépasser 35 V quelle que soit la polarité. A des fins d'essai, un circuit ouvert doit être défini comme une charge qui présente une résistance de 100 kΩ en parallèle avec une capacité de 15 pF;

d) au cours d'une émission, un appareil donné ne doit pas subir de défaillance permanente lorsqu'une résistance de charge de ≤ 1 Ω est appliquée pendant 1 s;

e) la différence entre amplitude positive et amplitude négative, mesurée comme cela est représenté à la Figure 80, ne doit pas dépasser ± 50 mV crête;

f) le bruit en sortie d'une MAU en réception ou non alimentée ne doit pas dépasser 1 mV eff., mesuré de manière différentielle sur une bande de fréquence de 1 kHz à 100 kHz, en référence à la ligne principale;

g) la tension différentielle sur la charge d'essai doit donner une modification monotonique de la tension, entre 10 % et 90 % de la valeur crête à crête. Par la suite, la tension du signal ne doit pas varier de plus de ± 10 % de la valeur crête à crête jusqu'à ce que la transition suivante ait lieu. Cette variation admise doit inclure toutes les formes de distorsion de signal de sortie, c'est-à-dire la surtension, la suroscillation et le statisme.

NOTE 2 En cours de transmission, la tension de sortie présente aux bornes de l'appareil peut augmenter de manière substantielle par rapport à celle spécifiée au 12.4.3 g), mais toujours dans les limites spécifiées au 12.4.3 c), en raison des effets combinés de l'impédance série de l'appareil, du câble de ligne secondaire et de tout appareil de protection du bus, comme cela est décrit au 12.8.3 c).

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### 12.4.4 Exigences de temporisation des sorties

Le circuit de transmission d'une MAU doit satisfaire aux exigences suivantes de temporisation des sorties:

a) l'instabilité de bit élémentaire transmise ne doit pas dépasser ± 0,025 $T_{bit}$ par rapport au point de passage par zéro théorique, mesuré en fonction du point de passage par zéro précédent (voir la Figure 81);

b) le circuit de transmission doit s'activer, ce qui signifie que le signal doit monter d'un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 12.4.3 f), jusqu'au niveau de pleine puissance, en moins de 2,0 $T_{bit}$. La forme d'onde correspondant au troisième temps binaire et au-delà, doit être telle qu'elle est représentée à la Figure 80;

c) le circuit de transmission doit se désactiver, ce qui signifie que le signal doit tomber depuis le niveau de pleine puissance jusqu'à un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 12.4.3 f), en moins de 2,0 $T_{bit}$. La durée nécessaire pour que le circuit de transmission revienne à son impédance d'état "non actif" ne doit pas dépasser 4 $T_{bit}$. À des fins d'essai, cette exigence doit être satisfaite dans la configuration d'essai du circuit de transmission de la 12.4.2, avec la capacité équivalente d'une longueur de câble maximale entre les bornes de l'appareil en essai.

NOTE 1 Cette exigence permet d'assurer que la capacité de la ligne a été pleinement déchargée lors de la transition du circuit de transmission de l'état actif à l'état passif.

d) les temps de croissance et de décroissance, mesurés de 10 % à 90 % de l'amplitude du signal crête à crête, ne doivent pas dépasser 0,25 $T_{bit}$ (voir la Figure 80);

e) le taux de dérive, mesuré en tout point dans une plage de 10 % à 90 % de l'amplitude du signal crête à crête, ne doit pas dépasser 0,2 V/ µs (voir la Figure 80).

NOTE 2 Les exigences d) et e) génèrent une forme d'onde trapézoïdale à la sortie du circuit de transmission. L'exigence d) limite le niveau des émissions de perturbation qui peuvent être couplées aux circuits adjacents, etc. L'exigence d) est calculée à partir de la formule suivante:

$$\text{taux de dérive max.} = 2 \times \text{taux de dérive min} = 2 \times 0{,}8\ V_o / 0{,}25\ \text{Tbit} = 6{,}4 \times V_o / \text{Tbit},$$

où $V_o$ est la tension de sortie maximale crête à crête (1,0 V) avec une charge normalisée.

### 12.4.5 Polarité du signal

Voir 11.4.5.

### 12.4.6 Transition de la réception à l'émission

Lorsqu'un appareil commence à émettre, la forme d'onde de sortie doit immédiatement satisfaire aux exigences du 12.4.3.

NOTE Il n'y a aucune exigence pour le passage du courant de l'appareil de sa valeur de réception à sa valeur de transmission.

La Figure 86 représente quatre exemples de différentes valeurs du courant passif de l'appareil.

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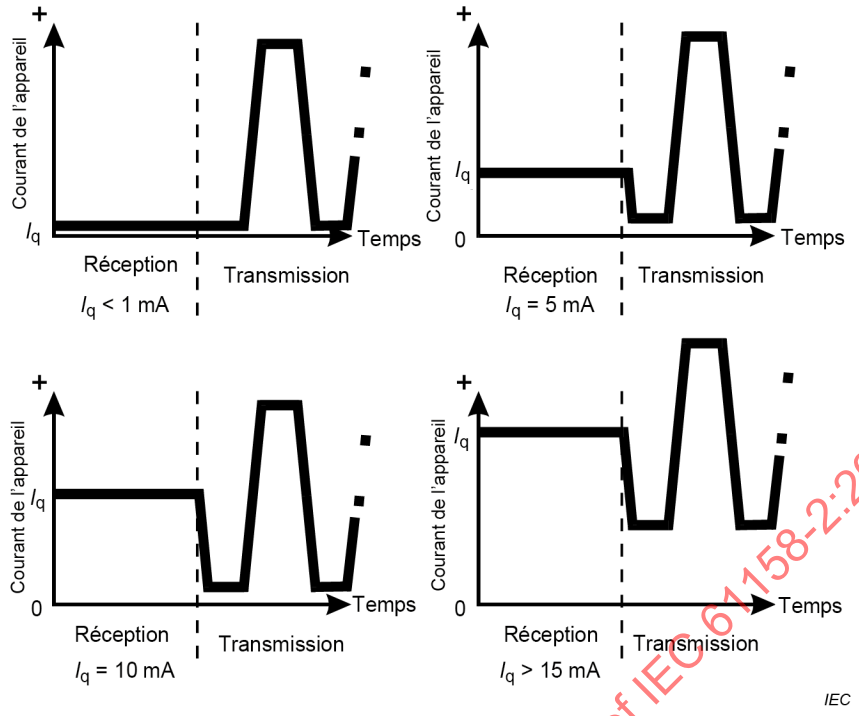


NOTE Cette figure est incluse dans le présent document à des fins d'explication et n'implique aucune mise en œuvre spécifique.

**Figure 86 – Transition de la réception à l'émission**

## 12.5 Spécification du circuit de réception de la MAU

### 12.5.1 Récapitulatif

Le Tableau 100 résume la spécification.

**Tableau 100 – Récapitulatif de la spécification du circuit de réception de la MAU**

| Caractéristiques du circuit de réception (valeurs en référence à la ligne principale) | Limites (alimenté par bus et/ou IS) |
|---|---|
| Impédance d'entrée, mesurée sur la plage de fréquences 0,25 fr à 1,25 fr | ≥ 3 kΩ |
| Sensibilité; signal minimal crête à crête dont l'acceptation est exigée (voir la Figure 83) | 150 mV |
| Suppression du bruit; bruit maximal crête à crête dont le rejet est exigé (voir la Figure 83) | 75 mV |
| Instabilité maximale de bit élémentaire reçu (écart du point de passage par zéro (voir la Figure 80) | ±0,10 Tbit |

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### 12.5.2 Impédance d'entrée

L'impédance d'entrée différentielle d'un circuit de réception de MAU ne doit pas être inférieure à 3 kΩ sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz). Cette exigence doit s'appliquer après une période de démarrage de 20 ms suivant la connexion au réseau ou à la mise sous tension du réseau. Les appareils alimentés séparément et les appareils alimentés par le réseau qui peuvent être mis hors tension lorsqu'ils sont connectés au réseau, doivent satisfaire aux exigences en état sous tension et hors tension, ainsi que lors des transitions entre ces états. Cette impédance doit être mesurée aux bornes de l'élément de communication à l'aide d'une onde sinusoïdale d'une amplitude de signal supérieure au seuil de sensibilité du récepteur et inférieure à 2,0 V crête à crête.

NOTE 1 L'exigence d'une impédance d'entrée de ≥ 3 kΩ pendant la mise sous tension et hors tension peut être satisfaite par désactivation automatique de l'émetteur au cours de ces périodes.

NOTE 2 Il est possible que les appareils qui sont équipés de circuits électroniques de déconnexion en cas de défaut aient des impédances inférieures à la valeur spécifiée dans des conditions de défaut.

### 12.5.3 Sensibilité du récepteur et suppression du bruit

Un circuit de réception de MAU doit être capable de recevoir un signal d'entrée d'une amplitude d'au moins 150 mV crête à crête, y compris la surtension et l'oscillation (voir "niveau du signal" ainsi que "amplitude positive" et "amplitude négative" à la Figure 83).

Le circuit de réception de MAU ne doit pas répondre à un signal d'entrée d'amplitude crête à crête non supérieur à 75 mV (voir "suppression du bruit" à la Figure 83).

### 12.5.4 Instabilité de bit élémentaire reçu

Le circuit de réception doit accepter un signal codé Manchester transmis conformément au 12.2 et au 12.4. En outre, le récepteur doit fonctionner correctement à des signaux avec une variation temporelle, entre deux points adjacents quelconques de transition des signaux (passage par zéro) de 0,10 $T_{bit}$t, au plus. Voir la Figure 81.

NOTE 1 Cette spécification n'exclut pas l'utilisation de récepteurs dont les performances sont supérieures à la présente spécification.

NOTE 2 En fonction de la configuration du symbole, la durée nominale entre passages par zéro est d'un demi temps binaire ou d'un temps binaire.

NOTE 3 Il n'y a aucune exigence quant au rejet d'un signal donné avec une valeur de variation temporelle spécifiée. Le récepteur rend compte d'une erreur lorsque l'instabilité de bit élémentaire reçu dépasse l'aptitude du récepteur à décoder la signalisation de manière fiable.

### 12.5.5 Susceptibilité au brouillage et taux d'erreurs

Lorsqu'un bus de terrain fonctionne dans différents environnements de bruit normalisés, il convient que la probabilité qu'une unité de données utilisateur de couche Application contienne une erreur non détectée, du fait du fonctionnement des entités physiques et DLL d'acheminement, soit inférieure à 1 sur 6 x $10^9$ (1 erreur en 20 années à 10 messages/s).

Un élément de communication est réputé conforme à cette exigence théorique lorsqu'il satisfait aux exigences suivantes de susceptibilité au brouillage. Ces exigences sont spécifiées sur la base d'un taux d'erreur de trame détecté obtenu au moyen d'un rapport d'erreurs détectées/non détectées de $10^6$.

NOTE 1 Cela est facilement réalisable au moyen d'une séquence de contrôle de trame de 16 bits au niveau de la DLL.

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Un élément de communication qui inclut une MAU, qui utilise des trames contenant 32 bits de données utilisateur aléatoires, à un débit de trame maximal et avec des signaux d'une amplitude de 375 mV crête à crête, ne doit pas produire plus de 10 erreurs de trame détectées sur 60 000 trames pendant son fonctionnement en présence d'une tension en mode commun ou de bruit gaussien comme cela est décrit ci-après:

a) un signal sinusoïdal en mode commun à toute fréquence de 63 Hz à 2 MHz, d'une amplitude de 4 V eff. et de 47 Hz à 63 Hz avec une amplitude de 250 V eff.;

b) un signal en courant continu en mode commun de 10 V;

c) un bruit blanc gaussien différentiel additionnel dans la bande de fréquence de 1 kHz à 100 kHz, avec une densité de bruit de 70 µV/√Hz eff.

NOTE 2 Les valeurs spécifiées pour la tension en mode commun et le bruit gaussien correspondent à des essais de conformité de circuit de réception avec des charges symétriques et ne sont pas représentatives d'une quelconque pratique d'installation de système.

Un élément de communication qui inclut une MAU, qui utilise des trames contenant 32 bits de données utilisateur aléatoires, à une moyenne de 10 messages/s, avec des signaux d'une amplitude de 375 mV crête à crête, ne doit pas produire plus de 10 erreurs de trame détectées sur 1 000 trames, lorsqu'il est utilisé dans des environnements de perturbations électromagnétiques ou électriques comme cela est décrit ci-après:

1) champ électromagnétique de 10 V/m, comme cela est spécifié dans l'IEC 61000-4-3 au niveau de sévérité 3;

2) transitoires électriques rapides, comme cela est spécifié dans l'IEC 61000-4-4 au niveau de sévérité 3.

La spécification du taux d'erreur supérieur au bruit doit également être satisfaite après, mais non pendant le fonctionnement dans les environnements de bruit suivants:

i) décharge électrostatique de 8 kV sur une structure métallique exposée, comme cela est spécifié dans l'IEC 61000-4-2, au niveau de sévérité 3. Si l'appareil subit une perte temporaire de fonctions ou de performances par suite de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai;

ii) essais de perturbation à haute fréquence, comme cela est spécifié dans l'IEC 60255-22-1:1988, Annexe E, classe III de tension d'essai (valeurs crêtes de 2,5 kV et 1 kV de la première demi-alternance, respectivement en mode longitudinal et transversal). Si l'appareil subit une perte temporaire de fonctions ou de performances du fait de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai.

### 12.6 Inhibition du bavardage

La MAU doit comporter une capacité d'interruption automatique pour empêcher les signaux émis d'atteindre le support. Le matériel dans la MAU (sans message extérieur autre que la détection des signaux de sortie ou de fuite par la fonction de transmission) doit fournir une fenêtre d'une durée comprise entre 120 ms et 240 ms au cours de laquelle une trame normale peut être émise. Si la longueur de trame dépasse cette durée, la fonction d'inhibition du bavardage doit empêcher d'autres signaux en sortie d'atteindre le support et doit désactiver l'écho sur la ligne RxS (voir 10.2.2.2) pour indiquer à la MDS la détection de bavardage.

La MAU doit réinitialiser la fonction d'interruption automatique après une période de 3,0 s avec une tolérance de ± 50 %.

NOTE Cette disposition neutralise le trafic sur le bus pendant 16 % (≈ 240 ms / 1,5 s) du temps disponible au plus.

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## 12.7 Distribution de l'alimentation

### 12.7.1 Généralités

Un appareil peut recevoir son alimentation par l'intermédiaire des conducteurs de signaux ou peut être alimenté de manière séparée.

Un appareil peut être certifié comme étant de sécurité intrinsèque quelle que soit la méthode d'alimentation.

NOTE Le présent document n'inclut pas d'exigences pour la certification IS, mais cherche à exclure des conditions ou situations qui empêchent la certification IS.

Un appareil à alimentation séparée peut être connecté à un bus de terrain alimenté.

Pour faciliter le renvoi aux textes correspondants, les exigences du 12.7 pour les appareils alimentés par le réseau et les alimentations du réseau sont résumées dans le Tableau 101 et le Tableau 102.

**Tableau 101 – Caractéristiques des appareils alimentés par le réseau**

| Caractéristiques des appareils alimentés par le réseau | Limites pour 31,25 kbit/s |
|---|---|
| Tension de service | 9,0 V à 32,0 VDC |
| Tension de tenue minimale, quelle que soit la polarité, sans dommage | 35 V |
| Taux de variation maximal du courant passif (pas de transmission); cette exigence ne s'applique pas au cours des 20 premières ms après connexion de l'appareil à un réseau opérationnel ou dans les 20 premières ms après mise sous tension du réseau. | 1,0 mA/ms [a, b] |
| Courant maximal; cette exigence s'applique au cours de l'intervalle de temps de 500 □s à 20 ms après connexion de l'appareil à un réseau opérationnel ou 500 □s à 20 ms après mise sous tension du réseau (voir Note 1 et Note 2) | Courant passif assigné plus 20 mA |
| NOTE 1 Ces exclusions permettent de générer un "délestage" au niveau des appareils alimentés par la même source au cours de cet intervalle d'exclusion.<br><br>NOTE 2 Ces exclusions peuvent augmenter de manière substantielle les exigences en courant de l'alimentation au cours de l'intervalle d'exclusion qui a lieu immédiatement après mise sous tension du segment PhL. | |
| [a] Les premières 500 µs sont exclues pour permettre le chargement des filtres RFI et autres capacités de l'appareil. La spécification du taux de variation s'applique après 20 ms.<br><br>[b] Il convient que le courant maximal au cours de ces 500 premières µs ne soit pas supérieur à deux fois le courant maximal spécifié ci-dessus, afin de réduire le plus possible les effets d'appels de courant sur les autres composantes du réseau de bus de terrain connecté. | |

**Tableau 102 – Exigences d'alimentation réseau**

| Exigences d'alimentation réseau [a] | Limites pour 31,25 kbit/s |
|---|---|
| Tension de sortie, non IS | ≤ 32 VDC |
| Tension de sortie, IS | En fonction des caractéristiques assignées de la barrière |
| Ondulation de sortie et bruit | Voir la Figure 87. |
| Impédance de sortie | Voir 12.7.4. |
| [a] Il convient que les alimentations soient conçues de manière à tenir compte du courant de choc lors de la connexion de l'appareil ou à la mise sous tension, comme cela est défini dans le Tableau 101. | |

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### 12.7.2 Tension d'alimentation

Un appareil de bus de terrain qui revendique la conformité à l'Article 12 doit pouvoir fonctionner dans une plage de tension de 9 V à 32 V DC entre les deux conducteurs, y compris l'ondulation. L'appareil doit résister à une tension minimale de ±35 V DC sans aucun dommage.

### 12.7.3 Alimentation par l'intermédiaire de conducteurs de signaux

Un appareil de bus de terrain qui revendique la conformité à l'Article 12 doit satisfaire aux exigences de l'Article 12 lorsqu'il est alimenté par une source qui présente les spécifications suivantes:

a) la tension de sortie maximale de l'alimentation, pour des réseaux non IS, doit être de 32 V courant continu, y compris l'ondulation;

NOTE 1 Pour des systèmes IS, la tension de service peut être limitée par les exigences de certification. Dans ce cas, l'alimentation est placée dans la zone de sécurité et sa tension de sortie est atténuée par une barrière de sécurité ou composante équivalente.

b) les exigences de claquage de l'isolation du circuit de signaux et du circuit de distribution de l'alimentation par rapport à la masse et par rapport à l'autre circuit doivent être conformes à l'IEC 61131-2;

NOTE 2 Voir 11.7.5, Note 3.

c) lorsqu'une source donnée alimente au moins deux segments, l'impédance de l'isolation de chaque segment doit être partagée à ±10 % entre les deux conducteurs de signaux du segment.

Un appareil de bus de terrain qui revendique la conformité à l'Article 12 qui est alimenté par les conducteurs de signaux doit satisfaire aux exigences de l'Article 12 lorsqu'il fonctionne à des valeurs maximales d'ondulation et de bruit de l'alimentation, de la manière suivante:

d) 16 mV crête à crête sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz);

e) 2,0 V crête à crête sur la plage de fréquences de 47 Hz à 63 Hz pour des applications non IS;

f) 0,2 V crête à crête sur la plage de fréquences de 47 Hz à 625 Hz pour des applications IS;

g) 1,6 V crête à crête à des fréquences supérieures à 125 $f_r$, jusqu'à une fréquence maximale de 25 MHz;

h) des niveaux, à des fréquences intermédiaires, généralement conformes à la Figure 87.

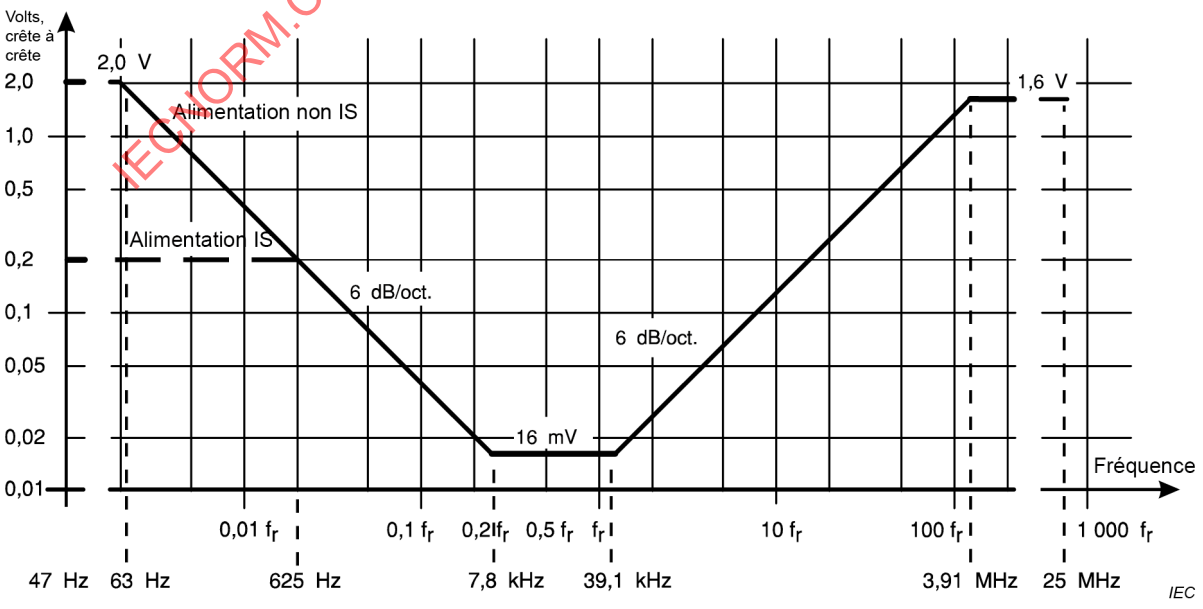


**Figure 87 – Ondulation et bruit de l'alimentation**

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Un appareil de bus de terrain qui revendique la conformité à l'Article 12 et qui est alimenté par les conducteurs de signaux, doit présenter un taux maximal de variation du courant prélevé du réseau de 1 mA/ms. Cette exigence ne s'applique pas:

1) en cours de transmission;
2) au cours des 20 premières ms après connexion de l'appareil à un réseau opérationnel;
3) au cours des 20 premières ms après mise sous tension du réseau; ou
4) lors de la déconnexion du réseau ou de la mise hors tension du réseau.

Un appareil doit porter un marquage qui indique son courant passif assigné. Un appareil ne doit pas prélever sur le réseau plus de 20 mA au-dessus de son courant assigné au cours de l'intervalle de temps de 500 µs à 20 ms après connexion de l'appareil à un réseau opérationnel ou 500 µs à 20 ms après mise sous tension du réseau.

NOTE 3 Les 500 premières µs sont exclues pour permettre le chargement des filtres RFI et autres capacités dans l'appareil. La spécification du taux de variation s'applique après 20 ms.

Il convient que le courant maximal au cours de ces 500 premières µs ne soit pas supérieur à deux fois le courant maximal spécifié ci-dessus, afin de réduire le plus possible les effets d'appels de courant sur les autres composantes du réseau de bus de terrain connecté.

NOTE 4 Ces exclusions permettent de générer un "délestage" au niveau des appareils alimentés par la même source au cours de cet intervalle d'exclusion.

NOTE 5 Ces exclusions peuvent augmenter de manière substantielle les exigences en courant de l'alimentation au cours de l'intervalle d'exclusion qui a lieu immédiatement après mise sous tension du segment PhL.

### 12.7.4 Impédance d'alimentation

#### 12.7.4.1 Impédance des alimentations à sortie unique

Il convient que les alimentations soient conçues de manière à tenir compte du courant de choc lors de la connexion de l'appareil ou à la mise sous tension, comme cela est défini au 12.7.3.

L'impédance des alimentations à sortie unique doit être mesurée au moyen du circuit d'essai de la Figure 88.

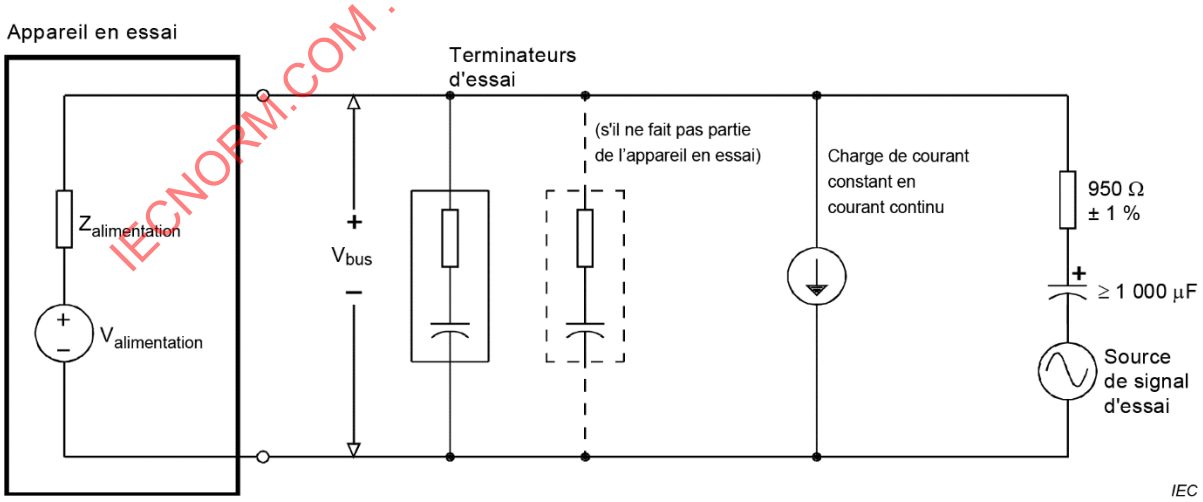


**Figure 88 – Circuit d'essai pour des alimentations à sortie unique**

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Les terminateurs d'essai représentés à la Figure 88 doivent chacun avoir une valeur de 100 Ω avec une tolérance de ± 1 % en série, avec 1 µF avec une tolérance de ± 5 %. Deux terminateurs d'essai doivent être utilisés dans le circuit d'essai si l'alimentation soumise à l'essai ne comporte pas un terminateur interne. Si l'alimentation soumise à l'essai comporte un terminateur interne qui est toujours connecté, un seul terminateur d'essai doit être utilisé dans le circuit d'essai. Si l'alimentation soumise à l'essai comporte un terminateur interne qui peut être éventuellement connecté au circuit, l'alimentation doit être soumise à l'essai a) avec le terminateur interne et un terminateur d'essai, et b) avec deux terminateurs d'essai et pas de terminateur interne.

S'il est prévu d'utiliser l'alimentation avec un réseau externe à détermination de l'impédance (par exemple, cela peut être le cas d'alimentations conçues pour être utilisées en redondance), l'alimentation doit être soumise à l'essai avec le réseau externe connecté.

L'alimentation doit être soumise à l'essai à 20 %, 50 % et 80 % de son courant de sortie assigné (ou 20 mA, selon la plus grande valeur retenue), avec application d'une charge à courant continu constante qui présente une conformité égale à 1 mA/V ou meilleure (c'est-à-dire une impédance de ≥ 1 kΩ).

L'alimentation doit être soumise à l'essai par une surveillance de la tension continue du bus, $V_{BUS}$, tout en appliquant une onde sinusoïdale de 10 $V_{pk-pk}$ à partir d'une source de signal d'essai, à travers une résistance de 950 Ω avec une tolérance de ± 1 % et un condensateur de couplage d'au moins 1 000 µF.

La tension alternative du bus mesurée, $V_{BUS}$, doit être conforme aux valeurs suivantes.

a) **Pour des alimentations non IS destinées à fournir l'énergie à des barrières IS:** $V_{BUS}$ doit être comprise entre 0,40 $V_{pk-pk}$ et 0,60 $V_{pk-pk}$ à toutes les fréquences comprises entre 50 Hz et 39 kHz.

b) **Pour des alimentations IS, ainsi que pour des alimentations non IS qui ne sont pas destinées à fournir de l'énergie à des barrières IS:** $V_{BUS}$ doit être comprise entre 0,40 $V_{pk-pk}$ et 0,60 $V_{pk-pk}$, pour des fréquences de 3 kHz à 39 kHz, et elle ne doit pas croître ou décroître à un taux supérieur à 20 dB par décade, à toute fréquence de 50 Hz à 3 kHz.

NOTE Il est acceptable que les fonctions de l'alimentation et du terminateur soient combinées, à condition que la combinaison résultante soit électriquement équivalente aux appareils indépendants qui satisfont aux exigences de l'Article 12 et si les règles de configuration du réseau du 12.3 sont respectées.

Les alimentations qui ne sont pas conçues pour fournir de l'énergie à des barrières IS doivent porter un marquage indiquant "Ne pas utiliser avec des barrières IS".

#### 12.7.4.2 Distribution de l'alimentation par l'intermédiaire d'une barrière IS

Il convient que les alimentations soient conçues de manière à tenir compte du courant de choc lors de la connexion de l'appareil ou à la mise sous tension, comme cela est admis au 12.7.3.

L'impédance de sortie de barrières de sécurité intrinsèque doit être définie en matière de caractéristiques en fonction de la fréquence lorsque la barrière est connectée au circuit d'essai de la Figure 89.

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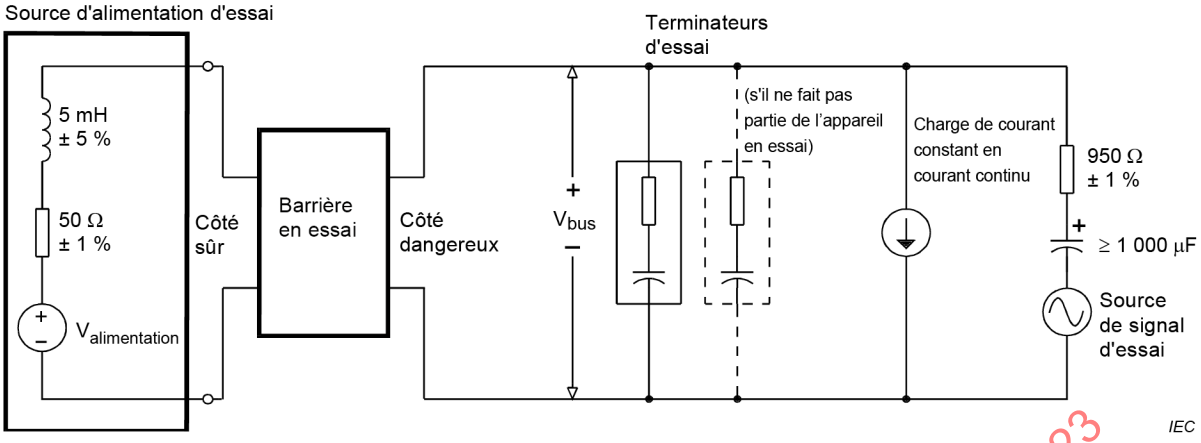


**Figure 89 – Circuit d'essai pour distribution de l'alimentation par l'intermédiaire d'une barrière IS**

La source d'alimentation d'essai représentée à la Figure 89 est constituée d'une source de tension continue de faible impédance en série avec 5 mH avec une tolérance de ± 5 % et 50 Ω avec une tolérance de ± 1 %. Les terminateurs d'essai doivent chacun avoir une valeur de 100 Ω avec une tolérance de ± 1 % en série, avec 1 µF avec une tolérance de ± 5 %. Si la barrière comporte un terminateur interne, elle doit être soumise à l'essai avec un terminateur d'essai. Dans le cas contraire, la barrière doit être soumise à l'essai avec deux terminateurs d'essai.

La barrière doit être soumise à l'essai à 20 %, 50 % et 80 % de son courant de sortie assigné (ou 20 mA, selon la plus grande valeur retenue), avec application d'une charge à courant continu constante qui présente une conformité égale à 1 mA/V ou meilleure (c'est-à-dire une impédance ≥ 1 kΩ).

La barrière doit être soumise à l'essai par une surveillance de la tension du bus, $V_{BUS}$, tout en appliquant une onde sinusoïdale de 10 $V_{pk-pk}$ à partir d'une source de signal d'essai, à travers une résistance de 950 Ω avec une tolérance de ± 1 % et un condensateur de couplage d'au moins 1 000 µF.

La tension alternative du bus $V_{BUS}$ mesurée du côté dangereux de la barrière doit être comprise entre 0,40 $V_{pk-pk}$ et 0,60 $V_{pk-pk}$, pour des fréquences de 3 kHz à 39 kHz, et elle ne doit pas croître ou décroître à un taux supérieur à 20 dB par décade à toute fréquence de 50 Hz à 3 kHz.

NOTE Il est acceptable que les fonctions de l'alimentation, de la barrière IS et du terminateur soient combinées de différentes manières, tant que la combinaison obtenue est électriquement équivalente aux appareils indépendants qui satisfont aux exigences de l'Article 12 et si les règles de configuration du réseau du 12.3 sont respectées.

### 12.7.4.3 Impédance des alimentations à sorties multiples avec couplage du signal entre sorties

NOTE 1 Le paragraphe 12.7.4.3 est applicable aux sectionneurs galvaniques, aux coupleurs actifs et aux autres appareils qui comportent plusieurs accès d'alimentation et de signaux.

Il convient que les alimentations soient conçues de manière à tenir compte du courant de choc lors de la connexion de l'appareil ou à la mise sous tension, comme cela est admis au 12.7.3.

Pour des alimentations à sorties multiples avec couplage du signal de communication du bus de terrain entre sorties, l'impédance d'alimentation doit être mesurée au moyen du circuit d'essai de la Figure 90.

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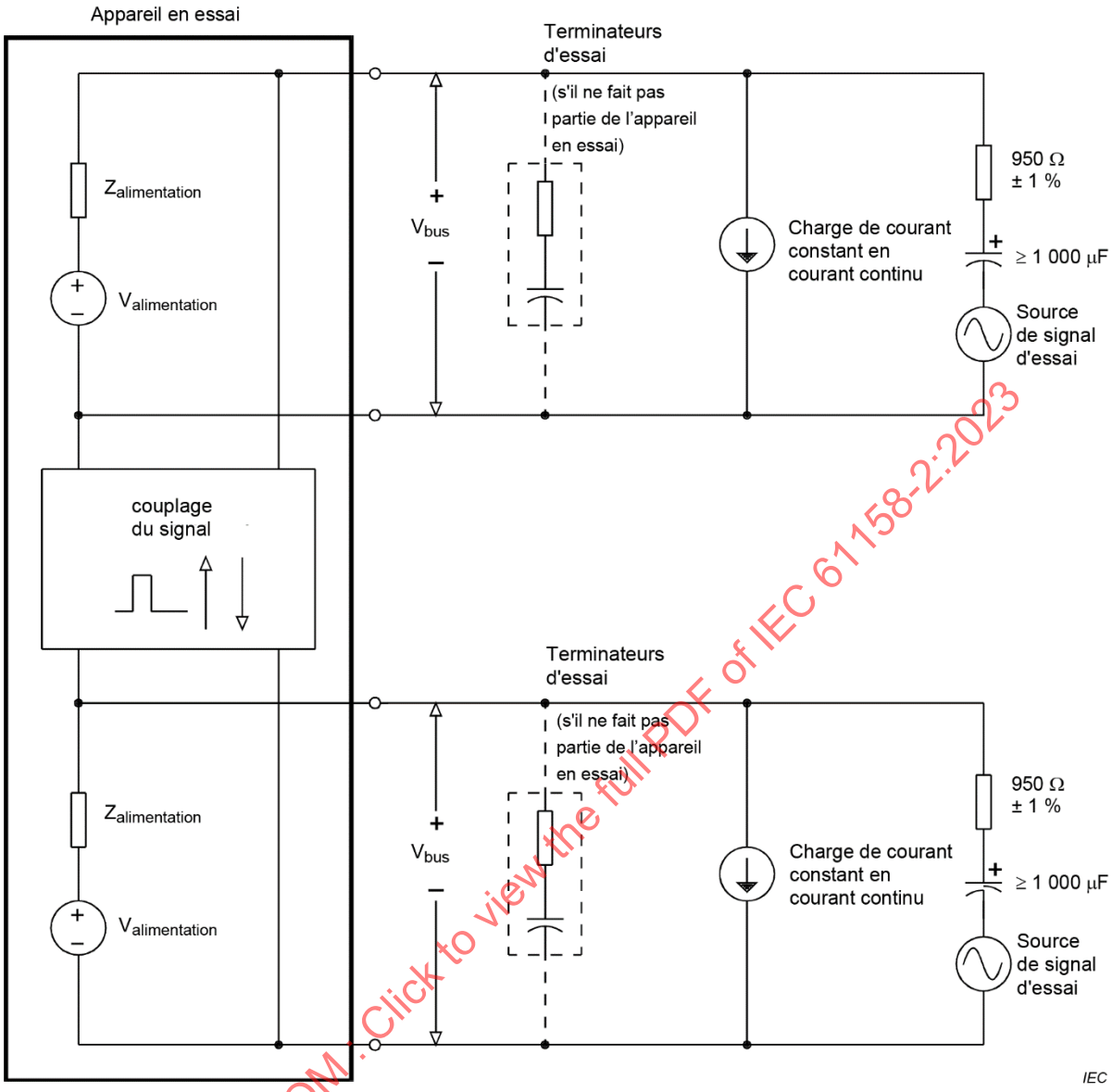


**Figure 90 – Circuit d'essai pour des alimentations à sorties multiples avec couplage du signal**

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Les terminateurs d'essai représentés à la Figure 90 doivent chacun avoir une valeur de 100 Ω avec une tolérance de ± 1 % en série, avec 1 µF avec une tolérance de ± 5 %. Deux terminateurs d'essai doivent être utilisés dans le circuit d'essai si l'appareil en essai ne comporte pas un terminateur interne. Si l'appareil en essai comporte un terminateur interne qui est toujours connecté, un seul terminateur d'essai doit être utilisé dans le circuit d'essai. Si l'appareil en essai comporte un terminateur interne qui peut être éventuellement connecté au circuit, l'appareil doit être soumis à l'essai a) avec le terminateur interne et un terminateur d'essai, et b) avec deux terminateurs d'essai et pas de terminateur interne.

S'il est prévu d'utiliser l'appareil en essai avec un réseau externe à détermination de l'impédance (par exemple, cela peut être le cas d'alimentations conçues pour être utilisées en redondance), l'alimentation doit être soumise à l'essai avec le réseau externe connecté.

L'appareil en essai doit être soumis à l'essai à 20 %, 50 % et 80 % de son courant de sortie assigné (ou 20 mA, selon la plus grande valeur retenue) sur chaque sortie, l'appareil étant soumis à une charge à courant continu constante qui présente une conformité égale à 1 mA/V ou meilleure (c'est-à-dire une impédance de ≥ 1 kΩ).

La tension alternative du bus $V_{BUS}$ mesurée doit être comprise entre 0,40 $V_{pk-pk}$ et 0,60 $V_{pk-pk}$, pour des fréquences de 3 kHz à 39 kHz, et elle ne doit pas croître ou décroître à un taux supérieur à 20 dB par décade à toute fréquence de 50 Hz à 3 kHz.

NOTE 2 Il est acceptable que les fonctions de l'alimentation, du sectionneur ou du coupleur et du terminateur soient combinées de différentes manières, tant que l'impédance de la combinaison obtenue est équivalente à l'impédance parallèle d'appareils indépendants qui satisfont aux exigences de l'Article 12 et si les règles de configuration du réseau du 12.3 sont respectées.

### 12.7.5 Alimentation séparée à partir des conducteurs de signaux

NOTE La distribution de l'alimentation pour des appareils de bus de terrain non alimentés par le bus s'effectue au moyen de conducteurs séparés qui fournissent l'énergie à des alimentations locales, des régulateurs ou des barrières de sécurité. La certification IS peut exiger que ces conducteurs soient dans un câble séparé de celui des conducteurs de signaux et peut également imposer des exigences de niveau de courant plus strictes que celles qui sont spécifiées.

Un appareil de bus de terrain alimenté séparément ne doit pas prélever plus de 10 mA en courant continu sur les conducteurs de signaux et ne doit pas fournir plus de 100 µA en courant continu aux conducteurs de signaux, lorsqu'il n'y a pas de transmission. Un appareil doit porter un marquage qui indique son courant passif assigné prélevé du réseau.

### 12.7.6 Isolation électrique

Tous les appareils de bus de terrain, alimentés séparément ou par l'intermédiaire des conducteurs de signaux, doivent assurer une isolation basse fréquence entre la masse et le câble de ligne principale du bus de terrain.

NOTE 1 Cette isolation s'effectue par isolation de l'ensemble de l'appareil de la masse ou au moyen d'un transformateur, d'un optocoupleur ou de tout autre organe d'isolation entre le câble de ligne principale et l'appareil.

Une alimentation et un élément de communication combinés ne doivent pas exiger d'isolation électrique.

Pour les câbles blindés, l'impédance d'isolation mesurée entre le blindage du câble de bus de terrain et la masse de l'appareil de bus de terrain doit être supérieure à 250 kΩ à toutes les fréquences inférieures à 63 Hz.

La capacité dissymétrique maximale par rapport à la masse de toute borne d'entrée d'un appareil ne doit pas dépasser 250 pF.

Les exigences de claquage de l'isolation du circuit de signaux et du circuit de distribution de l'alimentation par rapport à la masse et par rapport à l'autre circuit doivent être conformes à l'IEC 61131-2.

NOTE 2 Voir 11.7.5, Note 3.

### 12.8 Spécifications dusupport

### 12.8.1 Connecteur

Les éventuels connecteurs de câbles doivent être conformes au présent document (pour la transmission synchrone de Type 1, voir l'Annexe A et pour la transmission synchrone de Type 3, voir l'Annexe I). Des techniques de terminaison sur le terrain, comme les bornes à vis ou à lames, ainsi que les terminaisons permanentes, peuvent également être utilisées.

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### 12.8.2 Câble d'essai normalisé

Le câble utilisé pour les essais d'appareils de bus de terrain qui revendiquent la conformité aux exigences de l'Article 12, doit être un câble unique à paire torsadée, à blindage global, qui satisfait aux exigences minimales suivantes, à une température de 25 °C:

a) impédance à une fréquence $f_r$ (31,25 kHz) = 100 Ω avec une tolérance de ± 20 %;

b) affaiblissement maximal à une fréquence de 1,25 $f_r$ (39 kHz) = 3,0 dB/km;

c) déséquilibre capacitif maximal par rapport au blindage = 4 nF/km, soumis à l'essai au moyen d'un échantillon d'une longueur minimale de 30 m;

d) résistance maximale en courant continu (par conducteur) = 24 Ω/km;

e) variation du délai maximal de propagation à une fréquence de 0,25 $f_r$ à 1,25 $f_r$ = 1,7 µs/km;

f) section du conducteur (dimension des fils) = 0,8 $mm^2$, valeur nominale;

g) la couverture minimale du blindage doit être de 90 %.

La spécification ci-dessus concerne les essais de conformité d'une MAU. D'autres types de câbles peuvent être utilisés dans les installations réelles (voir l'Annexe B). Les câbles à spécifications améliorées peuvent permettre de plus grandes longueurs de lignes principales ou une meilleure immunité aux perturbations, ou encore il peut être exigé qu'ils satisfassent à des conditions d'environnement ou d'installation. En revanche, les câbles qui présentent des spécifications inférieures peuvent être utilisés, sous réserve d'une limitation des longueurs utilisées, tant pour les lignes principales que secondaires, à laquelle s'ajoute une éventuelle non-conformité aux exigences de susceptibilité aux perturbations radioélectriques (RFI) et électromagnétiques (EMI).

Pour des applications de sécurité intrinsèque, il convient que le rapport inductance/résistance (L/R) soit inférieur à la limite spécifiée par l'organisme de réglementation local pour la mise en œuvre particulière.

### 12.8.3 Coupleur

Le coupleur doit fournir un ou plusieurs points de connexion à la ligne principale. Il peut être intégré à l'appareil de bus de terrain, auquel cas il n'y a pas de ligne secondaire. Dans le cas contraire, il comporte au moins trois points d'accès comme cela est représenté à la Figure 91: un pour la ligne secondaire et un pour chaque côté de la ligne principale.

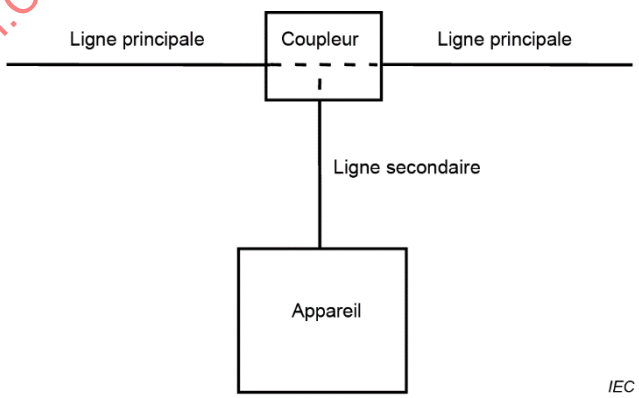


**Figure 91 – Coupleur de bus de terrain**

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Un coupleur passif peut inclure un ou tous les éléments facultatifs décrits ci-dessous:

a) un transformateur qui assure l'isolation galvanique et la transformation de l'impédance entre la ligne principale et la ligne secondaire;

b) des connecteurs qui facilitent le branchement à la ligne secondaire et/ou à la ligne principale;

c) des résistances de protection, telles qu'elles sont représentées à la Figure 92, pour protéger le trafic sur le bus entre d'autres appareils, des effets d'une ligne secondaire en court-circuit sur une ligne principale non alimentée et non de sécurité intrinsèque.

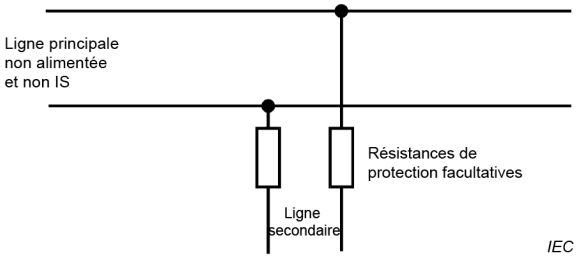


**Figure 92 – Résistances de protection**

NOTE Ces résistances série augmentent de manière inhérente la tension aux bornes de l'appareil lorsqu'il est en émission. Cela affecte la tension aux bornes de réception des appareils électriquement "proches". Voir 12.4.3 pour la tension de tenue maximale exigée de tous ces appareils.

Les coupleurs actifs qui exigent une alimentation externe, comportent des composantes d'amplification et de réémission des signaux. Le niveau de transmission et les exigences de temporisation doivent être conformes au 12.3.

### 12.8.4 Épissures

NOTE 1 Une épissure est toute partie du réseau dans laquelle l'impédance caractéristique du câble de réseau n'est pas maintenue. Cela peut être dû à la séparation des conducteurs du câble, au retrait de blindage du câble, au changement de calibre ou de type de fil, à la connexion de lignes secondaires, à la fixation à des barrettes à bornes, etc. Une définition pratique d'une épissure est par conséquent toute partie du réseau qui n'est pas une longueur continue du support spécifié.

Pour des réseaux d'une longueur de câblage totale (ligne principale et lignes secondaires) supérieure à 400 m, la somme des longueurs de toutes les épissures ne doit pas dépasser 2,0 % de la longueur totale du câble. Pour des longueurs de câblage de 400 m au plus, la somme des longueurs de toutes les épissures ne doit pas dépasser 8 m.

NOTE 2 Cette spécification est motivée par le fait qu'il est nécessaire de préserver la qualité de transmission en exigeant que le réseau soit presque entièrement constitué du support spécifié.

La continuité de tous les conducteurs du câble doit être maintenue dans une épissure.

### 12.8.5 Terminateur

Un terminateur doit être placé aux deux extrémités du câble de ligne principale et connecté d'un conducteur de signal à l'autre. Il ne doit y avoir aucune connexion entre le terminateur et le blindage du câble.

La valeur de l'impédance du terminateur doit être de 100 Ω – 2 Ω/+ 6 Ω sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz). L'impédance du terminateur doit être équivalente à une résistance en série de 100 Ω avec une capacité de 1,0 µF. Les tolérances maximales des composants doivent être de 100 Ω ± 2 Ω et 1,0 µF ± 0,2 µF.

NOTE 1 Cette valeur d'impédance correspond approximativement à la valeur moyenne de l'impédance caractéristique du câble, pour les câbles appropriés aux fréquences adaptées, et elle est choisie pour réduire le plus possible les réflexions de la ligne de transmission.

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Il convient que les composants du terminateur soient choisis de manière à satisfaire aux valeurs spécifiées sur la plage de températures indiquée et pendant toute la durée de vie en fonctionnement de l'installation. Il est recommandé que les caractéristiques assignées des composants à 25 °C soient de 100 Ω ± 1 Ω et 1 µF ± 0,1 µF.

Le courant continu de fuite à travers le terminateur ne doit pas dépasser 100 µA. Le terminateur doit être non polarisé.

Tous les terminateurs utilisés pour les applications IS doivent satisfaire aux exigences d'isolation (lignes de fuite et distances d'isolement) en fonction de l'homologation IS exigée. L'homologation IS ne doit pas être exigée pour des terminateurs destinés à des applications non IS.

NOTE 2 Il est acceptable que les fonctions de l'alimentation, de la barrière de sécurité et du terminateur soient combinées de différentes manières, tant que l'impédance de la combinaison obtenue soit équivalente à l'impédance parallèle d'appareils indépendants qui satisfont aux exigences de l'Article 12 et si les règles de configuration du réseau du 12.3.3 sont respectées.

### 12.8.6 Règles de blindage

Lorsque les exigences d'immunité au bruit du 12.5 doivent être satisfaites au moyen d'un blindage, il est nécessaire d'assurer l'intégrité du blindage sur toute la longueur du câblage, dans les connecteurs et dans les coupleurs. Les règles suivantes peuvent aider à la satisfaction de ces exigences, mais ne constituent pas en soi une exigence:

a) il convient que le câble soit blindé sur plus de 90 % de sa longueur totale;

b) il convient que le blindage couvre complètement les circuits électriques des connecteurs, des coupleurs et des épissures.

NOTE 1 Toute dérogation à ces règles de blindage peut dégrader l'immunité au bruit.

NOTE 2 Du fait des longueurs d'onde importantes, en général, les ruptures de la couverture du blindage sur 25 cm environ au niveau des connecteurs, des coupleurs et des épissures, y compris les points de fixation des lignes secondaires, ne posent pas de problèmes, à condition que la continuité du blindage soit maintenue.

NOTE 3 Les enveloppes de connecteurs, de coupleurs et d'épissures qui utilisent des boîtes de jonction métalliques peuvent assurer un blindage de protection contre les sources de bruit hors de la boîte de jonction.

### 12.8.7 Règles de mise à la masse (mise à la terre)

NOTE Mise à la masse (à la terre) signifie une connexion permanente à la terre par l'intermédiaire d'une impédance suffisamment basse et ayant un courant admissible suffisant pour prévenir un amorçage en tension qui peut entraîner un danger excessif pour le matériel connecté ou les personnes.

Les appareils de bus de terrain doivent fonctionner conformément aux exigences de l'Article 12, le point médian d'un terminateur ou d'un coupleur inductif étant directement connecté à la masse.

Les appareils de bus de terrain ne doivent pas raccorder l'un des conducteurs de la paire torsadée à la masse, quel que soit le point du réseau. Les signaux doivent être appliqués et préservés de manière différentielle sur l'ensemble du réseau. Les lignes de tension zéro (commun) peuvent être reliées à la masse où elles sont galvaniquement isolées de la ligne principale du bus de terrain.

Il est habituel dans la pratique de mettre effectivement à la masse le blindage du câble de ligne principale de bus de terrain (le cas échéant) en un point sur la longueur du câble. De ce fait, il convient que les appareils de bus de terrain permettent une isolation en courant continu du blindage du câble par rapport à la masse.

La pratique courante est également de raccorder les conducteurs de signaux à la masse de manière symétrique, au même point, au moyen, par exemple, de la prise médiane d'un terminateur ou d'un transformateur de couplage.

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Pour des systèmes alimentés par le bus, il convient que la mise à la masse du blindage et des conducteurs de signaux équilibrés soit proche de l'unité d'alimentation.

Pour les systèmes IS, il convient que la mise à la masse soit effectuée au niveau de la connexion à la terre de la barrière de sécurité.

Un couplage capacitif est admis entre le blindage ou les conducteurs de signaux équilibrés et la mise à la masse locale de l'appareil pour une meilleure immunité aux interférences électromagnétiques, sous réserve de satisfaire aux exigences IS.

### 12.8.8 Code de couleur des câbles

Voir 11.8.8.

Si les pratiques locales, telles que celles spécifiées au 11.8.8, le permettent, il est recommandé d'utiliser les couleurs de câble suivantes pour les systèmes de Type 3, comme cela est présenté dans le Tableau 103.

**Tableau 103 – Spécification des couleurs de câbles pour le Type 3**

| Paramètre du câble | Couleur |
|---|---|
| Couleur de gaine non IS | Noire |
| Couleur de gaine IS | Bande bleue ou bleue/noire |
| Couleur du conducteur intérieur du câble A (PA-) | Verte |
| Couleur du conducteur intérieur du câble B (PA+) | Rouge |

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## 12.9 Sécurité intrinsèque

### 12.9.1 Généralités

Le présent document n'a pas pour objet d'énumérer les exigences par lesquelles un équipement peut être certifié comme étant de sécurité intrinsèque et n'exige pas non plus que l'équipement soit de sécurité intrinsèque. Il cherche plutôt à exclure les conditions ou situations qui empêchent la certification IS.

### 12.9.2 Barrière de sécurité intrinsèque

L'impédance de la barrière doit être supérieure à 460 Ω, à toute fréquence dans une plage de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz). La spécification de l'impédance de la barrière IS doit s'appliquer à toutes les barrières utilisées comme parties de PhL, qu'elles soient installées comme un élément séparé de matériel de réseau ou intégrées dans une carte d'alimentation. L'impédance de la barrière doit être mesurée entre les bornes des deux côtés de la barrière. L'impédance de la barrière doit être mesurée avec l'alimentation réseau réglée à la tension de service assignée (et non la tension de sécurité) de la barrière.

NOTE Il est acceptable que les fonctions de l'alimentation, de la barrière de sécurité et du terminateur soient combinées de différentes manières, tant que l'impédance de la combinaison obtenue est équivalente à l'impédance parallèle d'appareils indépendants qui satisfont aux exigences de l'Article 12 et si les règles de configuration du réseau du 12.3.3 sont respectées.

À la tension de service assignée de la barrière et à toute fréquence dans une plage de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz), la capacité mesurée à la borne positive du réseau "+" (côté dangereux) et la masse ne doit pas s'écarter de plus de 250 pF par rapport à la capacité mesurée entre la borne négative du réseau "-" (côté dangereux) et la masse.

#### 12.9.3 Mise en place de barrières et de terminateurs

Une barrière doit être séparée du terminateur le plus proche de 100 m de câble au plus.

### 12.10 Sectionneurs galvaniques

Les caractéristiques de communication des sectionneurs galvaniques utilisés sur le bus de terrain doivent satisfaire aux spécifications données au 12.4, 12.5 et 12.9. Les sectionneurs galvaniques qui alimentent les appareils de bus de terrain doivent également satisfaire aux spécifications d'alimentation du 12.7.

## 13 Type 1: Unité de liaison au support: mode courant, support câblé à paire torsadée

### 13.1 Généralités

La MAU en mode courant de 1,0 Mbit/s fournit simultanément l'accès à un réseau de communication et à un réseau de distribution d'énergie. Les appareils raccordés au réseau communiquent par l'intermédiaire du support et peuvent ou non être alimentés par ce support. L'alimentation est distribuée comme un courant alternatif constant. Les signaux de communication sont superposés à l'alimentation en courant alternatif.

Le support de réseau est composé d'un câble à paire torsadée blindé.

Des formes d'onde trapézoïdales sont utilisées pour réduire les émissions électromagnétiques et la distorsion des signaux.

Dans les applications de sécurité intrinsèque, la puissance disponible peut limiter le nombre d'appareils.

Les appareils sont connectés en série sur le bus tandis que dans les variantes en mode tension, les appareils sont connectés au bus en parallèle.

### 13.2 Débit binaire de transmission

Le débit binaire moyen, BR ± ΔBR, doit être de 1,0 Mbit/s avec une tolérance de ± 0,01 %, moyenné sur une trame d'une longueur minimale de 16 octets. Le temps binaire instantané, $T_{bit}$ ± $\Delta T_{bit}$, doit être de 1,0 µs ± 0,025 µs.

### 13.3 Spécifications du réseau

#### 13.3.1 Composants

Une MAU fonctionne sur un réseau constitué des composants suivants:

a) un câble;
b) des terminateurs;
c) des coupleurs;
d) des appareils (qui comportent au moins un élément de communication).

Un réseau filaire en mode courant peut en outre inclure les composants suivants:

a) des connecteurs;
b) des alimentations;
c) des appareils qui comprennent les alimentations;
d) des barrières de sécurité intrinsèque.

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Le support de réseau est composé d'un câble à paire torsadée blindé. Indépendamment de la topologie, tous les appareils connectés, sauf éventuellement l'appareil de transmission, présentent une faible impédance pour éviter une surcharge importante du réseau.

### 13.3.2 Topologies

Une MAU câblée doit fonctionner sur un réseau de topologie de bus linéaire constitué d'une ligne principale, terminée à chaque extrémité comme cela est spécifié au 13.8.5, et à laquelle des éléments de communication sont connectés par l'intermédiaire de coupleurs et de lignes secondaires.

Le coupleur et l'élément de communication peuvent être intégrés dans un seul appareil (c'est-à-dire une ligne secondaire de longueur zéro).

Une topologie arborescente dont tous les éléments de communication sont placés aux extrémités de la ligne principale est considérée comme un cas particulier de bus aux fins de l'Article 13.

Plusieurs éléments de communication peuvent être connectés à la ligne principale en un point donné, au moyen d'un coupleur multivoies. Un coupleur actif peut être utilisé pour étendre une ligne secondaire sur une longueur qui exige une terminaison afin d'éviter les réflexions et distorsions. Des répéteurs actifs peuvent être utilisés pour étendre la longueur de la ligne principale au-delà d'un segment unique comme le permettent les règles de configuration du réseau.

### 13.3.3 Règles de configuration du réseau

Une MAU qui revendique la conformité à l'Article 13 doit satisfaire aux exigences de l'Article 13 lorsqu'elle est utilisée sur un réseau qui satisfait aux présentes règles.

**Règle 1:** Un bus de terrain doit être capable de prendre en charge la communication d'un nombre d'appareils compris entre deux et 32, qui fonctionnent tous au même débit binaire, qu'il s'agisse d'un bus alimenté ou non alimenté et dans une zone dangereuse qui utilise des barrières distribuées.

NOTE 1 L'utilisation d'une barrière unique dans la zone de sécurité peut limiter le nombre d'appareils dans la zone dangereuse.

NOTE 2 Cette règle n'exclut pas l'utilisation d'un nombre d'appareils supérieur à celui spécifié dans un système installé. Le nombre d'appareils a été calculé sur l'hypothèse selon laquelle un appareil alimenté par le bus prélève 100 mW.

**Règle 2:** Un segment de bus de terrain à pleine charge (qui comporte le nombre maximal d'appareils connectés) en mode courant doit avoir une longueur totale de câble, entre deux appareils quelconques, jusqu'à 750 m au plus.

NOTE 3 Cette longueur maximale du câble de 750 m est l'exigence de conformité à l'Article 13, mais n'exclut pas l'utilisation de longueurs supérieures dans un système installé.

**Règle 3:** Le nombre total de régénérations de forme d'onde par des répéteurs et des coupleurs actifs entre deux appareils quelconques dépend de la mise en œuvre du répéteur concerné.

NOTE 4 Ce nombre total était limité à quatre dans les éditions précédentes du présent document.

**Règle 4:** Le délai maximal de propagation entre deux appareils quelconques ne doit pas dépasser 40 $T_{bit}$.

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Pour que le réseau fonctionne efficacement, il convient que cette partie du temps de retournement de tout appareil du réseau, générée par une PhE entre la fin d'une trame reçue et le début d'une trame émise qui contient une réponse immédiate associée, ne dépasse pas 5 temps binaires, dont il convient que 2 temps binaires au plus soient dus à la MAU.

NOTE 5 Sachant qu'il n'est pas obligatoire d'exposer l'interface DLL – PhL ou l'interface MDS – MAU, cette partie du temps de retournement d'un appareil de bus de terrain due à la PhL ou à la MAU n'est pas spécifiée et donc non disponible pour des essais de conformité.

**Règle 5:** Le bus de terrain doit pouvoir fonctionner en continu lorsqu'un appareil y est connecté ou déconnecté. Les erreurs de données générées lors de la connexion ou de la déconnexion doivent être détectées.

**Règle 6:** La défaillance de tout élément de communication ou de toute ligne secondaire (y compris un court-circuit, ou un circuit ouvert, mais à l'exception des bavardages) ne doit pas interférer avec les transactions entre d'autres éléments de communication pendant plus de 1 ms.

**Règle 7:** Le réseau ne doit pas être sensible à la polarité, avec ou sans énergie injectée sur la ligne.

**Règle 8:** La dégradation des caractéristiques électriques du signal, entre deux appareils quelconques, due à l'affaiblissement, à la distorsion d'affaiblissement et à la désadaptation, doit être limitée aux valeurs indiquées ci-dessous.

a) Affaiblissement du signal: L'affaiblissement du signal dû à chaque appareil ne doit pas dépasser 0,2 dB. La configuration du bus (longueurs de la ligne principale et des lignes secondaires, nombre d'appareils, barrières IS, sectionneurs galvaniques et éventuels appareils d'adaptation) doit être telle que l'affaiblissement entre deux appareils quelconques, à la fréquence qui correspond au débit binaire, ne doit pas dépasser 16 dB.

b) Distorsion d'affaiblissement: La configuration du bus (les longueurs de la ligne principale et des lignes secondaires, ainsi que le nombre d'appareils) doit être telle qu'entre deux appareils quelconques:

   [Affaiblissement (1,25 $f_r$) – Affaiblissement (0,25 $f_r$)] ≤ 6 dB

   Affaiblissement (1,25 $f_r$) ≥ Affaiblissement (0,25 $f_r$)

   où $f_r$ est la fréquence qui correspond au débit binaire. L'affaiblissement doit être monotonique pour toutes les fréquences de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz).

c) Distorsion de désadaptation: La désadaptation (due à des lignes secondaires ou à tout autre effet, y compris une ligne secondaire en circuit ouvert de longueur maximale) sur le bus doit être telle qu'en tout point sur la ligne principale dans la bande de fréquence comprise entre 0,25 $f_r$ et 1,25 $f_r$ (250 kHz à 1,25 MHz):

   $|Z - Zf_r| / |Z + Zf_r| \leq 0,2$

   où

   $Z_o$ est l'impédance caractéristique du câble de ligne principale;

   Z est la combinaison parallèle de $Z_o$ et de l'impédance de charge au niveau du coupleur.

NOTE 6 Cette règle permet de réduire le plus possible les restrictions, en matière de longueurs de la ligne principale et des lignes secondaires ainsi qu'en matière de nombre d'appareils, etc. en ne spécifiant que les limites de transmission imposées par des combinaisons de ces facteurs. Il est possible d'utiliser différentes combinaisons en fonction des besoins de l'application.

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**Règle 9:** Les règles suivantes doivent s'appliquer aux systèmes mis en œuvre avec des supports redondants:

a) chaque canal (câble) doit satisfaire aux règles de configuration du réseau;

b) il ne doit pas y avoir de segment non redondant entre deux segments redondants;

c) les répéteurs doivent également être redondants;

d) si le système est configuré (par la Gestion systèmes) pour émettre sur plusieurs canaux simultanément, alors la différence de délai de propagation entre deux appareils quelconques sur deux canaux quelconques ne doit pas dépasser cinq temps binaires;

e) les numéros de canaux doivent être maintenus sur l'ensemble des bus de terrain, c'est-à-dire que les canaux 1, 2, 3... en provenance de la Gestion systèmes doivent toujours être connectés aux canaux physiques 1, 2, 3...

#### 13.3.4 Règles de distribution de l'alimentation pour la configuration du réseau

Voir 11.3.4.

### 13.4 Spécification du circuit de transmission de la MAU

#### 13.4.1 Généralités

Les exigences du 13.4 sont résumées dans le Tableau 104 et le Tableau 105.

**Tableau 104 – Récapitulatif de la spécification du niveau de transmission de la MAU**

| Caractéristiques du niveau de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 93) | Limites (alimenté par bus et/ou IS) |
|---|---|
| Niveau de sortie (crête à crête, voir la Figure 80)<br>Avec charge d'essai (> 2 x la $Z_o$ nominale du câble de ligne principale) | ≥ 2,5 V<br>320 Ω avec une tolérance de ± 1 % |
| Différence d'amplitude positive et négative maximale (biais de la signalisation) telle qu'elle est représentée à la Figure 81 | ±0,2 V |
| Niveau de sortie; circuit ouvert (crête à crête) | ≤ 4,0 V |
| Distorsion maximale du signal de sortie, c'est-à-dire surtension, suroscillation et statisme (voir la Figure 80) | ±10 % |
| Sortie d'émetteur passif, c'est-à-dire bruit de l'émetteur (mesuré sur la bande de fréquence de 1 kHz à 4 MHz) | ≤ 1 mV (eff.) |

**Tableau 105 – Récapitulatif de la spécification de temporisation de transmission de la MAU**

| Caractéristiques de temporisation de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 93) | Limites (alimenté par bus et/ou IS) |
|---|---|
| Débit binaire de transmission | 1 Mbit/s avec une tolérance de ± 0,01 % |
| Temps binaire instantané | 1 µs ± 0 025 µs |
| Temps de croissance et de décroissance (10 % à 90 % du signal crête à crête, voir la Figure 80) | ≤ 20 % Tbit |
| Taux de dérive (en tout point de 10 % à 90 % du signal crête à crête) | ≤40,0 V/µs |
| Instabilité maximale de bit élémentaire reçu (écart du point de passage par zéro (voir la Figure 81) | ± 2,5 % Tbit |
| Délai d'activation/désactivation de transmission (c'est-à-dire durée pendant laquelle il est admis que la forme d'onde de sortie ne satisfasse pas aux exigences de transmission) | ≤ 2,0 Tbit |

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### 13.4.2 Configuration d'essai

La Figure 93 représente la configuration qui doit être utilisée pour les essais.

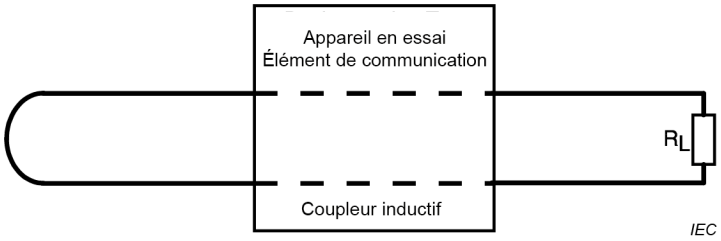


**Figure 93 – Configuration d'essai d'une MAU en mode courant**

La configuration d'essai de l'Article 13 doit être telle qu'elle est représentée à la Figure 93 sauf spécification contraire dans une exigence particulière.

NOTE Résistance de la charge d'essai R = 320 Ω (deux fois la valeur $Z_o$ maximale du câble), la sortie étant chargée par une boucle série de la ligne principale.

### 13.4.3 Exigences de niveau de sortie

NOTE La Figure 80 présente un exemple de cycle de forme d'onde de bus de terrain, qui représente certains éléments-clés de la spécification du circuit de transmission. Seules les tensions des signaux sont indiquées; ce schéma ne tient aucunement compte des tensions d'alimentation.

Un circuit de transmission de MAU en mode courant doit satisfaire aux exigences de niveau de sortie suivantes, et toutes les amplitudes sont mesurées au point médian estimé entre toute crête ou creux en haut et en bas de la forme d'onde ("point médian" à la Figure 80):

a) la tension de sortie sur la charge d'essai après élévation/abaissement par le transformateur ne doit pas être inférieure à 2,5 V crête à crête avec une résistance de charge de 320 Ω avec une tolérance de ± 1 % ("min o/p" à la Figure 80);

b) la tension de sortie au niveau de la ligne principale ou aux bornes de transmission, avec toute charge qui comprend un circuit ouvert, ne doit pas dépasser 4,0 V crête à crête ("max. o/c ligne principale" à la Figure 80). A des fins d'essai, un circuit ouvert doit être défini comme une charge qui présente une résistance de 100 kΩ en parallèle avec une capacité de 15 pF;

c) au cours d'une émission, un appareil donné ne doit pas subir de défaillance permanente lorsqu'une résistance de charge de ≤ 1 Ω est appliquée pendant 1 s;

d) la différence entre amplitude positive et amplitude négative, mesurée comme cela est représenté à la Figure 80, ne doit pas dépasser ± 0,2 V crête;

e) le bruit en sortie d'une MAU en mode courant qui est en réception ou non alimentée ne doit pas dépasser 1 mV eff., mesuré de manière différentielle sur la bande de fréquence de 1 kHz à 4 MHz, en référence à la ligne principale;

f) la tension différentielle sur la charge d'essai doit donner une modification monotonique de la tension, entre 10 % et 90 % de la valeur crête à crête. Par la suite, la tension du signal ne doit pas varier de plus de ±10 % de la valeur crête à crête jusqu'à ce que la transition suivante ait lieu. Cette variation admise doit inclure toutes les formes de distorsion de signal de sortie, c'est-à-dire la surtension, la suroscillation et le statisme.

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### 13.4.4 Exigences de temporisation des sorties

Un circuit de transmission d'une MAU en mode courant doit satisfaire aux exigences suivantes de temporisation des sorties:

a) les temps de croissance et de décroissance, mesurés de 10 % à 90 % de l'amplitude du signal crête à crête, ne doivent pas dépasser 0,2 $T_{bit}$ (voir la Figure 80);

b) le taux de dérive, mesuré en tout point dans une plage de 10 % à 90 % de l'amplitude du signal crête à crête, ne doit pas dépasser 40 V/ µs (voir la Figure 80);

NOTE 1 Les exigences a) et b) génèrent une forme d'onde trapézoïdale à la sortie du circuit de transmission. L'exigence b) limite le niveau des émissions de perturbation qui peuvent être couplées aux circuits adjacents, etc. L'exigence b) est calculée à partir de la formule suivante:

$$\text{taux de dérive max.} = 3 \text{ x taux de dérive min} = 3 \times 0{,}8\ V_o / 0{,}2\ Tbit = 12 \times V_o / Tbit,$$

où $V_o$ est une estimation de la tension de sortie maximale crête à crête avec une charge normalisée (3,3 V).

c) l'instabilité de bit élémentaire émis ne doit pas dépasser ±0,025 du temps binaire nominal par rapport au point de passage par zéro théorique, mesuré en fonction du point de passage par zéro précédent (voir la Figure 94);

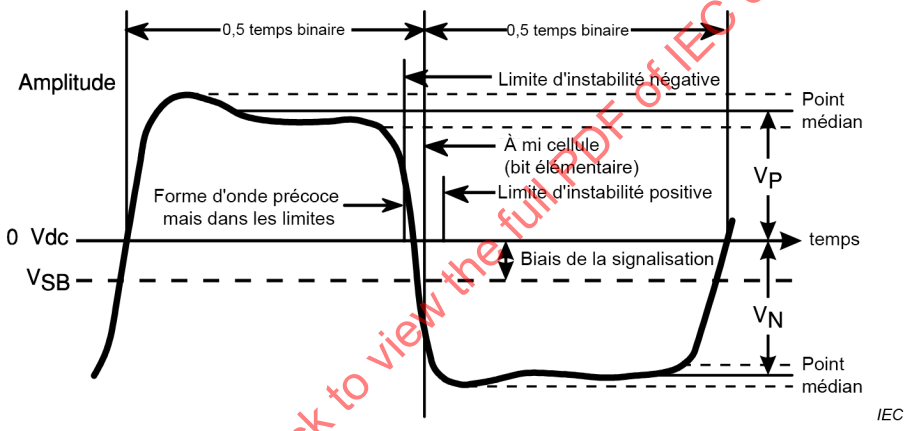


**Figure 94 – Instabilité de bit élémentaire transmis et reçu (écart du point de passage par zéro)**

d) le circuit de transmission doit s'activer, ce qui signifie que le signal doit monter d'un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 13.4.3 e), jusqu'au niveau de pleine puissance, en moins de 2,0 $T_{bit}$. La forme d'onde qui correspond au troisième temps binaire et au-delà, doit être telle qu'elle est spécifiée dans d'autres paragraphes du 13.4;

e) le circuit de transmission doit se désactiver, ce qui signifie que le signal doit tomber depuis le niveau de pleine puissance jusqu'à un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 13.4.3 e), en moins de 2,0 $T_{bit}$. La durée nécessaire pour que le circuit de transmission revienne à son impédance d'état "non actif" ne doit pas dépasser 4,0 $T_{bit}$. A des fins d'essai, cette exigence doit être satisfaite dans la configuration d'essai du circuit de transmission de la 13.4.2, avec la capacité équivalente d'une longueur de câble maximale entre les bornes de l'appareil en essai.

NOTE 2 Cette exigence permet d'assurer que la capacité de la ligne a été pleinement déchargée lors de la transition du circuit de transmission de l'état actif à l'état passif.

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### 13.5 Spécification du circuit de réception de la MAU

#### 13.5.1 Généralités

Pour faciliter le renvoi aux textes correspondants, les exigences définies au 13.4 sont résumées dans le Tableau 106.

**Tableau 106 – Récapitulatif de la spécification du circuit de réception**

| Caractéristiques du circuit de réception (valeurs en référence à la ligne principale) | Limites (alimenté par bus et/ou IS) |
|---|---|
| Impédance d'entrée, mesurée sur la plage de fréquences 0,25 fr à 1,25 fr | ≤ 2,5 Ω |
| Sensibilité; signal minimal crête à crête dont l'acceptation est exigée (voir la Figure 83) | 1,3 mA |
| Suppression du bruit; bruit maximal crête à crête dont le rejet est exigé (voir la Figure 83) | 0,8 mA |
| Instabilité maximale de bit élémentaire reçu (écart du point de passage par zéro (voir la Figure 94) | ±0,10 $T_{bit}$ |

#### 13.5.2 Impédance d'entrée

L'impédance d'entrée différentielle d'un circuit de réception de MAU en mode courant ne doit pas dépasser 2,5 Ω en série avec la phase sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz). Cette exigence doit être satisfaite à l'état hors tension et sous tension (sans émission), ainsi que pendant la transition entre ces états. L'impédance doit être mesurée au niveau du coupleur inductif au moyen d'une forme d'onde de courant sinusoïdale d'une amplitude de signal supérieure au seuil de sensibilité du récepteur et inférieure à 20 mA crête à crête.

NOTE L'exigence d'une impédance d'entrée ≤ 2,5 Ω pendant la mise sous tension et hors tension peut être satisfaite par désactivation automatique de l'émetteur au cours de ces périodes.

#### 13.5.3 Sensibilité du récepteur et suppression du bruit

Un circuit de réception de MAU doit être capable de recevoir un signal d'entrée de 1,3 mA crête à crête à 20,0 mA crête à crête, y compris la surtension et l'oscillation (voir "niveau du signal", ainsi que "amplitude positive" et "amplitude négative" à la Figure 80).

Un circuit de réception de MAU ne doit pas répondre à un signal d'entrée dont l'amplitude crête à crête de courant de ligne ne dépasse pas 0,8 mA (voir "suppression du bruit" à la Figure 83).

#### 13.5.4 Instabilité de bit élémentaire reçu

Le circuit de réception doit accepter un signal codé Manchester transmis conformément au 13.2 et au 13.4. En outre, le récepteur doit fonctionner correctement à des signaux avec une variation temporelle, entre deux points adjacents quelconques de transition des signaux (passage par zéro) de 0,10 $T_{bit}$t, au plus. Voir la Figure 94.

NOTE 1 Cette spécification n'exclut pas l'utilisation de récepteurs dont les performances sont supérieures à la présente spécification.

NOTE 2 En fonction de la configuration du symbole, la durée nominale entre passages par zéro est d'un demi temps binaire ou d'un temps binaire.

NOTE 3 Il n'y a aucune exigence quant au rejet d'un signal donné avec une valeur de variation temporelle spécifiée. Le récepteur rend compte d'une erreur lorsque l'instabilité de bit élémentaire reçu dépasse l'aptitude du récepteur à décoder la signalisation de manière fiable.

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### 13.5.5 Susceptibilité au brouillage et taux d'erreurs

Lorsque le bus de terrain fonctionne dans différents environnements de bruit normalisés, il convient que la probabilité qu'une unité de données utilisateur de couche Application contienne une erreur non détectée, du fait du fonctionnement des entités physiques et DLL d'acheminement, soit inférieure à 1 sur $10^{12}$ (1 erreur en 20 années à 1 600 messages/s).

Un élément de communication est réputé conforme à cette exigence théorique lorsqu'il satisfait aux exigences suivantes de susceptibilité au brouillage. Ces exigences sont spécifiées sur la base d'un taux d'erreur de trame détecté obtenu au moyen d'un rapport d'erreurs détectées/non détectées de $10^6$.

NOTE 1 Cela est facilement réalisable au moyen d'une séquence de contrôle de trame de 16 bits au niveau de la DLL.

Un élément de communication qui inclut une MAU en mode courant, qui utilise des trames contenant 64 bits de données utilisateur aléatoires, à un débit de trame maximal et avec des signaux d'une amplitude de 4,0 mA crête à crête, ne doit pas produire plus de trois erreurs de trame détectées sur 3 x $10^6$ trames pendant son fonctionnement en présence d'une tension en mode commun ou de bruit gaussien comme cela est décrit ci-après:

a) un signal sinusoïdal en mode commun à toute fréquence de 63 Hz à 2 MHz, d'une amplitude de 4 V eff. et de 47 Hz à 63 Hz avec une amplitude de 250 V eff.;

b) un signal DC en mode commun de ±10 V;

c) un bruit blanc gaussien différentiel additionnel dans la bande de fréquence de 1 kHz à 4 MHz, avec une densité de bruit de 0,09 µA/√Hz eff. à l'aide du circuit d'essai de la Figure 95.

NOTE 2 Les valeurs spécifiées pour la tension en mode commun et le bruit gaussien correspondent à des essais de conformité de circuit de réception avec des charges symétriques et ne sont pas représentatives d'une quelconque pratique d'installation de système.

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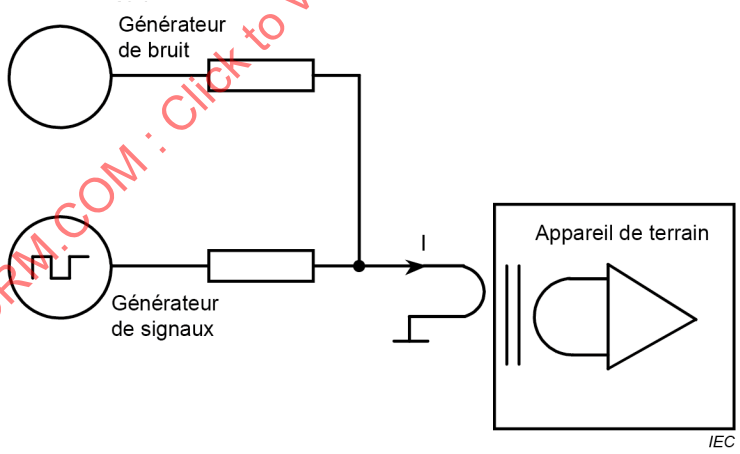


**Figure 95 – Circuit d'essai du bruit d'une MAU en mode courant**

Un élément de communication qui inclut une MAU en mode courant, qui utilise des trames contenant 64 bits de données utilisateur aléatoires, à une moyenne de 1 600 messages/s, avec des signaux d'une amplitude de 4,0 mA crête à crête, ne doit pas produire plus de six erreurs de trame détectées sur 100 000 trames, lorsqu'il est utilisé dans des environnements de perturbations électromagnétiques ou électriques comme cela est décrit ci-après:

1) champ électromagnétique de 10 V/m, comme cela est spécifié dans l'IEC 61000-43 au niveau de sévérité 3;

2) transitoires électriques rapides, comme cela est spécifié dans l'IEC 61000-4-4 au niveau de sévérité 3.

Le taux d'erreur spécifié ci-dessus doit également être satisfait après, mais non pendant le fonctionnement dans les environnements de bruit suivants:

i) décharge électrostatique de 8 kV sur une structure métallique exposée, comme cela est spécifié dans l'IEC 61000-4-2, au niveau de sévérité 3. Si l'appareil subit une perte temporaire de fonctions ou de performances par suite de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai;

ii) essais de perturbation à haute fréquence, comme cela est spécifié dans l'IEC 60255-22-1:1988, classe III de tension d'essai (valeurs crêtes de 2,5 kV et 1 kV de la première demi-alternance, respectivement en mode longitudinal et transversal). Si l'appareil subit une perte temporaire de fonctions ou de performances du fait de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai.

### 13.6 Inhibition du bavardage

La MAU doit comporter une capacité d'interruption automatique pour empêcher les signaux émis d'atteindre le support. Le matériel dans la MAU (sans message extérieur autre que la détection des signaux de sortie ou de fuite par la fonction de transmission) doit fournir une fenêtre d'une durée comprise entre 5 ms et 15 ms au cours de laquelle une trame normale peut être émise. Si la longueur de trame dépasse cette durée, la fonction d'inhibition du bavardage doit empêcher d'autres signaux en sortie d'atteindre le support et doit désactiver l'écho sur la ligne RxS (voir 10.2.2.2) pour indiquer à la MDS la détection de bavardage.

La MAU doit réinitialiser la fonction d'interruption automatique après une période de 500 ms avec une tolérance de ± 50 %.

NOTE Cette disposition neutralise le trafic sur le bus pendant 6 % (= 15/250) du temps disponible au plus.

### 13.7 Distribution de l'alimentation

#### 13.7.1 Généralités

Un appareil peut, facultativement, recevoir son alimentation par l'intermédiaire des conducteurs de signaux ou être alimenté de manière séparée.

Un appareil peut être certifié comme étant de sécurité intrinsèque quelle que soit la méthode d'alimentation.

Le présent document n'inclut pas d'exigences pour la certification IS, mais cherche à exclure des conditions ou situations qui empêchent la certification IS.

Un appareil à alimentation séparée peut être connecté à un bus de terrain alimenté.

Pour faciliter le renvoi aux textes correspondants, les exigences définies au 13.7 sont résumées dans le Tableau 107.

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**Tableau 107 – Exigences d'alimentation réseau**

| Exigences d'alimentation réseau | Limites |
|---|---|
| Courant de sortie | 50 mA à 200 mA eff. |
| Fréquence de sortie | 16 kHz ± 0,5 % |
| Tension de sortie maximale, IS | En fonction des caractéristiques assignées de la barrière |
| Taux d'harmoniques du courant d'alimentation | ≤ 0,2 % |
| Impédance de sortie, mesurée sur la plage de fréquences 0,25 fr à 1,25 fr | ≤ 5 Ω |

### 13.7.2 Alimentation par l'intermédiaire de conducteurs de signaux

Un appareil doit fonctionner sur une plage de courant constant de 50 mA à 200 mA.

NOTE La tension de sortie de l'alimentation dépend des pertes dues au câble et de la puissance consommée par chaque appareil.

Un appareil de bus de terrain peut être conçu pour consommer une ou plusieurs charges normalisées. Une charge normalisée est égale à 100 mW.

La tension de sortie en circuit ouvert de l'alimentation doit être inférieure à la limite spécifiée par l'organisme de réglementation local pour la mise en œuvre particulière. L'impédance de sortie de l'alimentation doit être ≤ 5 Ω sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz).

La chute de tension dans le coupleur de signaux doit être inférieure à 0,1 V à une fréquence de 16 kHz.

La chute de tension dans les terminaisons doit être inférieure à 0,3 V à une fréquence de 16 kHz.

La forme d'onde d'alimentation doit être une sinusoïde pure d'une fréquence de 16 kHz avec une tolérance de ± 0,5 % et une distorsion harmonique maximale de 0,2 %.

L'appareil ne doit pas introduire, dans la ligne principale, de composantes harmoniques de la fréquence industrielle supérieure à 1,0 mV crête à crête entre phases.

### 13.7.3 Alimentation séparée du signal

NOTE La distribution de l'alimentation pour des appareils de bus de terrain non alimentés par le bus s'effectue au moyen de conducteurs séparés qui fournissent l'énergie à des alimentations locales, des régulateurs ou des barrières de sécurité. La certification IS peut exiger que ces conducteurs soient dans un câble séparé de celui des conducteurs de signaux et peut également imposer des exigences de niveau de courant plus strictes que celles qui sont spécifiées.

Un appareil de bus de terrain alimenté séparément, qui revendique la conformité à l'Article 13 ne doit pas provoquer de chute de tension supérieure à 1 mV eff, à la fréquence industrielle sur les conducteurs de signaux, et ne doit pas fournir un courant de plus de 100 µA eff aux conducteurs de signaux, lorsqu'il n'y a pas de transmission.

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### 13.7.4 Isolation électrique

Tous les appareils de bus de terrain, alimentés séparément ou par l'intermédiaire des conducteurs de signaux, doivent assurer une isolation basse fréquence entre la masse et le câble de ligne principale du bus de terrain.

NOTE 1 Cette isolation peut s'effectuer par un coupleur inductif avec une isolation suffisante, par isolation de l'ensemble de l'appareil de la masse ou au moyen d'un transformateur, d'un optocoupleur ou de tout autre organe d'isolation entre le câble de ligne principale et l'appareil.

Une alimentation et un élément de communication combinés ne doivent pas exiger d'isolation électrique.

L'impédance d'isolation mesurée entre le blindage du câble de bus de terrain et la masse de l'appareil de bus de terrain doit être supérieure à 250 kΩ à toutes les fréquences inférieures à 63 Hz.

L'isolation doit être contournée par une capacité à des fréquences élevées, de sorte que l'impédance mesurée entre le blindage du câble du bus de terrain et la masse de l'appareil de bus de terrain soit inférieure à 15 Ω entre 3 MHz et 30 MHz.

NOTE 2 La capacité entre la masse et le blindage du câble de ligne principale nécessaire pour satisfaire à ces exigences peut prendre toute valeur comprise entre 3,5 nF et 10,6 nF.

La capacité dissymétrique maximale par rapport à la masse de toute borne d'entrée d'un appareil ne doit pas dépasser 250 pF.

Les exigences de claquage de l'isolation du circuit de signaux et du circuit de distribution de l'alimentation par rapport à la masse et par rapport à l'autre circuit doivent être conformes à l'IEC 61131-2.

La tension d'essai équivalente doit être appliquée entre circuits isolés indépendants ou entre circuits isolés et parties conductrices accessibles.

NOTE 3 Pour des circuits de tension nominale ≤ 50 V en courant continu ou efficace, les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 444 V eff., 635 V en courant continu et 635 V crête. Pour des circuits de tension nominale comprise entre 150 V et 300 V eff., les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 2 260 V eff., 3 175 V en courant continu et 3 175 V crête.

## 13.8 Spécifications du support

### 13.8.1 Connecteur

Si des connecteurs de câbles sont utilisés, ils doivent être conformes à la norme de bus de terrain correspondante de l'IEC (voir l'Annexe A). Des techniques de terminaison sur le terrain, comme les bornes à vis ou à lames, ainsi que les terminaisons permanentes, peuvent également être utilisées.

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### 13.8.2 Câble d'essai normalisé

Le câble utilisé pour les essais d'appareils de bus de terrain avec une MAU en mode courant, destinés à vérifier la satisfaction aux exigences de l'Article 13, doit être un câble unique à paire torsadée, à blindage global, qui satisfait aux exigences minimales suivantes, à une température de 25 °C:

a) $Z_o$ à une fréquence de 0,25 $f_r$ (250 kHz) = 150 Ω avec une tolérance de ± 10 %;

b) $Z_o$ à une fréquence de 1,25 $f_r$ (1,25 MHz) = 150 Ω avec une tolérance de ± 10 %;

c) affaiblissement maximal à une fréquence de 0,25 $f_r$ (250 kHz) = 6,5 dB/km;

d) affaiblissement maximal à une fréquence de 1,25 $f_r$ (1,25 MHz) = 13 dB/km;

e) déséquilibre capacitif maximal par rapport au blindage = 1,5 nF/km;

f) résistance maximale en courant continu (par conducteur) = 57,1 Ω/km;

g) section du conducteur (dimension des fils) = 0,33 $mm^2$, valeur nominale;

h) résistivité minimale entre chaque conducteur et le blindage = 16 GΩ/km;

i) la couverture minimale du blindage doit être de 95 %.

La spécification ci-dessus concerne les essais de conformité d'une MAU. D'autres types de câbles peuvent être utilisés dans les installations réelles (voir l'Annexe B). Les câbles à spécifications améliorées peuvent permettre l'utilisation de longueurs de ligne principale plus importantes et/ou une meilleure immunité aux perturbations. En revanche, les câbles qui présentent des spécifications inférieures peuvent être utilisés, sous réserve d'une limitation des longueurs utilisées, tant pour les lignes principales que secondaires, à laquelle s'ajoute une éventuelle non-conformité aux exigences de susceptibilité aux perturbations radioélectriques (RFI) et électromagnétiques (EMI).

Pour des applications de sécurité intrinsèque, il convient que le rapport inductance/résistance (L/R) soit inférieur à la limite spécifiée par l'organisme de réglementation local pour la mise en œuvre particulière.

### 13.8.3 Coupleur

Un coupleur inductif connecte un appareil ou une ligne secondaire à la ligne principale. Il assure l'échange des signaux de données à destination et en provenance de l'appareil, et peut transférer l'alimentation à l'appareil. Le câble de ligne principale fonctionne comme une spire primaire unique du transformateur du coupleur inductif. Les options suivantes sont admises:

a) le couplage peut être réalisé sans violation de l'isolation du câble;

b) le coupleur inductif peut être utilisé comme connecteur;

c) un élément de barrière IS peut être inclus comme partie intégrante du coupleur inductif.

Le coupleur doit faire partie intégrante de la MAU si l'appareil est connecté à la ligne principale. L'impédance d'entrée du coupleur doit avoir une valeur maximale de 2,5 Ω en série avec la phase.

### 13.8.4 Épissures

NOTE Une épissure est toute partie du réseau dans laquelle l'impédance caractéristique du câble de réseau n'est pas maintenue. Cela peut être dû à la séparation des conducteurs du câble, au retrait de blindage du câble, à la modification de calibre ou de type de fil, à la connexion de lignes secondaires, etc. Une définition pratique d'une épissure est par conséquent toute partie du réseau qui n'est pas une longueur continue du support spécifié.

La continuité de tous les conducteurs du câble doit être maintenue dans une épissure.

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### 13.8.5 Terminateur

Un terminateur doit être placé aux deux extrémités du câble de ligne principale et connecté d'un conducteur de signal à l'autre. Il ne doit y avoir aucune connexion entre le terminateur et le blindage du câble.

A des fins d'essai, en utilisant le câble spécifié au 13.8.2, le terminateur doit avoir une valeur d'impédance de 120 Ω avec une tolérance de ± 2 % sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz).

NOTE 1 La valeur de la résistance du terminateur a été choisie pour être inférieure à la valeur de l'impédance caractéristique du câble d'essai, car les appareils en mode courant ajoutent des impédances série au terminateur. La valeur a été choisie pour réduire les réflexions de la ligne de transmission pour un bus de terrain qui comporte de 2 à 32 appareils.

NOTE 2 Dans des applications pratiques, lorsque l'alimentation est fournie par les conducteurs de signaux, le terminateur est contourné aux fréquences industrielles afin de réduire le plus possible les pertes de puissance.

Le courant continu de fuite à travers le terminateur ne doit pas dépasser 100 µA. Le terminateur doit être non polarisé.

Tous les terminateurs utilisés pour les applications IS doivent satisfaire aux exigences d'isolation (lignes de fuite et distances d'isolement) en fonction de l'homologation IS exigée. L'homologation IS ne doit pas être exigée pour des terminateurs destinés à des applications non IS.

### 13.8.6 Règles de blindage

Pour une entière satisfaction aux exigences d'immunité au bruit du 13.5, il est nécessaire d'assurer l'intégrité du blindage sur toute la longueur du câblage, dans les connecteurs et dans les coupleurs, de la manière suivante:

a) la couverture du blindage doit être supérieure à 95 % de la longueur totale du câble;

b) le blindage doit couvrir complètement les circuits électriques des connecteurs, des coupleurs et des épissures.

NOTE Toute dérogation à ces règles de blindage peut dégrader l'immunité au bruit.

### 13.8.7 Règles de mise à la masse

NOTE 1 Mise à la masse signifie une connexion permanente à la terre par l'intermédiaire d'une impédance suffisamment basse et ayant un courant admissible suffisant pour prévenir un amorçage en tension qui peut entraîner un danger excessif pour le matériel connecté ou les personnes.

Les lignes de tension zéro (commun) peuvent être reliées à la masse où elles sont galvaniquement isolées de la ligne principale du bus de terrain.

Les appareils de bus de terrain doivent fonctionner conformément aux exigences de l'Article 13, le point médian d'un terminateur ou d'un coupleur inductif étant directement connecté à la masse.

Les appareils de bus de terrain ne doivent pas raccorder l'un des conducteurs de la paire torsadée à la masse, quel que soit le point du réseau. Les signaux doivent être appliqués et préservés de manière différentielle sur l'ensemble du réseau.

Il est habituel dans la pratique de mettre effectivement à la masse le blindage du câble de ligne principale de bus de terrain (le cas échéant) en un point sur la longueur du câble. De ce fait, il convient que les appareils de bus de terrain permettent une isolation en courant continu du blindage du câble par rapport à la masse.

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Pour des systèmes alimentés par le bus, il convient que la mise à la masse du blindage et des conducteurs de signaux équilibrés soit proche de l'unité d'alimentation.

Pour les systèmes IS, il convient que la mise à la masse soit effectuée au niveau de la connexion à la terre de la barrière de sécurité. Un couplage capacitif est admis entre le blindage ou les conducteurs de signaux équilibrés et la mise à la masse locale de l'appareil pour une meilleure immunité aux interférences électromagnétiques sous réserve de satisfaire aux exigences IS.

#### 13.8.8 Code de couleur des câbles

Voir 11.8.8.

## 14 Type 1: Unité de liaison au support: mode courant (1 A), support câblé à paire torsadée

### 14.1 Généralités

Une MAU en mode courant de 1,0 Mbit/s fournit simultanément l'accès à un réseau de communication et à un réseau de distribution d'énergie avec une capacité d'alimentation étendue. Les appareils raccordés au réseau communiquent par l'intermédiaire du support et peuvent ou non être alimentés par ce support. L'alimentation est distribuée comme un courant alternatif constant d'une fréquence bien inférieure à la fréquence des signaux. Les signaux de communication sont superposés à l'alimentation en courant alternatif.

Le support de réseau est composé d'un câble à paire torsadée blindé.

Dans des applications de zone dangereuse, un bus non IS peut comporter des barrières IS intégrées aux appareils connectés, ce qui permet d'augmenter le nombre d'appareils admissible dans la zone dangereuse sur une configuration de barrière unique.

Les appareils sont connectés en série sur le bus, tandis que dans les variantes en mode tension, les appareils sont connectés au bus en parallèle.

### 14.2 Débit binaire de transmission

Voir 13.2.

### 14.3 Spécifications du réseau

#### 14.3.1 Composants

Une MAU fonctionne sur un réseau constitué des composants suivants:

a) un câble;
b) des terminateurs;
c) des coupleurs;
d) des montages pour coupleurs;
e) des appareils (qui comportent au moins un élément de communication).

Un réseau filaire en mode courant peut en outre inclure les composants suivants:

a) des connecteurs;
b) des alimentations;
c) des appareils qui comprennent les alimentations;
d) des barrières de sécurité intrinsèque (IS).

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Le support de réseau est composé d'un câble à paire torsadée blindé. Indépendamment de la topologie, tous les appareils connectés, sauf éventuellement l'appareil de transmission, présentent une faible impédance pour éviter une surcharge importante du réseau.

Un montage pour coupleur est un élément du réseau qui permet de connecter un coupleur au support réseau. Il peut être considéré comme un enroulement primaire de transformateur (coupleur inductif) et, en tant que tel, il présente des caractéristiques électriques qui affectent le réseau.

### 14.3.2 Topologies

Une MAU câblée doit fonctionner sur un réseau de topologie de bus linéaire constitué d'une ligne principale, terminée à chaque extrémité comme cela est spécifié au 14.8.5, et à laquelle des éléments de communication sont connectés par l'intermédiaire de coupleurs.

Le coupleur et l'élément de communication peuvent être intégrés dans un seul appareil (comme une ligne secondaire de longueur zéro).

Plusieurs éléments de communication peuvent être connectés à la ligne principale en un point donné, au moyen d'un coupleur multivoies. Un coupleur actif peut être utilisé pour étendre une ligne secondaire sur une longueur qui exige une terminaison afin d'éviter les réflexions et distorsions. Des répéteurs actifs peuvent être utilisés pour étendre la longueur de la ligne principale au-delà d'un segment unique comme le permettent les règles de configuration du réseau.

### 14.3.3 Règles de configuration du réseau

Une MAU qui revendique la conformité à l'Article 14 doit satisfaire aux exigences de l'Article 14 lorsqu'elle est utilisée sur un réseau qui satisfait à ces règles.

**Règle 1:** Un bus de terrain doit être capable de prendre en charge la communication d'un nombre d'appareils compris entre deux et 30, qui fonctionnent tous au même débit binaire, qu'il s'agisse d'un bus alimenté ou non alimenté et dans une zone dangereuse qui utilise des barrières distribuées.

NOTE 1 Cette règle n'exclut pas l'utilisation d'un nombre d'appareils supérieur à celui spécifié dans un système installé. Le nombre d'appareils a été calculé sur l'hypothèse selon laquelle un appareil alimenté par le bus prélève 1,0 W.

**Règle 2:** Un segment de bus de terrain à pleine charge (qui comporte le nombre maximal d'appareils connectés) en mode courant doit avoir une longueur totale de câble, entre deux appareils quelconques, jusqu'à 400 m au plus.

NOTE 2 Cette longueur maximale du câble de 400 m est l'exigence de conformité à l'Article 14, mais n'exclut pas l'utilisation de longueurs supérieures dans un système installé.

**Règle 3:** Le nombre total de régénérations de forme d'onde par des répéteurs et des coupleurs actifs entre deux appareils quelconques dépend de la mise en œuvre du répéteur concerné.

NOTE 3 Ce nombre total était limité à cinq dans les éditions précédentes du présent document.

**Règle 4:** Le délai maximal de propagation entre deux appareils quelconques ne doit pas dépasser 40 $T_{bit}$.

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Pour que le réseau fonctionne efficacement, il convient que cette partie du temps de retournement de tout appareil du réseau, générée par une PhE entre la fin d'une trame reçue et le début d'une trame émise qui contient une réponse immédiate associée, ne dépasse pas cinq temps binaires, dont il convient que 2 temps binaires au plus soient dus à la MAU.

NOTE 4 Sachant qu'il n'est pas obligatoire d'exposer l'interface DLL – PhL ou l'interface MDS – MAU, cette partie du temps de retournement d'un appareil de bus de terrain due à la PhL ou à la MAU n'est pas spécifiée et donc non disponible pour des essais de conformité.

**Règle 5:** Le bus de terrain doit pouvoir fonctionner en continu lorsqu'un appareil y est connecté ou déconnecté. Les erreurs de données générées lors de la connexion ou de la déconnexion doivent être détectées.

**Règle 6:** La défaillance de tout élément de communication ou de toute ligne secondaire (y compris un court-circuit, ou un circuit ouvert, mais à l'exception des bavardages) ne doit pas interférer avec les transactions entre d'autres éléments de communication pendant plus de 1 ms.

**Règle 7:** Le réseau ne doit pas être sensible à la polarité, avec ou sans énergie injectée sur la ligne.

**Règle 8:** La dégradation des caractéristiques électriques du signal, entre deux appareils quelconques, due à l'affaiblissement, à la distorsion d'affaiblissement et à la désadaptation, doit être limitée aux valeurs indiquées ci-dessous.

a) Affaiblissement du signal: l'affaiblissement du signal dû à chaque appareil ne doit pas dépasser 0,35 dB. L'affaiblissement du signal dû à chaque montage pour coupleur, qu'il soit plein ou vide, ne doit pas dépasser 0,6 dB. La configuration du bus (longueurs de la ligne principale et des lignes secondaires, nombre d'appareils, barrières IS, sectionneurs galvaniques et éventuels appareils d'adaptation) doit être telle que l'affaiblissement entre deux appareils quelconques, à la fréquence qui correspond au débit binaire, ne doit pas dépasser 10 dB.

   NOTE 5 L'affaiblissement du signal dû à un appareil est calculé avec un câble d'une impédance caractéristique de 80 Ω. Si un câble d'impédance plus faible est utilisé, alors l'affaiblissement par appareil augmente.

   Il est exigé que les appareils soient connectés au bus au moyen d'un montage pour atteindre le nombre maximal d'appareils connectés.

b) Distorsion d'affaiblissement: la configuration du bus (les longueurs de la ligne principale et des lignes secondaires, ainsi que le nombre d'appareils) doit être telle qu'entre deux appareils quelconques:

   [Affaiblissement (1,25 $f_r$) – Affaiblissement (0,25 $f_r$)] ≤ 6 dB

   Affaiblissement (1,25 $f_r$) ≥ Affaiblissement (0,25 $f_r$)

   où $f_r$ est la fréquence qui correspond au débit binaire. L'affaiblissement doit être monotonique pour toutes les fréquences de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz).

c) Distorsion de désadaptation: La désadaptation (due à des lignes secondaires ou à tout autre effet, y compris une ligne secondaire en circuit ouvert de longueur maximale) sur le bus doit être telle qu'en tout point sur la ligne principale dans la bande de fréquence comprise entre 0,25 $f_r$ et 1,25 $f_r$ (250 kHz à 1,25 MHz):

   $|Z - Zf_r| / |Z + Zf_r| \leq 0,2$

   où

   $Z_o$ est l'impédance caractéristique du câble de ligne principale;

   $Z$ est la combinaison série de $Z_o$ et de l'impédance de charge au niveau du coupleur.

NOTE 6 Cette règle permet de réduire le plus possible les restrictions, en matière de longueurs de la ligne principale et des lignes secondaires, ainsi qu'en matière de nombre d'appareils, etc. en ne spécifiant que les limites de transmission imposées par des combinaisons de ces facteurs. Il est possible d'utiliser différentes combinaisons en fonction des besoins de l'application.

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**Règle 9:** Les règles suivantes doivent s'appliquer aux systèmes mis en œuvre avec des supports redondants:

a) chaque canal (câble) doit satisfaire aux règles de configuration du réseau;

b) il ne doit pas y avoir de segment non redondant entre deux segments redondants;

c) les répéteurs doivent également être redondants;

d) si le système est configuré (par la Gestion systèmes) pour émettre sur plusieurs canaux simultanément, alors la différence de délai de propagation entre deux appareils quelconques sur deux canaux quelconques ne doit pas dépasser cinq temps binaires;

NOTE 7 Ce délai est égal à la valeur par défaut de la dérive du signal entre canaux (voir 9.2.9). La différence de temps de propagation peut être plus importante si le paramètre de dérive du signal entre canaux est établi de manière à correspondre à cette différence.

e) les numéros de canaux doivent être maintenus sur l'ensemble des bus de terrain, c'est-à-dire que les canaux 1, 2, 3… en provenance de la gestion système doivent toujours être connectés aux canaux physiques 1, 2, 3…

### 14.3.4 Règles de distribution de l'alimentation pour la configuration du réseau

Voir 11.3.4.

## 14.4 Spécification du circuit de transmission de la MAU

### 14.4.1 Généralités

Les exigences du 14.4 sont résumées dans le Tableau 108 et le Tableau 109.

**Tableau 108 – Récapitulatif de la spécification du niveau de transmission de la MAU en mode courant**

| Caractéristiques du niveau de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 93) | Limites (alimenté par bus et/ou IS) |
|---|---|
| Niveau de sortie (crête à crête, voir la Figure 80)<br>Avec charge d'essai (> 2 x la $Z_o$ nominale du câble de ligne principale) | ≥ 2,25 V<br>160 Ω avec une tolérance de ± 1 % |
| Distorsion maximale du signal de sortie; c'est-à-dire surtension, suroscillation et statisme (voir la Figure 80) | ±10 % |
| Sortie d'émetteur passif, c'est-à-dire bruit de l'émetteur (mesuré sur la bande de fréquence de 1 kHz à 4 MHz) | ≤ 1 mV (eff.) |

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**Tableau 109 – Récapitulatif de la spécification de temporisation de la transmission de la MAU en mode courant**

| Caractéristiques du niveau de transmission, valeurs en référence à la ligne principale (mais mesurées à l'aide de la charge d'essai représentée à la Figure 93) | Limites (alimenté par bus et/ou IS) |
|---|---|
| Débit binaire de transmission | 1 Mbit/s avec une tolérance de ± 0,01 % |
| Temps binaire instantané | 1 µs ± 0 025 µs |
| Temps de croissance et de décroissance (10 % à 90 % du signal crête à crête, voir la Figure 80) | ≤ 20 % $T_{bit}$ |
| Taux de dérive (en tout point de 10 % à 90 % du signal crête à crête) | ≤ 200,0 V/µs |
| Instabilité maximale de bit élémentaire émis (écart du point de passage par zéro, voir la Figure 96) | ± 2,5 % $T_{bit}$ |
| Délai d'activation/désactivation de transmission (c'est-à-dire durée pendant laquelle il est admis que la forme d'onde de sortie ne satisfasse pas aux exigences de transmission) | ≤ 2,0 $T_{bit}$ |

### 14.4.2 Configuration

La Figure 93 représente la configuration qui doit être utilisée pour les essais.

La configuration d'essai de l'Article 14 doit être telle qu'elle est représentée à la Figure 93 sauf spécification contraire dans une exigence particulière.

NOTE Résistance de la charge d'essai $R_L$ = 160 Ω avec une tolérance de ± 1 %, la sortie étant chargée par une boucle série de la ligne principale.

### 14.4.3 Exigences de niveau de sortie

NOTE La Figure 80 présente un exemple de cycle de forme d'onde de bus de terrain, qui représente certains éléments-clés de la spécification du circuit de transmission. Seules les tensions des signaux sont indiquées; ce schéma ne tient aucunement compte des tensions d'alimentation.

Un circuit de transmission de MAU en mode courant doit satisfaire aux exigences de niveau de sortie suivantes, et toutes les amplitudes sont mesurées au point médian estimé entre toute crête ou creux en haut et en bas de la forme d'onde ("point médian" à la Figure 80):

a) la tension de sortie sur la charge d'essai après élévation/abaissement par le transformateur ne doit pas être inférieure à 2,25 V crête à crête avec une résistance de charge de 160 Ω avec une tolérance de ± 1 % ("min o/p" à la Figure 80);

b) au cours d'une émission, un appareil donné ne doit pas subir de défaillance permanente lorsqu'une résistance de charge de ≤1 Ω est appliquée pendant 1 s;

c) le bruit en sortie d'une MAU en mode courant qui est en réception ou non alimentée ne doit pas dépasser 1 mV (efficace), mesuré de manière différentielle sur la bande de fréquence de 100 kHz à 4 MHz, en référence à la ligne principale;

d) la tension différentielle sur la charge d'essai doit donner une modification monotonique de la tension, entre 10 % et 90 % de la valeur crête à crête. Par la suite, la tension du signal ne doit pas varier de plus de ±10 % de la valeur crête à crête jusqu'à ce que la transition suivante ait lieu. Cette variation admise doit inclure toutes les formes de distorsion de signal de sortie, telles que la surtension, la suroscillation et le statisme.

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### 14.4.4 Exigences de temporisation des sorties

Le circuit de transmission d'une MAU doit satisfaire aux exigences suivantes de temporisation des sorties:

a) les temps de croissance et de décroissance, mesurés de 10 % à 90 % de l'amplitude du signal crête à crête, ne doivent pas dépasser 0,2 (voir la Figure 80);

b) le taux de dérive, mesuré en tout point dans une plage de 10 % à 90 % de l'amplitude du signal crête à crête, ne doit pas dépasser 200,0 V/ µs (voir la Figure 80);

c) l'instabilité de bit élémentaire émis ne doit pas dépasser ± 0,025 Tbit par rapport au point de passage par zéro théorique, mesuré en fonction du point de passage par zéro précédent (voir la Figure 96);

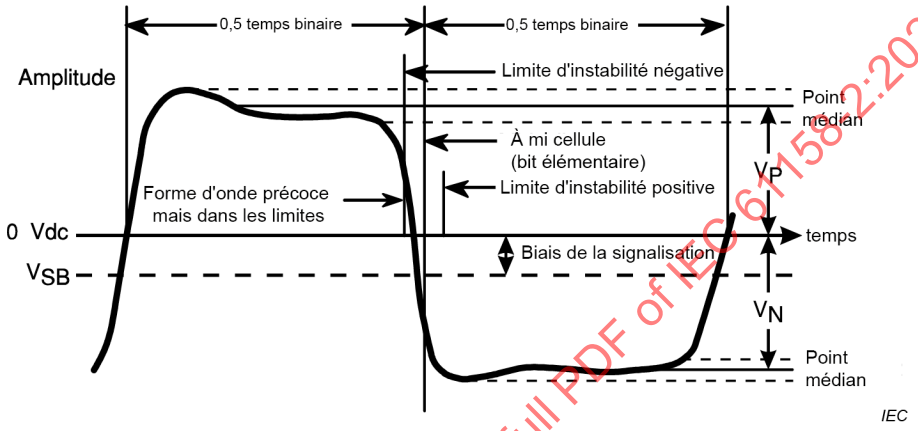


**Figure 96 – Instabilité de bit élémentaire transmis et reçu (écart du point de passage par zéro)**

d) le circuit de transmission doit s'activer, ce qui signifie que le signal doit monter, en moins de 2,0 $T_{bit}$, d'un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 14.4.3 c), jusqu'au niveau de pleine puissance. La forme d'onde qui correspond au troisième temps binaire et au-delà, doit être telle qu'elle est spécifiée dans d'autres paragraphes du 14.4;

e) le circuit de transmission doit se désactiver, ce qui signifie que le signal doit tomber, en moins de 2,0 $T_{bit}$, du niveau de pleine puissance à un niveau inférieur au bruit de sortie maximal du circuit de transmission, comme cela est spécifié au 14.4.3 c). La durée nécessaire pour que le circuit de transmission revienne à son impédance d'état "non actif" ne doit pas dépasser 4,0 $T_{bit}$. A des fins d'essai, cette exigence doit être satisfaite dans la configuration d'essai du circuit de transmission décrite au 14.4.2.

NOTE Cette exigence permet d'assurer que la capacité de la ligne a été pleinement déchargée lors de la transition du circuit de transmission de l'état actif à l'état passif.

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## 14.5 Spécification du circuit de réception de la MAU

### 14.5.1 Généralités

Les exigences du 14.5 sont résumées dans le Tableau 110.

L'impédance d'entrée du circuit de réception peut être inductive. Pour éviter que la partie résistive de l'impédance devienne trop élevée, l'impédance d'entrée totale maximale et la résistance d'entrée maximale sont spécifiées dans le Tableau 110.

**Tableau 110 – Récapitulatif de la spécification du circuit de réception de la MAU en mode courant**

| Caractéristiques du circuit de réception (valeurs en référence à la ligne principale) | Limites pour le mode courant (alimenté par bus et/ou IS) |
|---|---|
| Résistance d'entrée, mesurée sur la plage de fréquences comprise entre 0,25 $f_r$ et 1,25 $f_r$ (250 kHz à 1,25 MHz); | ≤ 0,5 Ω |
| Sensibilité; signal minimal crête à crête dont l'acceptation est exigée (voir la Figure 83) | 4,0 mA |
| Suppression du bruit; bruit maximal crête à crête dont le rejet est exigé (voir la Figure 83) | 2,0 mA |
| Instabilité maximale de bit élémentaire reçu (écart du point de passage par zéro (voir la Figure 94) | ±0,10 $T_{bit}$ |
| Impédance d'entrée mesurée sur la plage de fréquences comprise entre 0,25 $f_r$ et 1,25 $f_r$ (250 kHz à 1,25 MHz); | ≤ 4,0 Ω |

### 14.5.2 Impédance d'entrée

La résistance d'entrée différentielle d'un circuit de réception de MAU en mode courant ne doit pas dépasser 0,5 Ω, et l'impédance d'entrée différentielle d'un circuit de réception de MAU en mode courant ne doit pas dépasser 4,0 Ω en série avec la phase sur la fréquence de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz). Cette exigence doit être satisfaite à l'état hors tension et sous tension (sans émission), ainsi que pendant la transition entre ces états. L'impédance doit être mesurée au niveau du coupleur inductif au moyen d'une forme d'onde de courant sinusoïdale d'une amplitude de signal supérieure au seuil de sensibilité du récepteur et inférieure à 20 mA crête à crête.

### 14.5.3 Sensibilité du récepteur et suppression du bruit

Un circuit de réception de MAU doit être capable de recevoir un signal d'entrée de 4,0 mA crête à crête à 20,0 mA crête à crête, y compris la surtension et l'oscillation (voir "niveau du signal" ainsi que "amplitude positive" et "amplitude négative" à la Figure 80).

Un circuit de réception de MAU ne doit pas répondre à un signal d'entrée dont l'amplitude crête à crête de courant de ligne ne dépasse pas 2,0 mA (voir "suppression du bruit" à la Figure 83).

### 14.5.4 Instabilité de bit élémentaire reçu

Le circuit de réception doit accepter un signal codé Manchester transmis conformément au 14.2 et au 14.4. En outre, le récepteur doit fonctionner correctement à des signaux avec une variation temporelle, entre deux points adjacents quelconques de transition des signaux (passage par zéro) de ±0,10 $T_{bit}$ au plus. Voir la Figure 96.

NOTE 1 Cette spécification n'exclut pas l'utilisation de récepteurs dont les performances sont supérieures à la présente spécification.

En fonction de la configuration du symbole, la durée nominale entre passages par zéro peut être d'un demi temps binaire ou d'un temps binaire.

NOTE 2 Il n'y a aucune exigence quant au rejet d'un signal donné avec une valeur de variation temporelle spécifiée. Le récepteur rend compte d'une erreur lorsque l'instabilité de bit élémentaire reçu dépasse l'aptitude du récepteur à décoder la signalisation de manière fiable.

### 14.5.5 Susceptibilité au brouillage et taux d'erreurs

Voir 13.5.5.

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### 14.6 Inhibition du bavardage

Voir 13.6.

### 14.7 Distribution de l'alimentation

#### 14.7.1 Généralités

Un appareil peut, facultativement, recevoir son alimentation par l'intermédiaire des conducteurs de signaux ou être alimenté de manière séparée.

Un appareil peut être certifié comme étant de sécurité intrinsèque quelle que soit la méthode d'alimentation.

NOTE 1 Le présent document n'inclut pas d'exigences pour la certification de la sécurité intrinsèque, mais cherche à exclure des conditions ou situations qui empêchent la certification de la sécurité intrinsèque.

Un appareil à alimentation séparée peut être connecté à un bus de terrain alimenté.

NOTE 2 Pour faciliter le renvoi aux textes correspondants, les exigences définies au 14.7 sont résumées dans le Tableau 111

**Tableau 111 – Exigences d'alimentation réseau**

| Exigences d'alimentation réseau | Limites |
|---|---|
| Courant de sortie | 1,0 A eff. avec une tolérance de ± 5 % |
| Fréquence de sortie | 16 kHz avec une tolérance de ± 0,5 % |
| Taux d'harmoniques et bruit du courant d'alimentation | Voir la Figure 97 |
| Impédance de sortie, mesurée sur la plage de fréquences comprise entre 0,25 $f_r$ et 1,25 $f_r$ (250 kHz à 1,25 MHz) | ≤ 5 Ω |

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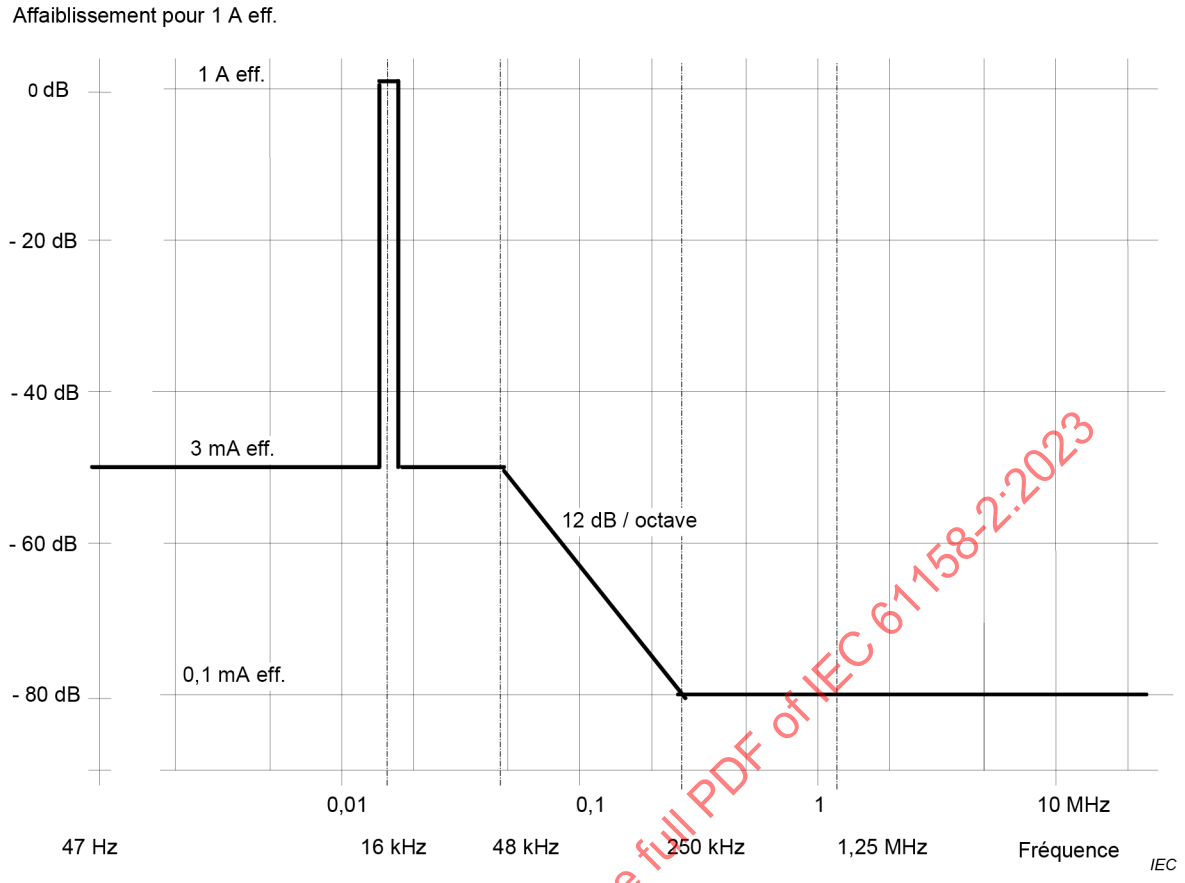


**Figure 97 – Distorsion harmonique et bruit de l'alimentation**

### 14.7.2 Alimentation par l'intermédiaire de conducteurs de signaux

Un appareil de bus de terrain qui revendique la conformité à l'Article 14 et qui est alimenté par les conducteurs de signaux doit satisfaire aux exigences de l'Article 14 lorsqu'il est alimenté par une source qui présente les spécifications suivantes.

a) Le courant de sortie de l'alimentation doit être de 1,0 A eff avec une tolérance de ± 5 %.

NOTE 1 La tension de sortie de l'alimentation dépend des pertes dues au câble et de la puissance consommée par chaque appareil.

Un appareil de bus de terrain peut être conçu pour consommer une ou plusieurs charges normalisées. Une charge normalisée est égale à 1,0 W.

NOTE 2 La tension de sortie en circuit ouvert de l'alimentation est inférieure à la limite spécifiée par l'organisme de réglementation local pour la mise en œuvre particulière.

b) L'impédance de sortie de l'alimentation doit être ≤ 5 Ω sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz).

c) La forme d'onde de l'alimentation doit être une sinusoïde dont la fréquence ainsi que la distorsion harmonique maximale et le bruit sont les suivants:

1) 0,1 mA eff. sur la plage de fréquences comprise entre 0,25 $f_r$ et 1,25 $f_r$ (250 kHz à 1,25 MHz);

2) 3,0 mA eff. sur la plage de fréquences comprise entre 47 Hz et 48 kHz, à l'exception de 16 kHz avec une tolérance de ± 0,5 %;

3) des niveaux, à d'autres fréquences, conformément à la Figure 97.

L'appareil ne doit pas introduire, dans la ligne principale, de composantes harmoniques de la fréquence industrielle supérieure à 15 µA eff.

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### 14.7.3 Alimentation séparée du signal

NOTE La distribution de l'alimentation pour des appareils de bus de terrain non alimentés par le bus s'effectue au moyen de conducteurs séparés qui fournissent l'énergie à des alimentations locales, des régulateurs ou des barrières de sécurité. La certification IS peut exiger que ces conducteurs soient dans un câble séparé de celui des conducteurs de signaux et peut également imposer des exigences de niveau de courant plus strictes que celles qui sont spécifiées.

Un appareil de bus de terrain alimenté séparément qui revendique la conformité à l'Article 14 ne doit pas provoquer de chute de tension supérieure à 200 mV eff, à la fréquence industrielle sur les conducteurs de signaux, et ne doit pas fournir un courant de plus de 100 µA eff. aux conducteurs de signaux, lorsqu'il n'y a pas de transmission.

### 14.7.4 Isolation électrique

Voir 13.7.4.

## 14.8 Spécifications du support

### 14.8.1 Connecteur

Voir 13.8.1.

### 14.8.2 Câble d'essai normalisé

Le câble utilisé pour les essais d'appareils de bus de terrain avec une MAU en mode courant, destinés à vérifier la satisfaction aux exigences de l'Article 14, doit être un câble unique à paire torsadée, à blindage global, qui satisfait aux exigences minimales suivantes, à une température de 25 °C:

a) $Z_o$ à une fréquence de 0,25 $f_r$ (250 kHz) = 80 Ω avec une tolérance de ± 10 %;

b) $Z_o$ à une fréquence de 1,25 $f_r$ (1,25 MHz) = 80 Ω avec une tolérance de ±10 %;

c) affaiblissement maximal à une fréquence de 0,25 $f_r$ (250 kHz) = 11,0 dB/km;

d) affaiblissement maximal à une fréquence de 1,25 $f_r$ (1,25 MHz) = 20,0 dB/km;

e) résistance maximale en courant continu (par conducteur) = 15,0 Ω/km;

f) section du conducteur (dimension des fils) = 1,5 $mm^2$, valeur nominale.

La spécification ci-dessus concerne les essais de conformité d'une MAU. D'autres types de câbles peuvent être utilisés dans les installations réelles (voir l'Annexe B). Les câbles à spécifications améliorées peuvent permettre l'utilisation de longueurs de ligne principale plus importantes et/ou une meilleure immunité aux perturbations. En revanche, les câbles qui présentent des spécifications inférieures peuvent être utilisés, sous réserve d'une limitation des longueurs utilisées, tant pour les lignes principales que secondaires, à laquelle s'ajoute une éventuelle non-conformité aux exigences de susceptibilité aux perturbations radioélectriques (RFI) et électromagnétiques (EMI).

### 14.8.3 Coupleur

Voir 13.8.3.

### 14.8.4 Épissures

Voir 13.8.4.

### 14.8.5 Terminateur

Un terminateur doit être placé aux deux extrémités du câble de ligne principale et connecté d'un conducteur de signal à l'autre. Il ne doit y avoir aucune connexion entre le terminateur et le blindage du câble.

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À des fins d'essai, en utilisant le câble spécifié au 14.8.2, le terminateur doit avoir une valeur d'impédance de 80 Ω avec une tolérance de ± 2 % sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (250 kHz à 1,25 MHz).

La chute de tension dans les terminaisons doit être inférieure à 0,3 V à une fréquence de 16 kHz.

NOTE Dans des applications pratiques, lorsque l'alimentation est fournie par les conducteurs de signaux, le terminateur est contourné aux fréquences industrielles afin de réduire le plus possible les pertes de puissance.

Le terminateur doit être non polarisé.

Tous les terminateurs utilisés pour des atmosphères potentiellement explosibles doivent satisfaire à des exigences conformes aux documents d'homologation exigés.

### 14.8.6 Règles de blindage

Pour une entière satisfaction aux exigences d'immunité au bruit du 14.5, il est nécessaire d'assurer l'intégrité du blindage sur toute la longueur du câblage, dans les connecteurs et dans les coupleurs, de la manière suivante:

a) la couverture du blindage doit être supérieure à 95 % de la longueur totale du câble;
b) le blindage doit couvrir complètement les circuits électriques des connecteurs, des coupleurs et des épissures.

NOTE Toute dérogation à ces règles de blindage peut dégrader l'immunité au bruit.

### 14.8.7 Règles de mise à la masse

Voir 13.8.7.

### 14.8.8 Code de couleur des câbles

Voir 11.8.8.

## 15 Type 1 et Type 7: Unité de liaison au support: supports à fibre optique double

### 15.1 Généralités

Le support réseau est constitué d'une paire de guides d'onde à fibre optique qui assure la bidirectionnalité par séparation des fibres pour chaque sens de propagation du signal. Ces supports sont connus sous l'appellation générale de trajet optique élémentaire.

Dans tous les réseaux qui comportent plusieurs appareils, les guides d'onde à fibre optique qui acheminent les signaux en provenance des appareils sont associés à un coupleur en étoile, actif ou passif, puis sont rediffusés sur tous les guides d'onde qui acheminent des signaux aux appareils. Une liaison point à point entre une paire d'appareils qui utilisent un seul trajet optique élémentaire est également possible.

Ces fibres optiques doubles sont connectées au CPIC d'un appareil de bus de terrain. Le système de transmission à fibre optique est en soi de sécurité intrinsèque.

### 15.2 Grandeurs dépendantes du débit binaire

Il est défini six débits binaires pour une MAU (Unité de liaison au support) de supports de réseau à fibre optique double, constitués d'une paire de guides d'onde à fibre optique unidirectionnels. Une MAU donnée doit prendre en charge au moins un de ces débits binaires.

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Le Tableau 112 indique les débits binaires pris en charge et définit les symboles relatifs aux grandeurs dépendantes du débit binaire utilisés tout au long du 15.2:

**Tableau 112 – Grandeurs dépendantes du débit binaire de réseaux à fibre optique double à grande vitesse (≥ 1 Mbit/s)**

| Grandeur | Symbole | Unité | Valeur | | | | | |
|---|---|---|---|---|---|---|---|---|
| Débit binaire nominal | BR | Mbit/s | 0,031 25 | 1 | 2,5 | 5 | 10 | 25 |
| Écart maximal par rapport à BR | ΔBR | | 0,2 % | 0,01 % | | | | |
| Durée binaire nominale | Tbit | µs | 32,0 | 1,0 | 0,4 | 0,2 | 0,1 | 0,04 |
| Écart maximal par rapport à *T*bit | ΔTbit | - | 0,025 % | 0,015 % | | | | |
| Délai maximal de propagation | PDmax | Tbit | 20 | 40 | | | | |

Le débit binaire moyen doit être BR ± ΔBR, moyenné sur une trame d'une longueur minimale de 16 octets. Le temps binaire instantané doit être $T_{bit}$ ± Δ $T_{bit}$.

### 15.3 Spécifications du réseau

#### 15.3.1 Composants

Une MAU à fibre optique fonctionne sur un réseau constitué des composants suivants:

a) un câble optique;
b) des appareils (qui comportent au moins un élément de communication);
c) des connecteurs;
d) des étoiles passives optiques;
e) des étoiles actives optiques.

#### 15.3.2 Topologies

Une MAU à fibre optique doit fonctionner sur un réseau à topologie en étoile ou sur un réseau point à point. Les appareils sont connectés aux étoiles optiques ou aux appareils homologues par des trajets optiques élémentaires. Les étoiles optiques sont interconnectées par des trajets optiques élémentaires.

#### 15.3.3 Règles de configuration du réseau

Une MAU qui revendique la conformité à l'Article 15 doit satisfaire aux exigences de l'Article 15 lorsqu'elle est utilisée sur un réseau qui satisfait à ces règles.

**Règle 1:** Tous les appareils du réseau fonctionnent au même débit binaire.

**Règle 2:** Il ne doit pas y avoir plus de quatre étoiles actives optiques entre deux appareils quelconques.

**Règle 3:** Le délai maximal de propagation entre deux appareils quelconques ne doit pas dépasser les valeurs indiquées dans le Tableau 112.

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Pour que le réseau fonctionne efficacement, il convient que cette partie du temps de retournement de tout appareil du réseau, générée par une PhE entre la fin d'une trame reçue et le début d'une trame émise qui contient une réponse immédiate associée, ne dépasse pas cinq temps binaires, dont il convient que 2 temps binaires au plus soient dus à la MAU.

NOTE Sachant qu'il n'est pas obligatoire d'exposer l'interface DLL – PhL ou l'interface MDS – MAU, cette partie du temps de retournement d'un appareil de bus de terrain due à la PhL ou à la MAU n'est pas spécifiée et donc non disponible pour des essais de conformité.

**Règle 4:** Le bus de terrain doit pouvoir fonctionner en continu lorsqu'un appareil y est connecté ou déconnecté. Les erreurs de données générées lors de la connexion ou de la déconnexion doivent être détectées.

**Règle 5:** Le réseau doit être acyclique, avec un seul trajet entre deux appareils quelconques.

**Règle 6:** Les règles suivantes doivent s'appliquer aux systèmes mis en œuvre avec des supports redondants:

a) chaque canal doit satisfaire aux règles de configuration du réseau;

b) il ne doit pas y avoir de segment ou d'équipement non redondant entre deux segments redondants;

c) si les appareils du système sont configurés (par la Gestion systèmes) pour émettre sur plusieurs canaux simultanément, alors la différence de délai de propagation entre deux appareils quelconques sur deux canaux quelconques ne doit pas dépasser cinq temps binaires;

d) les numéros de canaux et leur association aux supports de transmission physiques doivent être maintenus de manière cohérente sur l'ensemble des bus de terrain, c'est-à-dire que les canaux 1, 2, 3… en provenance de la gestion systèmes doivent toujours être connectés aux canaux physiques 1, 2, 3…

### 15.4 Spécifications du circuit de transmission de la MAU

#### 15.4.1 Configuration d'essai

NOTE Pour faciliter le renvoi aux textes correspondants, les exigences définies au 15.4 sont résumées dans le Tableau 113 et le Tableau 114.

Le niveau de sortie, ainsi que les spécifications de spectre et de temporisation sont mesurés à l'extrémité d'une fibre d'essai normalisée de 1 m connectée au CPIC.

#### 15.4.2 Spécification du niveau de sortie

Un circuit de transmission de MAU à fibre optique doit être conforme aux exigences de niveau de sortie et aux exigences spectrales suivantes. Le niveau et les caractéristiques spectrales sont mesurés à une température de 25 °C. Le niveau de sortie est la puissance d'injection effective d'un niveau élevé. Le niveau de sortie est spécifié dans le Tableau 113.

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**Tableau 113 – Récapitulatif de la spécification du niveau de transmission et des caractéristiques spectrales**

| Niveau de transmission et caractéristiques spectrales (valeurs en référence au CPIC avec fibre d'essai normalisée) | Limites, avec une fibre de 62,5/125 µm |
|---|---|
| Longueur d'onde de transmission crête (λp) | (850 ± 30) nm |
| Longueur d'onde type de demi-intensité (Δλ) | ≤ 50 nm |
| Niveau élevé de la puissance d'injection effective | (−11,5 ± 1,5) dBm |
| Dépassement de transitions | ≤ 15 % de la puissance effective |
| Rapport d'extinction | ≥ 20:1 |

### 15.4.3 Spécification de temporisation des sorties

Un circuit de transmission de MAU à fibre optique doit satisfaire aux exigences suivantes de temporisation des sorties (voir la Figure 98). Les caractéristiques de temporisation sont mesurées à une température de 25 °C. La spécification de temporisation des sorties est présentée dans le Tableau 114.

**Tableau 114 – Récapitulatif de la spécification de temporisation de transmission**

| Caractéristiques de temporisation de transmission (valeurs en référence au CPIC avec fibre d'essai normalisée) | Limites |
|---|---|
| Débit binaire de transmission | BR ± ΔBR |
| Temps binaire instantané | Tbit ± ΔTbit |
| Temps de croissance et de décroissance (10 % à 90 % du signal crête à crête) | ≤ 2,0 % Tbit |
| Différence entre les temps de croissance et de décroissance | ≤ 0,5 % Tbit |
| Instabilité maximale de bit élémentaire émis | ± 2,0 % Tbit |

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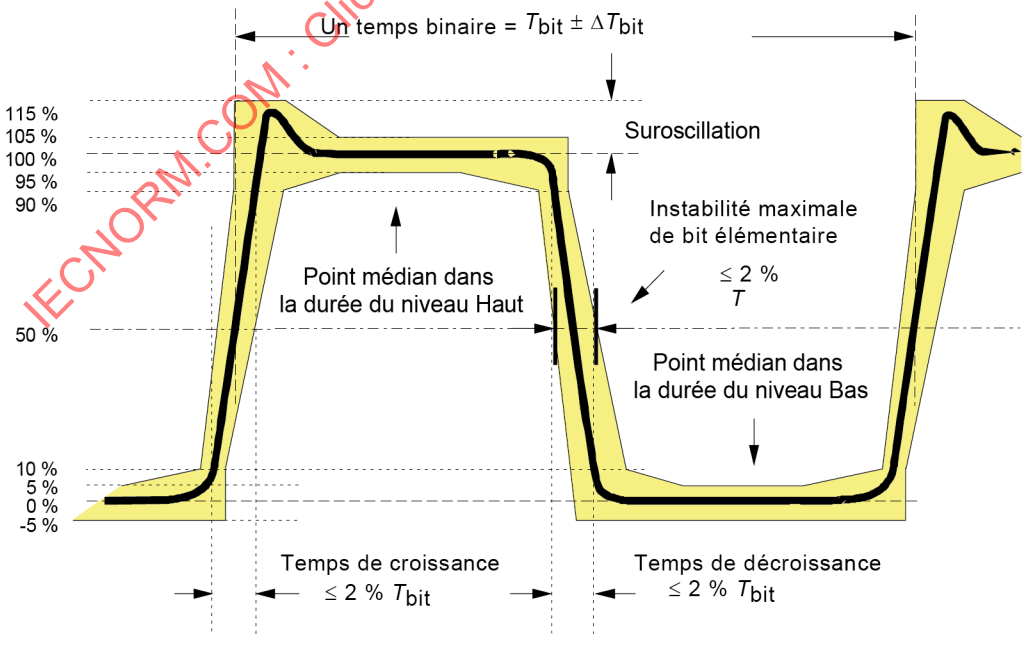


NOTE 0 % de puissance effective correspond au niveau de puissance à l'état bas.
100 % de puissance effective correspond au niveau de puissance à l'état haut.
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**Figure 98 – Modèle de forme d'onde optique**

## 15.5 Spécifications du circuit de réception de la MAU

### 15.5.1 Généralités

Les exigences du 15.5 sont résumées dans le Tableau 115.

**Tableau 115 – Récapitulatif de la spécification du circuit de réception**

| Caractéristiques du circuit de réception (valeurs en référence au CPIC avec fibre d'essai normalisée) | Limites | |
|---|---|---|
| | Système à faible sensibilité | Système à sensibilité élevée |
| Domaine de fonctionnement du récepteur | −30,0 dBm à −10,0 dBm | −40,0 dBm à −20,0 dBm |
| Instabilité maximale de bit élémentaire reçu | ± 14 % $T_{bit}$ | |

### 15.5.2 Domaine de fonctionnement du récepteur

La plage de sensibilité spécifiée pour le récepteur est la suivante

a) puissance effective de –30,0 dBm à –10,0 dBm pour une faible sensibilité;

b) puissance effective de –40,0 dBm à –20,0 dBm pour une sensibilité élevée.

### 15.5.3 Instabilité maximale de bit élémentaire reçu

Le circuit de réception doit accepter un signal codé Manchester transmis conformément au 15.4. En outre, le récepteur doit accepter des signaux qui présentent des variations temporelles, entre deux points adjacents quelconques de transition des signaux (passage par 50 %) de ±14,0 % Tbit au plus.

NOTE Cette spécification n'exclut pas l'utilisation de récepteurs dont les performances sont supérieures à la présente spécification, mais conformes aux tolérances relatives à l'instabilité de bit élémentaire reçu de la MDS (voir 9.2.6).

En fonction de la configuration du symbole, la durée nominale entre passages par 50 % peut être de 1,0 Tbit ou 0,5 Tbit.

### 15.5.4 Susceptibilité au brouillage et taux d'erreurs

#### 15.5.4.1 Basse vitesse (31,25 kbit/s)

Lorsque le bus de terrain fonctionne dans différents environnements de bruit normalisés, il convient que la probabilité qu'une unité de données utilisateur de couche Application contienne une erreur non détectée, du fait du fonctionnement des entités physiques et DLL d'acheminement, soit inférieure à 1 sur 6 x $10^9$ (une erreur en 20 années à 10 messages/s).

Un élément de communication est réputé conforme à cette exigence théorique lorsqu'il satisfait aux exigences suivantes de susceptibilité au brouillage. Ces exigences sont spécifiées sur la base d'un taux d'erreur de trame détecté obtenu au moyen d'un rapport d'erreurs détectées/non détectées de $10^6$.

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Un élément de communication qui inclut une MAU à fibre optique qui fonctionne à 31,25 kbit/s et utilise des trames de 32 bits de données utilisateur aléatoires, à une moyenne de 10 messages/s, avec des signaux de –25 dBm, ne doit pas produire plus de 10 erreurs de trame détectées sur 60 000 trames, lorsqu'il est utilisé dans des environnements de perturbations électromagnétiques ou électriques comme cela est décrit ci-après:

a) champ électromagnétique de 10 V/m, comme cela est spécifié dans l'IEC 61000-4-3 au niveau de sévérité 3;

b) transitoires électriques rapides, comme cela est spécifié dans l'IEC 61000-4-4 au niveau de sévérité 3.

#### 15.5.4.2 Vitesse élevée (≥ 1 Mbit/s)

Lorsque le bus de terrain fonctionne dans différents environnements de bruit normalisés, il convient que la probabilité qu'une unité de données utilisateur de couche Application contienne une erreur non détectée, du fait du fonctionnement des entités physiques et DLL d'acheminement, soit inférieure à 1 sur $10^{12}$ (une erreur en 20 années à 1 600 messages/s).

Un élément de communication est réputé conforme à cette exigence théorique lorsqu'il satisfait aux exigences suivantes de susceptibilité au brouillage. Ces exigences sont spécifiées sur la base d'un taux d'erreur de trame détecté obtenu au moyen d'un rapport d'erreurs détectées/non détectées de $10^6$.

Un élément de communication qui inclut une MAU à fibre optique qui fonctionne à ≥1 Mbit/s et utilise des trames de 64 bits de données utilisateur aléatoires, à une moyenne de 1 600 messages/s, avec des signaux de -25 dBm, ne doit pas produire plus de 6 erreurs de trame détectées sur 100 000 trames, lorsqu'il est utilisé dans des environnements de perturbations électromagnétiques ou électriques comme cela est décrit ci-après:

a) champ électromagnétique de 10 V/m, comme cela est spécifié dans l'IEC 61000-4-3 au niveau de sévérité 3;

b) transitoires électriques rapides, comme cela est spécifié dans l'IEC 61000-4-4 au niveau de sévérité 3.

#### 15.5.4.3 Commune

Les taux d'erreur spécifiés doivent également être satisfaits après, mais non pendant le fonctionnement dans les environnements de bruit suivants:

a) décharge électrique de 8 kV sur une structure métallique exposée, comme cela est spécifié dans l'IEC 61000-4-2, au niveau de sévérité 3. Si l'appareil subit une perte temporaire de fonctions ou de performances par suite de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai;

b) essais de perturbation à haute fréquence, comme cela est spécifié au 3.1 de l'IEC 60255-22-1:1988 (classe III de tension d'essai, valeurs crêtes de 2,5 kV et 1 kV de la première demi-alternance, respectivement en mode longitudinal et transversal). Si l'appareil subit une perte temporaire de fonctions ou de performances du fait de cet essai, il doit récupérer de cette perte éventuelle sans intervention de l'opérateur, dans les 3 s qui suivent la fin de l'essai.

### 15.6 Inhibition du bavardage

La MAU doit comporter une capacité d'interruption automatique pour empêcher les signaux émis d'atteindre le support. Le matériel dans la MAU (sans message extérieur autre que la détection des signaux de sortie ou de fuite par la fonction de transmission) doit fournir une fenêtre d'une durée comprise entre 3 750 Tbit et 7 500 Tbit au cours de laquelle une trame normale peut être émise. Si la longueur de trame dépasse cette durée, la fonction d'inhibition du bavardage doit empêcher d'autres signaux en sortie d'atteindre le support et doit désactiver l'écho sur la ligne RxS (voir 10.2.2.2) pour indiquer à la MDS la détection de bavardage.

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Pour un débit binaire de 31,25 kbit/s, la MAU doit réinitialiser la fonction d'interruption automatique après une période de 3 s avec une tolérance de ± 50 %.

NOTE 1 Cette disposition neutralise le trafic sur le bus pendant 8 % (≈ 1/12,5) du temps disponible au plus.

Pour un débit binaire de 1 Mbit/s ou plus, la MAU doit réinitialiser la fonction d'interruption automatique après une période de 500 000 Tbit avec une tolérance de ± 50 %.

NOTE 2 Cette disposition neutralise le trafic sur le bus pendant 3 % (≈ 1/32) du temps disponible au plus.

## 15.7 Spécifications du support

### 15.7.1 Connecteur

Si des connecteurs de câbles sont utilisés, ils doivent être conformes au présent document (voir l'Annexe A). Des terminaisons permanentes (épissures) peuvent également être utilisées.

### 15.7.2 Fibre d'essai normalisée

Le câble utilisé pour les essais d'appareils de bus de terrain ou d'étoiles actives optiques avec une MAU à fibre optique, destiné à vérifier la satisfaction aux exigences de l'Article 15, doit être un câble à fibre optique d'une longueur de 1 m qui comporte deux guides d'onde à fibre de silice. Les caractéristiques de ces guides d'onde doivent être compatibles avec l'IEC 60793 [type de fibre: A1b (62,5/125 µm)] en ce qui concerne:

– le diamètre du cœur(µm): 62,5 ± 3
– le diamètre de la gaine (µm): 125 ± 3
– la concentricité cœur/gaine (%): ≤ 6
– la non-circularité du cœur (%): ≤ 6
– la non-circularité de la gaine (%): ≤ 2
– le diamètre extérieur du revêtement primaire (µm): 250 ± 15
– l'ouverture numérique: 0,275 ± 0,015
– l'affaiblissement pour 850 nm (dB/km): ≤ 3,0
– la largeur de bande pour 850 nm (MHz × km): ≥ 200

D'autres types de fibres d'essai sont admis.

NOTE L'Annexe E décrit un fonctionnement avec utilisation d'une fibre d'essai alternative de 50 µm ou 100 µm.

### 15.7.3 Étoile passive optique

NOTE Pour plus d'informations, voir l'Annexe C.

### 15.7.4 Étoile active optique

#### 15.7.4.1 Définition

Un appareil ou un module optoélectronique dans un système de communication à fibre optique qui reçoit un signal, l'amplifie et le retransmet (la resynchronisation est facultative).

#### 15.7.4.2 En service

Trois types de liaisons doivent être pris en considération.

a) Liaison entre deux étoiles actives optiques

Toute trame qui provient directement d'une étoile active optique et qui atteint un accès optique d'une autre étoile active optique est retransmise sans retour d'information (l'accès qui reçoit la trame ne retransmet pas cette trame).

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b) Liaison entre une étoile active optique et un appareil de bus de terrain

Toute trame qui provient d'une étoile active optique et qui atteint un appareil de bus de terrain est reçue et non retransmise. Toute trame qui provient d'un appareil de bus de terrain et qui atteint une étoile active optique est retransmise sans retour d'information.

c) Liaison entre une étoile passive optique et une étoile active optique

Toute trame qui provient d'une étoile passive optique et qui atteint une étoile active optique est retransmise sans retour d'information. De par sa conception, une étoile passive reflète toutes les trames. Une étoile active optique ne doit pas réémettre les signaux de retour d'information d'une étoile passive optique.

Une étoile active optique rétablit les signaux à des niveaux de puissance de transmission normalisés. Les caractéristiques de temporisation (gigue) peuvent ou non être régénérées; cette fonction est facultative.

#### 15.7.4.3 Caractéristiques de transmission et de réception

Les caractéristiques suivantes sont indiquées:

a) Caractéristiques de niveau

Les spécifications de niveau de transmission et de réception sont identiques à celles d'une MAU à fibre optique (15.4.2 et 15.5.2). Le niveau et les caractéristiques spectrales sont mesurés à une température de 25 °C. Ces spécifications sont résumées dans le Tableau 116.

**Tableau 116 – Spécifications du niveau de transmission et de réception et des caractéristiques spectrales d'une étoile active optique**

| Niveau de transmission et caractéristiques spectrales (valeurs en référence au CPIC avec fibre d'essai normalisée) | Limites, avec une fibre de 62,5/125 µm | |
|---|---|---|
| Longueur d'onde de transmission crête ($\lambda p$) | (850 ± 30) nm | |
| Longueur d'onde type de demi-intensité ($\Delta\lambda$) | ≤ 50 nm | |
| Rapport d'extinction | ≥ 20:1 | |
| Niveau élevé de la puissance d'injection effective | (−11,5 ± 1,5) dBm | |
| Domaine de fonctionnement du récepteur (puissance effective) | Système à faible sensibilité | Système à sensibilité élevée |
| | −30,0 dBm à −10,0 dBm | −40,0 dBm à −20,0 dBm |

b) Caractéristiques de temporisation

Les spécifications de temporisation de transmission et de réception d'une étoile active optique concernent (voir le Tableau 117):

– les temps de croissance et de décroissance du signal émis;

– la déformation temporelle des signaux, due à une étoile active optique.

Les caractéristiques de temporisation sont mesurées à une température de 25 °C. Pour des étoiles actives optiques qui ont une fonction de régénération de la temporisation, les caractéristiques de temporisation sont identiques à celles d'une MAU à fibre optique.

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**Tableau 117 – Caractéristiques de temporisation d'une étoile active optique**

| Caractéristiques de temporisation (valeurs en référence au CPIC) | Limites |
|---|---|
| Temps de croissance et de décroissance des signaux émis (10 % à 90 % du signal crête à crête) | ≤ 2 % Tbit |
| Déformation temporelle maximale entre accès d'entrée optiques et accès de sortie optiques (voir la Note 1) | ± 3 % Tbit |
| Temps de propagation d'un bit de données entre un accès d'entrée optique et tout accès de sortie pour une étoile active avec fonction de régénération de la temporisation (voir la Note 2). | ≤ 2 Tbit |
| Instabilité maximale de bit élémentaire émis pour une étoile active optique avec fonction de régénération de la temporisation (voir la Note 2). | ± 2,0 % Tbit |
| NOTE 1 La déformation temporelle due à une étoile active optique est la différence temporelle de largeur d'un même bit physique, configuration binaire, forme d'onde ou autre terme approprié.<br>NOTE 2 Uniquement pour des étoiles actives optiques avec fonction de régénération de la temporisation. | |

# 16 Type 1: Unité de liaison au support: support optique monofibre 31,25 kbit/s

## 16.1 Généralités

Le support réseau est constitué d'un ensemble de guides d'onde monofibres bidirectionnelles, chaque guide étant appelé trajet optique élémentaire.

Dans tous les réseaux qui comportent plusieurs appareils, les guides d'onde à fibre optique qui acheminent les signaux en provenance des appareils sont associés à un coupleur en étoile réflectif passif, depuis lequel les signaux reçus sont retransmis sur tous les guides d'onde à fibre optique vers les appareils. Une liaison point à point entre une paire d'appareils qui utilisent un seul trajet optique élémentaire est également possible.

Ces monofibres bidirectionnelles sont connectées au CPIC d'un appareil de bus de terrain. Le système de transmission à fibre optique est en soi de sécurité intrinsèque.

## 16.2 Débit binaire de transmission

Le débit binaire de transmission, BR ± ΔBR, doit être de 31,25 kbit/s avec une tolérance de ± 0,2 %, moyenné sur une trame d'une longueur minimale de 16 octets. Le temps binaire instantané, $T_{bit}$ ± Δ $T_{bit}$, doit être de 32 µs avec une tolérance de ± 0,025 %.

## 16.3 Spécifications du réseau

### 16.3.1 Composants

Voir 15.3.1.

### 16.3.2 Topologies

Voir 15.3.2.

### 16.3.3 Règles de configuration du réseau

Une MAU qui revendique la conformité à l'Article 16 doit satisfaire aux exigences de l'Article 16 lorsqu'elle est utilisée sur un réseau qui satisfait à ces règles.

Les règles sont identiques au 15.3.3, à l'exception de ce qui suit.

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### 16.4 Spécifications du circuit de transmission de la MAU

#### 16.4.1 Configuration d'essai

NOTE Pour faciliter le renvoi aux textes correspondants, les exigences définies au 16.4 sont résumées dans le Tableau 118 et le Tableau 114.

Voir 15.4.1.

#### 16.4.2 Spécification du niveau de sortie

Un circuit de transmission de MAU à fibre optique doit être conforme aux exigences de niveau de sortie et aux exigences spectrales suivantes. Le niveau et les caractéristiques spectrales sont mesurés à une température de 25 °C. Le niveau de sortie est la puissance d'injection effective d'un niveau élevé. Le niveau de sortie est spécifié dans le Tableau 118

**Tableau 118 – Récapitulatif de la spécification du niveau de transmission et des caractéristiques spectrales**

| Niveau de transmission et caractéristiques spectrales (valeurs en référence au CPIC avec fibre d'essai normalisée) | Limites pour 31,25 kbit/s (fibre 100/140 µm) |
|---|---|
| Longueur d'onde de transmission crête (λp) | (850 ± 30) nm |
| Longueur d'onde type de demi-intensité (Δλ) | ≤ 50 nm |
| Niveau élevé de la puissance d'injection effective | (−13,5 ± 1,0) dBm |
| Dépassement de transitions | ≤ 15 % de la puissance effective |
| Rapport d'extinction | ≥ 20:1 |

#### 16.4.3 Spécification de temporisation des sorties

Un circuit de transmission de MAU à fibre optique doit satisfaire aux exigences suivantes de temporisation des sorties (voir la Figure 98). Les caractéristiques de temporisation sont mesurées à une température de 25 °C. La spécification de temporisation des sorties est présentée dans le Tableau 114.

### 16.5 Spécifications du circuit de réception de la MAU

#### 16.5.1 Généralités

Les exigences du 16.5 sont résumées dans le Tableau 115, qui concerne cependant la fibre d'essai normalisée 100/140 µm de l'Article 16.

#### 16.5.2 Domaine de fonctionnement du récepteur

La plage de sensibilité spécifiée pour le récepteur est la suivante

a) puissance effective de –30,0 dBm à –12,5 dBm pour une faible sensibilité;

b) puissance effective de –40,0 dBm à –20,0 dBm pour une sensibilité élevée.

#### 16.5.3 Instabilité maximale de bit élémentaire reçu

Voir 15.5.3.

#### 16.5.4 Susceptibilité au brouillage et taux d'erreurs

Voir 15.5.4.1 et 15.5.4.3.

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### 16.6 Inhibition du bavardage

L'exigence est identique à 15.6, à l'exception de ce qui suit.

La MAU doit réinitialiser la fonction d'interruption automatique après une période de 3 s avec une tolérance de ± 50 %.

NOTE Cette disposition neutralise le trafic sur le bus pendant 8 % (≈ 1/12,5) du temps disponible au plus.

### 16.7 Spécifications du support

#### 16.7.1 Connecteur

Voir 15.7.1.

#### 16.7.2 Fibre d'essai normalisée

Guide d'onde à fibre de silice dont les caractéristiques nominales sont compatibles avec l'IEC 60793 [type de fibre: A1d (100/140 µm)].

Le câble utilisé pour les essais d'appareils de bus de terrain ou d'étoiles actives optiques avec une MAU à fibre optique, destiné à vérifier la satisfaction aux exigences de l'Article 16, doit être un câble à fibre optique d'une longueur de 1 m qui comporte un guide d'onde à fibre optique et dont les caractéristiques sont les suivantes:

– le diamètre du cœur (µm): 100 ± 5
– le diamètre de la gaine (µm): 140 ± 4
– la concentricité cœur/gaine (%): ≤ 6
– la non-circularité du cœur (%): ≤ 6
– la non-circularité de la gaine (%): ≤ 4
– l'ouverture numérique: 0,26 ± 0,03
– l'affaiblissement pour 850 nm (dB/km): ≤ 4,0
– la largeur de bande pour 850 nm (MHz × km): ≥ 100

D'autres types de fibres d'essai sont admis.

NOTE L'Annexe E décrit un fonctionnement avec utilisation de fibres d'essai alternatives de 50 µm ou 62,5 µm.

#### 16.7.3 Étoile passive optique

NOTE Pour plus d'informations, voir l'Annexe C.

#### 16.7.4 Étoile active optique

##### 16.7.4.1 Définition

Le paragraphe 15.7.4.1 s'applique.

##### 16.7.4.2 En service

Le paragraphe 15.7.4.2 s'applique.

##### 16.7.4.3 Caractéristiques de transmission et de réception

###### 16.7.4.3.1 Caractéristiques de niveau

Les spécifications de niveau de transmission et de réception sont identiques à celles d'une MAU à fibre optique (voir 16.4.2 et 16.5.2). Le niveau et les caractéristiques spectrales sont mesurés à une température de 25 °C. Ces spécifications sont résumées dans le Tableau 119.

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**Tableau 119 – Spécifications du niveau de transmission et de réception et des caractéristiques spectrales d'une étoile active optique**

| Niveau de transmission et caractéristiques spectrales (valeurs en référence au CPIC avec fibre d'essai normalisée) | Limites, avec une fibre de 100/140 µm | |
|---|---|---|
| Longueur d'onde de transmission crête ($\lambda p$) | (850 ± 30) nm | |
| Longueur d'onde type de demi-intensité ($\Delta\lambda$) | ≤ 50 nm | |
| Rapport d'extinction | ≥ 20:1 | |
| Niveau élevé de la puissance d'injection effective | (−13,5 ± 1,0) dBm | |
| Domaine de fonctionnement du récepteur (puissance effective) | Système à faible sensibilité | Système à sensibilité élevée |
| | −30,0 dBm à −12,5 dBm | −40,0 dBm à −20,0 dBm |

#### 16.7.4.3.2 Caractéristiques de temporisation

Les caractéristiques de temporisation du 15.7.4.3 s'appliquent.

## 17 Vide

NOTE L'Article 17 est destiné à maintenir la numérotation des articles et réduire le plus possible la rupture avec des normes nationales et multinationales, ainsi que des documents de consortiums existants qui renvoient à l'édition précédente.

## 18 Type 2: Unité de liaison au support: Support à câble coaxial, de 5 Mbit/s, en mode tension

### 18.1 Généralités

Une seule méthode de connexion est spécifiée pour le support câblé coaxial de 5 Mbit/s en mode tension. D'autres méthodes peuvent être utilisées, mais elles doivent être conformes aux mêmes caractéristiques de signalisation et de performances. Si la méthode de connexion à support câblé coaxial spécifiée est utilisée, alors elle doit intégrer un couplage par transformateur au niveau du nœud et doit utiliser une prise passive pour connexion au support. La prise doit inclure une ligne secondaire de 1 m.

La variante de PhL à câble coaxial de 5 Mbit/s en mode tension, doit être connectée au support câblé coaxial avec des segments de réseaux jusqu'à 1 km de longueur et qui comprennent jusqu'à 48 nœuds (voir 18.5).

NOTE La couche physique peut être mise en œuvre de manière à permettre une certification pour un fonctionnement dans des atmosphères explosives sans sacrifier la distance ou réduire le nombre de nœuds. Le présent document n'inclut pas d'exigences pour la certification de la sécurité intrinsèque, mais cherche à exclure des conditions ou situations qui empêchent la certification de la sécurité intrinsèque.

La MAU doit comprendre un émetteur-récepteur, un transformateur et un connecteur comme cela est représenté à la Figure 99. L'émetteur-récepteur doit utiliser les signaux définis dans l'interface MDS-MAU pour générer ceux qui sont nécessaires pour piloter le transformateur. La connexion au support doit être effectuée par l'intermédiaire de connecteurs BNC ou TNC, comme cela est spécifié à l'Annexe F. L'isolation de la masse doit être assurée par l'intermédiaire du transformateur, comme cela est spécifié au 18.3.

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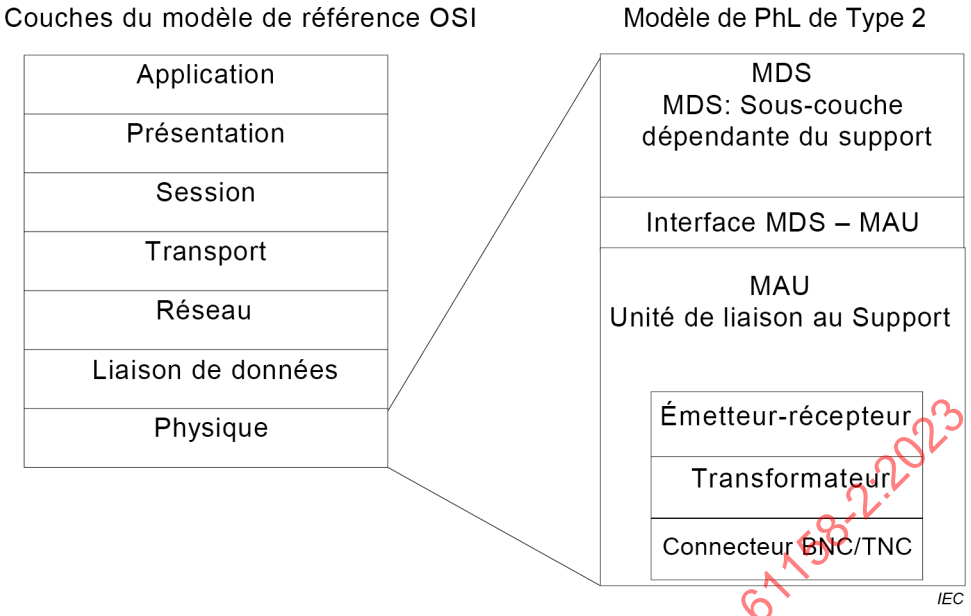


**Figure 99 – Composantes de la variante de PhL à câble coaxial de 5 Mbit/s en mode tension**

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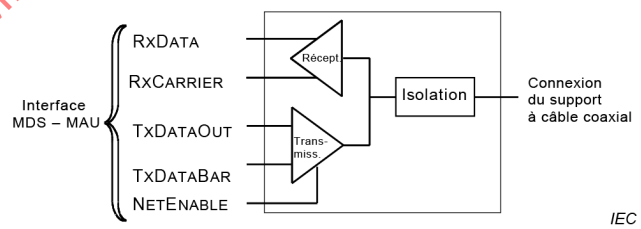
## 18.2 Émetteur-récepteur: Câble coaxial de 5 Mbit/s en mode tension

Lorsqu'il est utilisé un support à câble coaxial de 5 Mbit/s en mode tension, un émetteur-récepteur à câble coaxial doit être utilisé pour émettre et recevoir les signaux L (bas) et H (haut). La partie émettrice de l'émetteur-récepteur doit obtenir de l'interface MDS-MAU des signaux de transmission qui représentent des symboles H et L. Elle doit émettre sur le câble, par le transformateur d'isolation, un signal à extrémité unique et isolé à la masse. Le complément de cette fonction doit être réalisé dans le récepteur qui doit fournir à l'interface MDS-MAU les indications RXDATA et RXCARRIER.

Un diagramme fonctionnel qui décrit les composantes de la sous-couche MAU est représenté à la Figure 100.

NOTE 1 La Figure H.3 représente un exemple d'émetteur-récepteur redondant et la Figure H.4 un exemple d'émetteur-récepteur à un seul canal.




NOTE Ensemble, les blocs marqués Xmit et Isolation représentent l'émetteur.

**Figure 100 – Diagramme de bloc de MAU à câble coaxial**

La Figure 101 représente un schéma fonctionnel simplifié de l'émetteur.

NOTE 2 Pour plus de précisions, se reporter aux schémas donnés pour exemple à la Figure H.3 et à la Figure H.4.

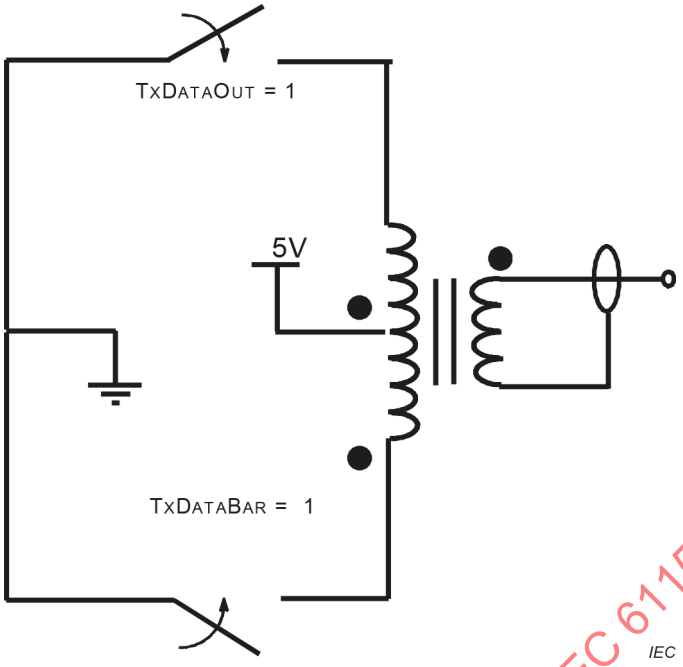



**Figure 101 – Émetteur de MAU à câble coaxial**

Trois signaux doivent être disponibles à l'interface MDS-MAU pour contrôler l'émission sur le support: TxDataOut, TxDataBar, et NetEnable. Ces trois signaux de transmission, lorsqu'ils sont connectés à l'émetteur-récepteur, doivent définir les symboles physiques présents sur le câble. La relation entre ces lignes de demande de l'émetteur-récepteur et les signaux sur le support, doit être telle qu'elle est spécifiée dans le Tableau 120.

**Tableau 120 – Définition des lignes de commande de transmission – Câble coaxial de 5 Mbit/s en mode tension**

| TxDataOut | TxDataBar | NetEnable | Symbole physique | Signal sur le support |
|---|---|---|---|---|
| sans effet(x) | sans effet(x) | faux(0) | aucun | Émetteur non actif, voir Tableau 123. |
| faux(0) | faux(0) | vrai(1) | aucun | Émetteur non actif, voir Tableau 123. |
| vrai(1) | faux(0) | vrai(1) | H | tension + (positive), voir Tableau 123. |
| faux(0) | vrai(1) | vrai(1) | L | – tension (négative), voir Tableau 123. |
| vrai(1) | vrai(1) | vrai(1) | non autorisé (voir Note) | non autorisé (voir Note) |
| NOTE Cet état peut endommager les circuits de l'émetteur. | | | | |

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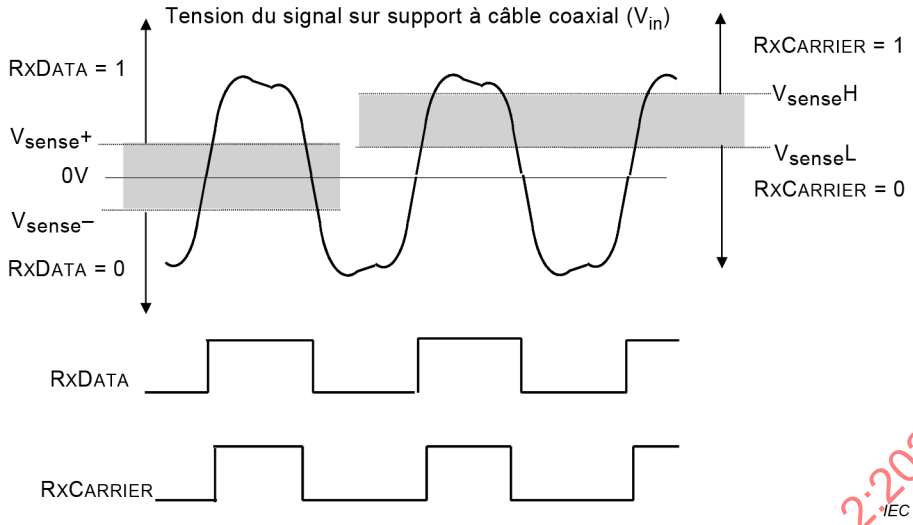


NOTE Les parties grisées ci-dessus ne sont pas définies.

**Figure 102 – Fonctionnement du récepteur avec MAU à câble coaxial**

Deux signaux d'indication doivent être fournis au niveau de l'interface MDS-MAU à partir de la MAU, avec RxDATA et RxCARRIER, comme cela est présenté dans le Tableau 120. La relation entre la tension du signal sur le câble et ces deux signaux pour les seuils nominaux, doit être telle qu'elle est présentée dans le Tableau 121 et le Tableau 122. Les valeurs indiquées dans le Tableau 121 et le Tableau 122 sont définies dans le Tableau 124. Le niveau d'entrée ($V_{in}$), comme cela est représenté à la Figure 102, doit être défini comme la tension mesurée entre le conducteur central du câble coaxial et le blindage du câble coaxial. Toutes les polarités doivent être définies en matière de tension sur le conducteur central du câble coaxial ($V_{in}$+ ou $V_{in}$–), en référence au blindage du câble coaxial.

**Tableau 121 – Définitions des sorties de données du récepteur: Câble coaxial de 5 Mbit/s en mode tension**

| Niveau d'entrée au support | RxDATA | Commentaires |
|---|---|---|
| $V_{in}$ est plus positif que la limite positive de sensibilité des données ($V_{sense}$+) | vrai (1) | Voir le Tableau 124 |
| $V_{in}$ est plus négatif que la limite négative de sensibilité des données ($V_{sense}$-) | faux (0) | Voir le Tableau 124 |
| $V_{in}$ se trouve entre les limites de sensibilité négative et positive des données | indéfini | Tient compte de l'hystérésis et de la tolérance |

**Tableau 122 – Définitions des sorties de porteuses du récepteur: Câble coaxial de 5 Mbit/s en mode tension**

| Niveau d'entrée au support | RxCARRIER | Commentaires |
|---|---|---|
| $V_{in}$ est plus positif que la limite haute de sensibilité de la porteuse ($V_{sense}$ H) | vrai (1) | Voir le Tableau 124 |
| $V_{in}$ est inférieur à la limite basse (ou négative) de sensibilité de la porteuse ($V_{sense}$ L) | faux (0) | Voir le Tableau 124 |
| $V_{in}$ se trouve entre les limites haute et basse de sensibilité de la porteuse | indéfini | Tient compte de l'hystérésis et de la tolérance |

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L'interface du support doit satisfaire aux exigences données dans le Tableau 123, le Tableau 124 et le Tableau 125.

**Tableau 123 – Interface du support à câble coaxial – Spécifications de transmission**

| Spécification | Limites / caractéristiques | Commentaires |
|---|---|---|
| Niveau de transmission (niveau Tx) crête à crête | 8,2 V ± 1,3 V [a, b, c] | Voir la Figure 103 |
| Asymétrie du niveau de transmission (entre 0 et 1) | < 450 mV max [b, d] | |
| Distorsion du signal de transmission (surtension, statisme, suroscillation) | ± 10 % [a, e] | Voir la Figure 103 |
| Instabilité de transmission totale (gigue Tx) | < 5 ns | Voir la Figure 103 |
| Impédance de sortie de l'émetteur | 20 Ω max | |
| Niveau de bruit maximal de l'émetteur à l'arrêt | 5 mV max [a] | |
| Temps depuis NETENABLE "faux" au niveau de bruit d'émetteur "non actif" | 400 ns [a] | |
| Limite de dérive | 1 V/ns max [a] | Voir la Figure 103 |
| Temps de croissance / décroissance (10 % à 90 % du signal crête à crête) | 30 ns max [a] | Voir la Figure 103 |

[a] Il doit s'agir d'une tension crête à crête mesurée sur une charge de 37,5 Ω de 0 MHz à 20 MHz.

[b] Le niveau de transmission doit être mesuré au point médian estimé entre toute crête ou creux, tant à la partie supérieure qu'à la partie inférieure de la forme d'onde.

[c] Ce niveau doit être inférieur de 0,5 V lorsqu'il est mesuré dans un diagramme en œil relatif au pilotage d'une prise pour un signal minimal de 6,4 V (crête à crête).

[d] Cette valeur doit être mesurée comme la différence absolue entre la valeur absolue du niveau de transmission pour 1 (tension +) et la valeur absolue du niveau de transmission pour 0 (tension –), mesurée sur une charge de 37,5 Ω de 0 MHz à 20 MHz.

[e] Les niveaux doivent être calculés en fonction de la tension de transmission réelle mesurée.

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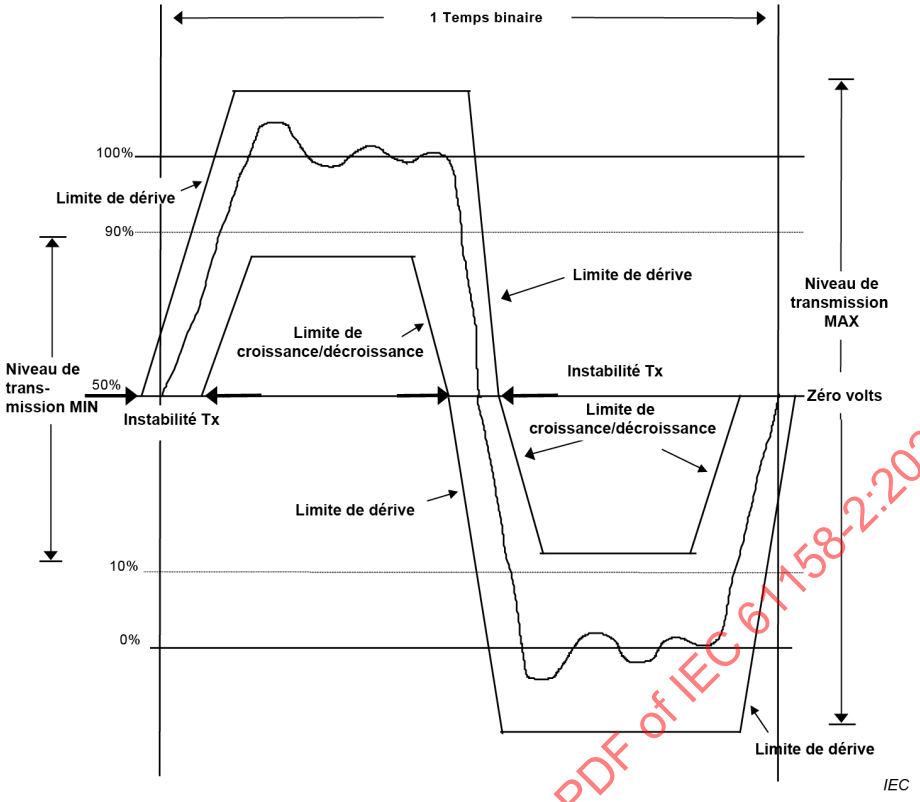


**Figure 103 – Masque de transmission de MAU à câble coaxial**

**Tableau 124 – Interface du support à câble coaxial – Réception**

| Spécification | Limites / caractéristiques | Commentaires |
|---|---|---|
| Niveau minimal du signal de réception (crête à crête) | 510 mV | Dans le diagramme en œil de la Figure 104 |
| Tension de seuil de données | zéro V | Les limites négatives et positives de sensibilité tiennent compte de l'hystérésis et de la tolérance |
| Limites négatives de sensibilité des données ($V_{sense}^-$) | -140 mV | Tient compte de l'hystérésis et de la tolérance |
| Limites positives de sensibilité des données ($V_{sense}^+$) | +140 mV | Tient compte de l'hystérésis et de la tolérance |
| Limite basse de sensibilité de la porteuse ($V_{sense\ L}$) | +23 mV | Tient compte de l'hystérésis et de la tolérance |
| Limite haute de sensibilité de la porteuse ($V_{sense\ H}$) | +255 mV | Tient compte de l'hystérésis et de la tolérance |
| Instabilité du modèle `RxData` (crête-à-crête) pour $V_{in}$ > 510 mV | < 40 ns | Dans le diagramme en œil de la Figure 104 doit être vrai lorsque $V_{in}$ > niveau minimal du signal de réception |

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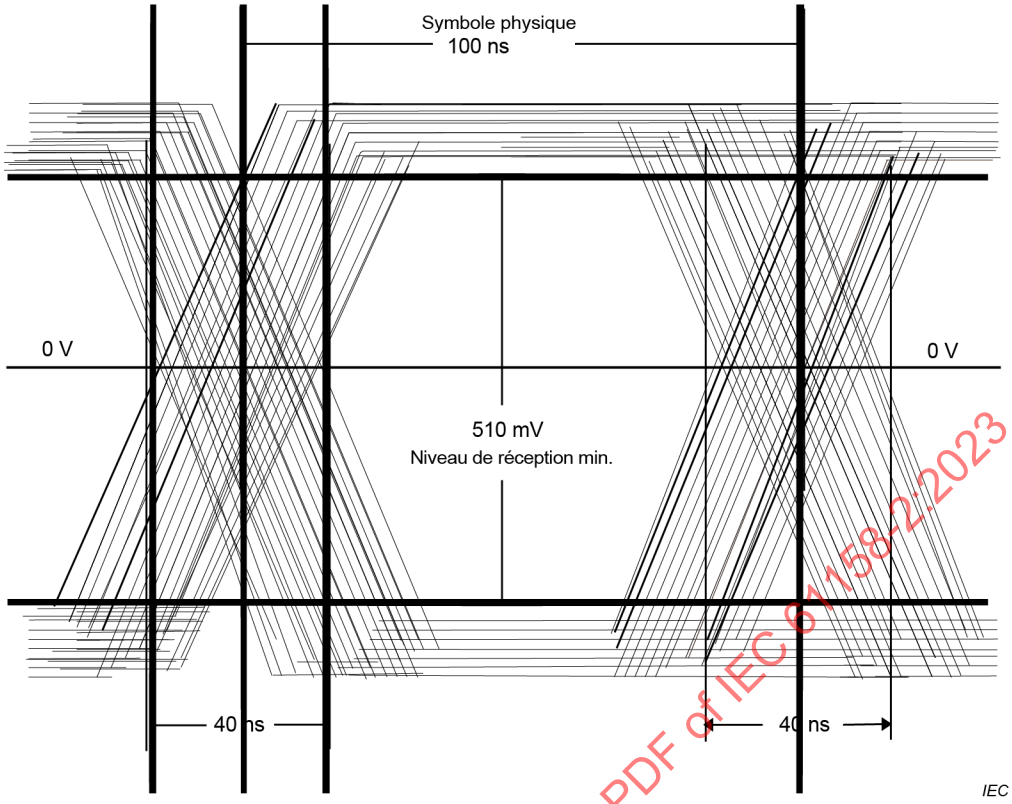


**Figure 104 – Masque de réception de MAU à câble coaxial**

**Tableau 125 – Interface du support à câble coaxial – Aspects généraux**

| Spécification | Limites / caractéristiques | Commentaires |
|---|---|---|
| Couplage | Couplage par transformateur | Masse isolée |
| Isolation à 0 Hz | 500 kΩ min [a] | Le blindage doit être couplé par R/C à la terre locale |
| Impédance d'entrée (Émission non active) | 0,2 dB de perte due à la prise | (Voir Figure 108)<br>Alternative au modèle d'impédance |
| Modèle d'impédance (Émission non active) | | Alternative à l'impédance d'entrée |
| Inductance série | 0,56 µH avec une tolérance de ± 20 % [b] | Mise sous tension |
| Inductance parallèle | 425 µH avec une tolérance de ± 20 % [b] | Mise sous tension |
| Capacité parallèle | 50 pF max [b]<br>55 pF max [b] | Sous tension<br>Hors tension |
| Résistance parallèle | 3,9 kΩ avec une tolérance de ± 20 % [b]<br>3,4 kΩ avec une tolérance de ± 20 % [b] | Sous tension<br>Hors tension |
| Connecteur | BNC ou TNC | Voir l'Annexe F pour plus d'informations |

[a] La valeur minimale du condensateur doit être de 0,01 µF/500 V. Cette exigence s'applique à toutes les interfaces de supports connectées au réseau.

[b] Toutes les impédances spécifiées doivent être satisfaites, l'émetteur étant à l'état non actif et avec mise sous tension ou hors-tension, comme cela est indiqué. Toutes les impédances spécifiées doivent être satisfaites sur l'ensemble de la plage dynamique du récepteur, du niveau de réception minimal au niveau de transmission maximal.

NOTE 3 Un exemple de conception de référence pour un émetteur-récepteur avec MAU à câble coaxial de 5 Mbit/s en mode tension est présenté au H.1.1.

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### 18.3 Transformateur pour câble coaxial de 5 Mbit/s en mode tension

NOTE 1 Le transformateur assure le couplage des signaux de transmission et de réception vers et en provenance du support. Une caractéristique importante du transformateur est qu'il assure l'isolation galvanique ou l'isolation à la terre entre nœuds. Cette disposition prévient des tensions en mode commun importantes dues aux différences de tension par rapport à la masse entre nœuds. Le transformateur évite également les boucles de masse importantes qui peuvent être sensibles au couplage magnétique à basse fréquence.

La Figure 105 représente la représentation schématique du transformateur.

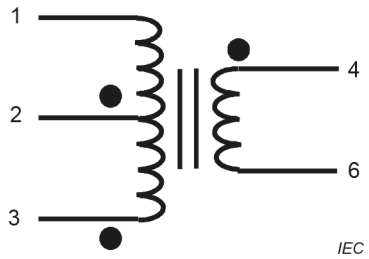


**Figure 105 – Schéma du transformateur**

Les transformateurs de couplage doivent satisfaire aux exigences spécifiées dans le Tableau 126.

**Tableau 126 – Spécifications électriques du transformateur à câble coaxial de 5 Mbit/s en mode tension**

| Spécification | Min. | Type | Max. |
|---|---|---|---|
| Inductance (mesurée à 40 kHz et 100 mV) | 350 µH | 750 µH | |
| Capacité d'enroulement (mesurée à 10 MHz) | 16,0 pF | 24,8 pF | 29,5 pF |
| Résistance parallèle (pertes dans le fer) | 8,0 kΩ | 9,1 kΩ | 11,2 kΩ |
| Inductance de fuite | 255 nH | 441 nH | 625 nH |
| Isolation galvanique (à (47-63) Hz, inférieure à 1,0 mA) | 500 $V_{eff}$ pendant 60 s<br>600 $V_{eff}$ pendant 1 s | | |
| Fréquence de résonance | 1,0 MHz | 1,4 MHz | 1,8 MHz |

L'inductance de fuite doit être mesurée entre les broches 1 et 2, et les broches 4 et 6 sont reliées ensemble. L'isolation galvanique doit être mesurée au moyen des broches 1, 2 et 3 reliées ensemble et les broches 4 et 6 reliées ensemble. L'isolation galvanique exigée doit être satisfaite de la broche 1 à la broche 4, de la broche 1 au noyau et de la broche 4 au noyau. Tous les autres mesurages doivent être effectués entre les broches 4 et 6, la broche 2 étant reliée à la masse de l'instrument.

NOTE 2 Un exemple de conception de référence pour un transformateur de MAU à câble coaxial de 5 Mbit/s en mode tension est présenté au H.1.2.

### 18.4 Connecteur de support à câble coaxial de 5 Mbit/s en mode tension

Le connecteur utilisé sur un nœud donné doit être une prise jack de type BNC ou TNC, conformément aux exigences du présent document (voir l'Annexe F).

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### 18.5 Topologie pour un support à câble coaxial de 5 Mbit/s en mode tension

Un segment doit être constitué d'une architecture ligne principale–ligne secondaire. La ligne principale doit être réalisée en câble coaxial et doit être terminée aux deux extrémités par une résistance de 75 Ω avec une tolérance de ± 5 %.

NOTE 1 Cette disposition permet de limiter les réflexions des signaux émis aux extrémités du câble de ligne principale.

Les nœuds doivent être connectés au réseau par des câbles de dérivation. Les câbles de dérivation doivent être connectés à la ligne principale au moyen de prises spécifiées. Ces prises doivent comprendre des circuits passifs qui permettent la connexion à la ligne principale tout en réduisant le plus possible les réflexions dues aux charges de connexion.

Les nœuds connectés à un réseau à commande déterministe ne doivent pas terminer directement à la masse le blindage du câble de dérivation. La terminaison du blindage doit être réalisée conformément au Tableau 125. Pour terminer correctement le blindage de chaque câble de dérivation, une résistance connectée en parallèle à un condensateur de 0,01 µF doit être utilisée. La R/C en parallèle doit être connectée du blindage à la masse.

Un exemple de topologie est représenté à la Figure 106.

NOTE 2 Dans cet exemple, deux segments sont connectés par un répéteur pour constituer une liaison à sept nœuds.

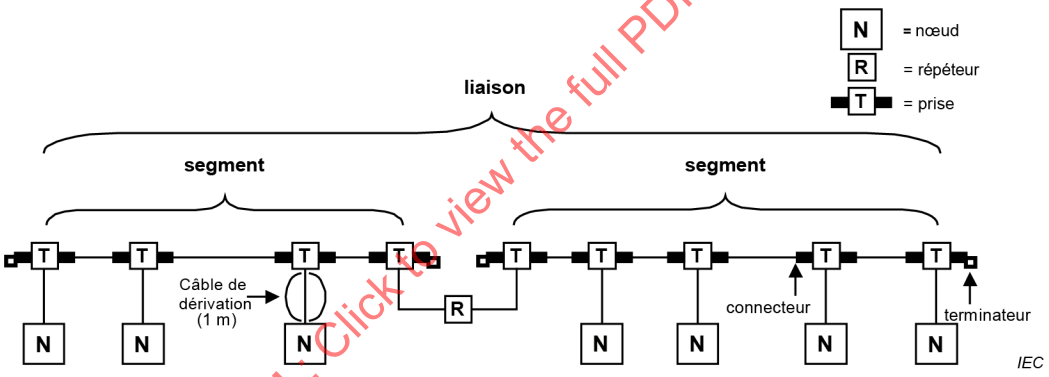


**Figure 106 – Exemple de topologie de câble coaxial de 5 Mbit/s en mode tension**

Les limites de cette topologie sont représentées à la Figure 107. Jusqu'à 48 nœuds peuvent être connectés à un segment d'une longueur jusqu'à 1 km, comme cela est représenté à la Figure 107. Le compromis entre distance et nombre de nœuds est représenté à la Figure 107. S'il est exigé une combinaison de nœuds et de distances qui dépasse les limites du segment, alors un appareil répéteur de PhL (voir l'Annexe G) doit être utilisé. En ce qui concerne le support, un appareil répéteur de PhL doit être semblable, du point de vue électrique et mécanique, à un nœud. L'appareil répéteur de PhL doit exiger une prise pour chaque segment auquel il est connecté et il peut par conséquent être connecté en tout point de chaque segment. Les répéteurs ne doivent pas être placés de manière à provoquer plusieurs connexions entre segments.

Toute topologie qui prend en charge un trajet unique entre deux entités PhL quelconques doit être mise en œuvre. Les trajectoires multiples entre des entités PhL ne doivent pas être admises par une application qui revendique la conformité à l'Article 18.

Cette variante de PhL peut être associée à d'autres variantes de PhL sur le même nœud, ou sur des nœuds différents, au moyen de la RM (machine répéteur) et/ou des appareils répéteurs de PhL (voir l'Annexe G).

NOTE 2 Pour plus d'informations sur les répéteurs, voir l'Annexe G.

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NOTE 3 Ces limites reposent sur les spécifications de câblage du 18.7.1.

La Figure 107 doit s'appliquer lorsqu'il est utilisé des prises comme cela est spécifié au 18.6 et le câble coaxial de ligne principale, comme cela est spécifié dans le Tableau 128. Les câbles qui présentent des caractéristiques d'affaiblissement autres que celles données dans le Tableau 128 peuvent être utilisés si un multiplicateur de longueur de segment approprié est appliqué conformément à la Figure 107.

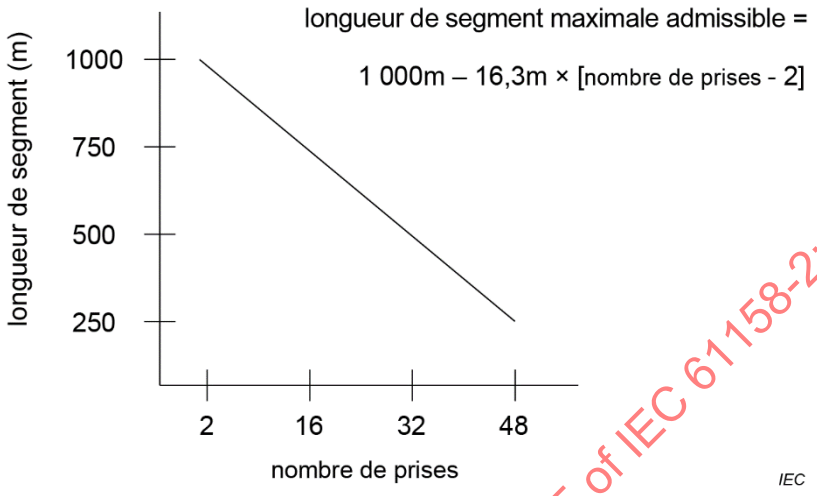


**Figure 107 – Limites de topologie d'un support à câble coaxial**

## 18.6 Prises pour un support à câble coaxial de 5 Mbit/s en mode tension

### 18.6.1 Description

La prise doit comporter des circuits passifs qui compensent les surcharges supplémentaires du nœud connecté.

NOTE 1 De cette manière, une perte de transmission moindre est obtenue plutôt qu'une discontinuité de l'impédance et par conséquent une réflexion sur la ligne principale pour chaque nœud.

Une prise doit être utilisée pour tous les nœuds qui satisfont à la méthode de connexion spécifiée du support à câble coaxial.

NOTE 2 Un exemple de conception de référence pour une prise de MAU à câble coaxial de 5 Mbit/s en mode tension est présenté au H.1.3.

### 18.6.2 Exigences

La variante de prise normalisée doit permettre des connexions au moyen de prises jack BNC au niveau de la ligne principale et d'une fiche BNC au niveau du nœud; la variante de prise étanche IP67 doit permettre des connexions de prise jack TNC au niveau de la ligne principale et d'une fiche TNC ou BNC au niveau du nœud, conformément aux exigences du présent document (voir l'Annexe F). Un câble de ligne secondaire de 1 m de longueur, du type spécifié, doit être utilisé dans la prise si une compensation correcte du câble de ligne secondaire doit être obtenue.

NOTE 1 Les exigences électriques de la prise sont définies par les caractéristiques émises et reflétées telles qu'elles sont perçues par la ligne principale lorsque l'accès de la prise est correctement connecté par la ligne secondaire exigée et une charge équivalente au nœud. Bien que la prise comporte trois accès, elle peut être perçue comme un appareil à deux accès lorsqu'elle est configurée de cette manière. Le terme "charge équivalente au nœud" signifie une charge qui représente l'impédance nominale d'un nœud. Une charge équivalente au nœud peut être constituée à partir de composants discrets tant que la charge équivalente satisfait à l'ensemble des exigences de l'Article 18.

Les exigences de transmission et de réflexion doivent être telles qu'elles sont représentées à la Figure 108. Les paramètres de diffusion (S11, S22, S12 et S21) doivent être utilisés pour

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définir les exigences électriques de la prise. S11 et S22 doivent être utilisés pour définir les caractéristiques de réflexion du connecteur de ligne principale d'une prise lorsque la ligne secondaire est terminée par une charge équivalente au nœud et que l'autre connecteur de ligne principale est terminé par un terminateur de ligne principale (75 Ω avec une tolérance de ± 5 %). S12 et S21 doivent être utilisés pour définir les caractéristiques de transmission de la prise d'un connecteur de ligne principale à l'autre, le câble de dérivation étant terminé par une charge équivalente au nœud. Les caractéristiques de transmission et de réflexion de toutes les prises doivent s'inscrire dans la zone d'acceptation définie à la Figure 108.

NOTE 2 La prise est un appareil réciproque (S11=S22, S12=S21), de sorte que l'orientation des accès de ligne principale est arbitraire.

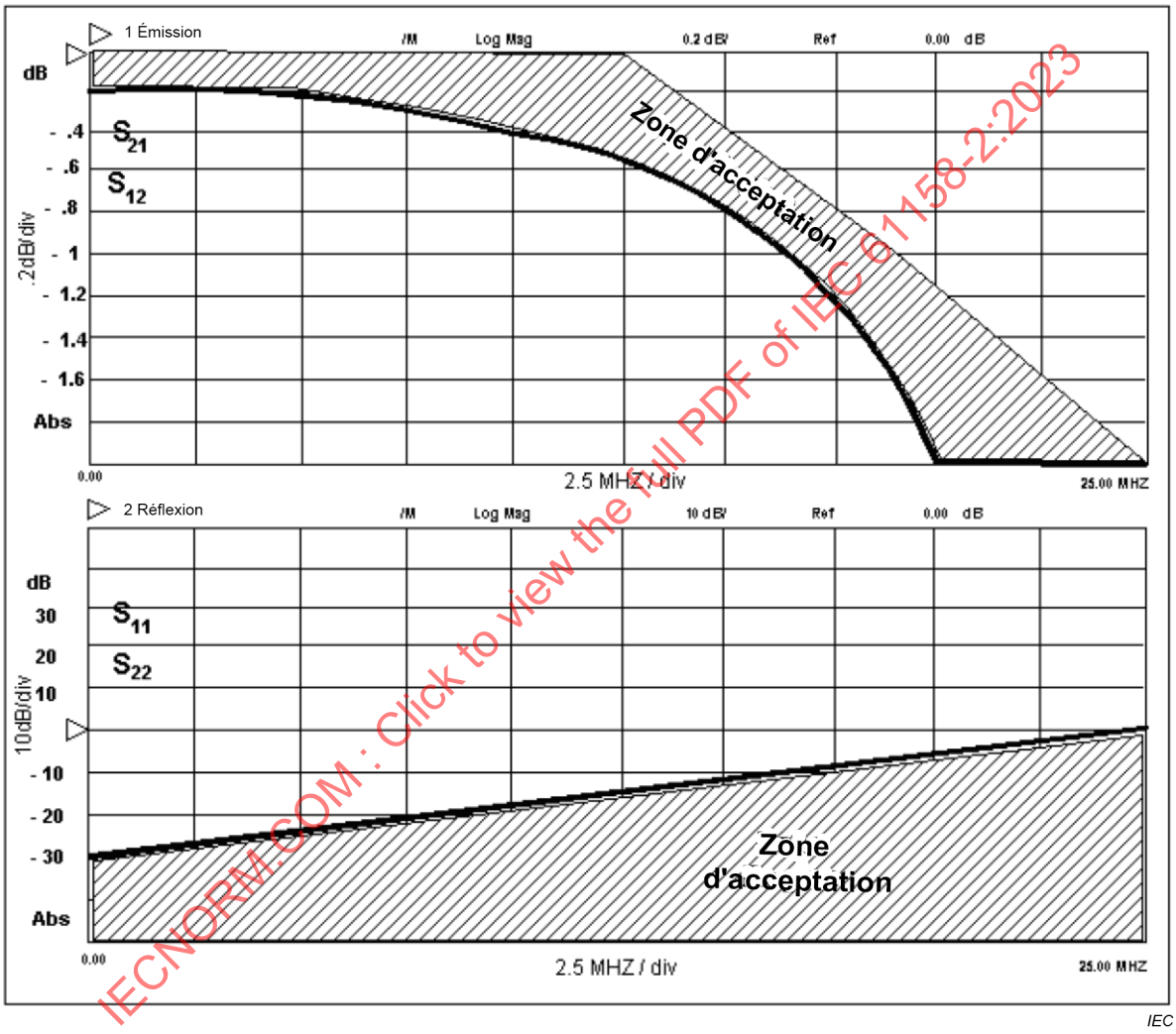


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**Figure 108 – Caractéristiques électriques d'une prise de support à câble coaxial**

### 18.6.3 Ligne secondaire

Le câble de ligne secondaire doit être conforme aux limites et caractéristiques indiquées dans le Tableau 127.

**Tableau 127 – Spécifications du câble coaxial de ligne secondaire**

| Spécification | Limites / caractéristiques |
|---|---|
| Blindage | Blindage à double tresse, chaque tresse ayant une couverture de 95 % |
| Impédance | 75 Ω ± 3 Ω |
| Retard | 4,1 ns/m ± 0,1 ns/m |
| Affaiblissement (dB/100 m) à | |
| 1 MHz | 1,25 |
| 5 MHz | 3,01 |
| 10 MHz | 4,33 |
| 25 MHz | 6,89 |
| 50 MHz | 10,1 |
| Affaiblissement de réflexion de régularité | 23 dB au moins, de 5 MHz à 50 MHz |
| Résistance en courant continu du conducteur | 92 Ω/km nominal |
| Résistance en courant continu du blindage | 10,5 Ω/km nominal |
| Capacité nominale | 54,13 pF/m |

## 18.7 Ligne principale pour un support à câble coaxial de 5 Mbit/s en mode tension

### 18.7.1 Câble de ligne principale

Le câble de ligne principale doit satisfaire aux spécifications du Tableau 128.

**Tableau 128 – Spécifications du câble coaxial de ligne principale**

| Spécification | Limites / caractéristiques |
|---|---|
| Blindage | Blindage quadruple |
| Impédance | 75 Ω ± 3 Ω |
| Retard | 4,1 ns/m ± 0,1 ns/m |
| Affaiblissement (dB/100 m) à | |
| 1 MHz | 1,15 |
| 2 MHz | 1,25 |
| 5 MHz | 1,48 |
| 10 MHz | 1,94 |
| 20 MHz | 2,82 |
| 50 MHz | 4,49 |
| Affaiblissement de réflexion de régularité | 23 dB au moins, de 5 MHz à 50 MHz |
| Résistance en courant continu du conducteur | 92 Ω/km nominal |
| Résistance en courant continu du blindage | 24 Ω/km nominal |
| Capacité nominale | 53,15 pF/m |

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Le câble de ligne secondaire spécifié dans le Tableau 127 peut également être utilisé comme câble de ligne principale sur des longueurs limitées (jusqu'à 10 m par segment).

### 18.7.2 Connecteurs

La connexion à la ligne principale doit utiliser une fiche BNC ou TNC, conformément aux exigences du présent document (voir l'Annexe F).

## 19 Type 2: Unité de liaison au support: support optique de 5 Mbit/s

### 19.1 Généralités

NOTE 1 L'Article 19 spécifie la variante de support optique et de PhL. Des informations importantes concernant la conception de la connexion de la PhL sont fournies.

NOTE 2 La méthode de connexion du support à fibre optique définit trois variantes de supports à fibre optique et de PhL. La première variante concerne les supports à fibre optique et PhL exigés pour un système de courte portée, pour des distances (nominales) jusqu'à 300 m, la seconde variante concerne des supports à fibre optique et PhL exigés pour un système de moyenne portée, pour des distances (nominales) jusqu'à 7 km et la dernière variante concerne des supports à fibre optique et PhL exigés pour un système de longue portée, pour des distances (nominales) jusqu'à 20 km.

La méthode de connexion du support à fibre optique doit comporter une topologie point à point ou en anneau en transmission bidirectionnelle simultanée, qui utilise un émetteur et un récepteur à chaque extrémité d'une paire de fibres.

Pour toutes les variantes, les méthodes de connexion du support à fibre optique doivent être définies comme une liaison point à point, ou une topologie en anneau. La liaison point à point doit relier des nœuds d'extrémité entre eux, des nœuds d'extrémité et des appareils répéteurs de PhL ou des répéteurs de PhL entre eux. La topologie en anneau doit connecter entre eux deux ou plusieurs nœuds ou appareils qui utilisent la machine répéteur d'anneau (RRM – *ring repeater machine*), décrite à l'Annexe G. Le passage entre support et topologies doit exiger l'utilisation d'un appareil répéteur de PhL. La mise en œuvre doit utiliser soit un concentrateur actif, une étoile active ou un anneau actif. Un concentrateur actif ou une étoile active doit comprendre au moins deux accès.

NOTE 3 La couche physique peut être mise en œuvre de manière à permettre une certification pour un fonctionnement dans des atmosphères explosives sans sacrifier la distance ou réduire le nombre de nœuds. Le présent document n'inclut pas d'exigences pour la certification de la sécurité intrinsèque, mais cherche à exclure des conditions ou situations qui empêchent la certification de la sécurité intrinsèque.

La MAU à support à fibre optique doit comprendre l'émetteur-récepteur à fibre optique et le connecteur à fibre optique. L'émetteur-récepteur doit utiliser les signaux définis dans l'interface MDS-MAU pour générer ceux qui sont nécessaires pour piloter l'émetteur-récepteur. La connexion au support doit être effectuée par l'intermédiaire de connecteurs à fibre optique.

### 19.2 Émetteur-récepteur de support optique de 5 Mbit/s

Pour prendre en charge un support à fibre optique, un émetteur-récepteur à fibre optique doit émettre et recevoir de la MDS les signaux L (bas) et H (haut). La partie émetteur de l'émetteur-récepteur doit obtenir des signaux de transmission de l'interface MDS-MAU, représentant les symboles H et L, et émet, au moyen d'un émetteur-récepteur directement couplé, des signaux "lumière active" (pour H) ou "lumière inactive" (pour L). Cela signifie que l'émetteur-récepteur doit être capable d'émettre et de recevoir la signalisation PhL à des fréquences comprises entre zéro (pas de transitions de symbole Ph) et 10 MHz au moins.

NOTE Les émetteurs-récepteurs directement couplés sont exigés, car les sous-couches MDS et MAU, telles qu'elles sont spécifiées, ne permettent pas l'insertion et la suppression d'une séquence de repos lorsqu'il n'y a pas de données L ou H à envoyer, c'est-à-dire au cours des périodes dans lesquelles il n'y a aucune activité de symbole Ph.

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Cette fonction doit être complétée dans le récepteur, qui doit fournir les indications RxData et RxCarrier à l'interface MDS-MAU, comme cela est représenté à la Figure 109, qui est un diagramme fonctionnel décrivant les composants de la MAU.

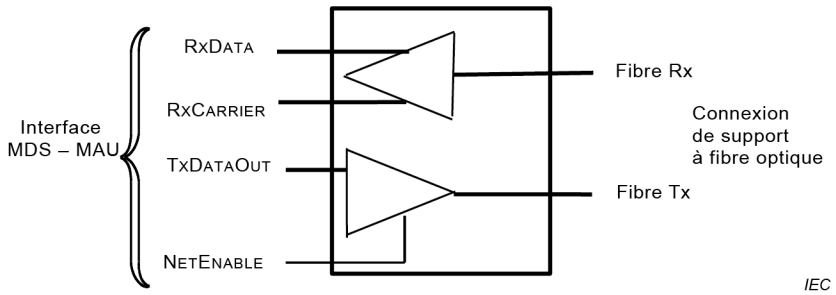


**Figure 109 – Diagramme de MAU 5 Mbit/s, support à fibre optique**

Les signaux de transmission doivent être tels qu'ils sont présentés dans le Tableau 129.

**Tableau 129 – Définitions des lignes de commande de transmission, support à fibre optique de 5 Mbit/s**

| TxDataOut | NetEnable | Symbole physique | Signal sur support à fibre optique |
|---|---|---|---|
| sans effet(x) | faux(0) | sans effet(x) | "lumière inactive'' |
| faux(0) | vrai(1) | L | "lumière inactive'' |
| vrai(1) | vrai(1) | H | "lumière active'' |

Les limites de transmission et de réception de l'interface à fibre optique doivent être conformes au Tableau 130.

**Tableau 130 – Interface de support à fibre optique de 5,0 Mbit/s**

| Spécification | Limites / caractéristiques | Commentaires |
|---|---|---|
| Instabilité du modèle d'entrée | 40 ns crête à crête max. | Mesurée sur RxData |
| Instabilité de transmission totale | < 5 ns crête à crête | |

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## 19.3 Topologie de support optique de 5 Mbit/s

La topologie des supports définie pour une variante de connexion de support à fibre optique, doit être une liaison point à point ou une topologie en anneau. La topologie point à point doit être utilisée entre deux entités PhL quelconques qui satisfont aux exigences de l'Article 19 et qui n'utilisent pas la RRM. La topologie en anneau doit être utilisée entre deux entités PhL quelconques qui satisfont aux exigences de l'Article 19 qui utilisent la RRM (voir l'Annexe G). Le passage entre ces deux topologies doit exiger l'utilisation d'un répéteur PhL ou de tout appareil qui utilise la fonction RRM et une PhL de répéteur. Dans les deux cas, les nœuds et les répéteurs doivent pouvoir être connectés en cascade, tant que chaque liaison satisfait aux exigences de l'Article 19. Le temps total de propagation du signal doit être utilisé pour le calcul de la durée de créneau, comme cela est décrit dans l'IEC 61158-4-2.

Toute topologie qui prend en charge un trajet unique entre deux entités PhL quelconques doit être mise en œuvre. Les trajectoires multiples entre des entités PhL ne doivent pas être admises par une application qui revendique la conformité à l'Article 19.

Cette variante de PhL peut être associée à d'autres variantes de PhL sur le même nœud, ou sur des nœuds différents, au moyen de la RM (machine répéteur) et/ou des appareils répéteurs de PhL (voir l'Annexe G).

### 19.4 Fibre optique de ligne principale de support de 5 Mbit/s

La fibre optique de la ligne principale doit satisfaire aux exigences spécifiées au 19.6 pour la variante appropriée de PhL à fibre optique.

### 19.5 Connecteurs de ligne principale de support à fibre optique de 5 Mbit/s

Les connecteurs de ligne principale doivent satisfaire aux exigences du présent document (voir l'Annexe F) pour les différentes variantes de PhL à fibre optique.

### 19.6 Spécifications de fibre optique de support de 5 Mbit/s

Les caractéristiques des signaux pour les supports à fibre optique et la variante de PhL correspondante, à une température de 25 ºC, doivent être telles qu'elles sont présentées dans le Tableau 131, le Tableau 132 et le Tableau 133.

**Tableau 131 – Spécification des signaux de support à fibre optique de 5 Mbit/s, de courte portée**

| Spécification | Min. | Nominale | Max. |
|---|---|---|---|
| **Fibre** | | | |
| Distance | 0 m | 300 m | |
| Affaiblissement de la fibre à λ | | 6 dB/km | |
| Technologie de fibre optique | à saut d'indice, silice gainée en dur (HCS – *hard clad silica*) | | |
| Cœur/gaine | 200/230 µm | | |
| Ouverture numérique | 0,5 | | |
| **Système** | | | |
| BER | $10^{-9}$ | | |
| Bilan de puissance | 3,9 dB | 9,5 dB | |
| **Émetteur** | | | |
| Longueur d'onde λ | 640 nm | 650 nm | 660 nm |
| Largeur spectrale | 21 nm | | |
| Puissance couplée, $P_{T\ on}$ (lumière d'émission active) | −16,1 dBm, crête | −12,5 dBm, crête | −8,5 dBm, crête |
| Puissance couplée, $P_{T\ off}$ (lumière d'émission inactive) | | | −44 dBm, crête |
| Temps de croissance optique $T_{rise}$ | | | |
| Temps de décroissance optique $T_{fall}$ | | | |
| **Récepteur** | | | |
| $P_{R\ MIN}$ (lumière de réception active) | | −25 dBm, crête | −23 dBm, crête |
| $P_{R\ MAX}$ (lumière de réception active) | −1,0 dBm | +3,0 dBm | |
| Distorsion de la largeur d'impulsion | | | 30 ns |

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**Tableau 132 – Spécification des signaux de support à fibre optique de 5 Mbit/s, de moyenne portée**

| Spécification | Min. | Nominale | Max. |
|---|---|---|---|
| **Fibre** | | | |
| Distance | 0 m | 7 km | |
| Affaiblissement de la fibre à λ | | 1,5 dB/km | |
| Technologie de fibre optique | à gradient d'indice, multimodale | | |
| Cœur/gaine | 62,5/125 µm | | |
| Ouverture numérique | 0, 275 | | |
| **Système** | | | |
| BER | $10^{-9}$ | | |
| Bilan de puissance | 11,3 dB | 16,4 dB | |
| **Émetteur** | | | |
| Longueur d'onde λ | 1 270 nm | 1 300 nm | 1 370 nm |
| Largeur spectrale | | 130 nm | 185 nm |
| Puissance couplée, $P_{T\ on}$ (lumière d'émission active) | −15,5 dBm, crête | −13,5 dBm, crête | −12,0 dBm, crête |
| Puissance couplée, $P_{T\ off}$ (lumière d'émission inactive) | | | −40 dBm, crête |
| Temps de croissance optique $T_{rise}$ | | 1,8 ns | 4,0 ns |
| Temps de décroissance optique $T_{fall}$ | | 2,2 ns | 4,0 ns |
| **Récepteur** | | | |
| $P_{R\ MIN}$ (lumière de réception active) | −33,5 dBm, crête | −31,8 dBm, crête | −28,8 dBm, crête |
| $P_{R\ MAX}$ (lumière de réception active) | | | |
| Distorsion de la largeur d'impulsion | | | 2 ns |

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**Tableau 133 – Spécification des signaux de support à fibre optique de 5 Mbit/s, de longue portée**

| Spécification | Min. | Nominale | Max. |
|---|---|---|---|
| **Fibre** | | | |
| Distance | | | 20 km |
| Affaiblissement de la fibre à λ | | 0,5 dB/km | |
| Technologie de fibre optique | à gradient d'indice, unimodale | | |
| Cœur/gaine | 10/125 µm | | |
| Ouverture numérique | 0,1 | | |
| **Système** | | | |
| BER | $10^{-9}$ | | |
| Bilan de puissance | 10 dB | | |
| **Émetteur** | | | |
| Longueur d'onde λ | 1 270 nm | 1 300 nm | 1 370 nm |
| Largeur spectrale | | 70 nm | |
| Puissance couplée, $P_{T\ on}$ (lumière d'émission active) | −18 dBm, crête | −15 dBm, crête | −10 dBm, crête |
| Puissance couplée, $P_{T\ off}$ (lumière d'émission inactive) | | | −40 dBm crête |
| Temps de croissance optique $T_{rise}$ | | 2 ns | 4,0 ns |
| Temps de décroissance optique $T_{fall}$ | | 2,2 ns | 4,0 ns |
| **Récepteur** | | | |
| $P_{R\ MIN}$ (lumière de réception active) | | −32 dBm, crête | −30 dBm, crête |
| $P_{R\ MAX}$ (lumière de réception active) | -10 dBm | | |
| Distorsion de la largeur d'impulsion | | | 2 ns |

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## 20 Type 2: Unité de liaison au support: port d'accès au réseau (NAP)

### 20.1 Généralités

La Figure 110 représente l'emplacement de la PhL du port d'accès au réseau (NAP) et du support dans le modèle de référence ISO/OSI.

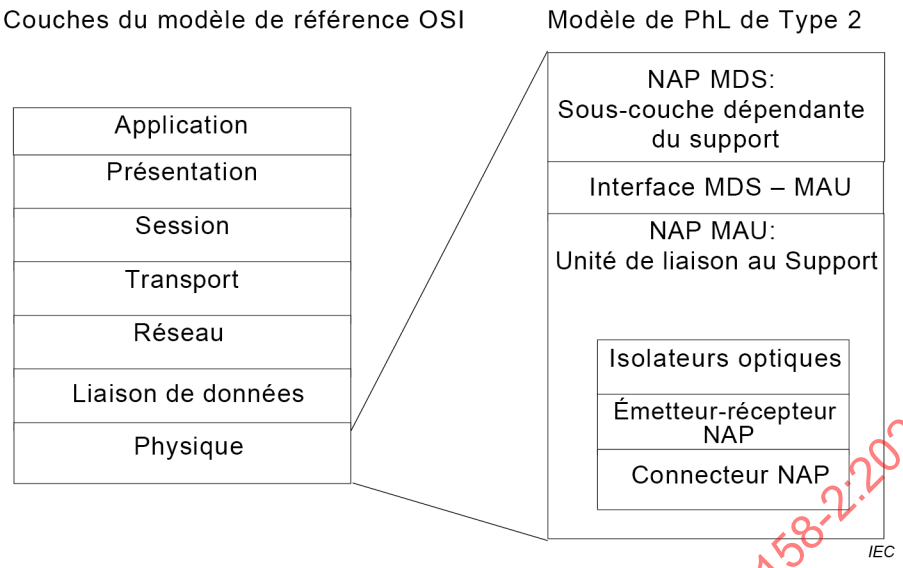


**Figure 110 – Modèle de référence NAP**

La connexion locale à un ordinateur (de bureau ou portable) à un appareil de programmation portatif ou toute autre connexion temporaire au réseau, doit être effectuée par l'intermédiaire de l'émetteur-récepteur NAP au moyen du protocole et des débits de données spécifiés pour la ligne principale. L'émetteur-récepteur NAP doit obtenir une ligne de transmission unique de l'interface MDS-MAU, envoyer des données et en recevoir d'un autre nœud à l'autre extrémité du câble NAP et fournir une seule ligne de réception en retour vers l'interface MDS-MAU.

S'agissant de lignes uniques, aucune représentation de l'activation/désactivation de la porteuse ne doit être présente. À tout moment, ces signaux doivent être soit un "zéro" logique soit un "un" logique. Le support doit à tout instant être piloté par la ligne de transmission unique.

La PhL du NAP doit prendre en charge une connexion point à point entre deux nœuds. Il ne doit pas y avoir une topologie de liaison multipoints qui prend en charge plus de deux nœuds.

Toute topologie qui prend en charge un trajet unique entre deux entités PhL quelconques doit être mise en œuvre. Les trajectoires multiples entre des entités PhL ne doivent pas être admises par une application qui revendique la conformité à l'Article 20.

Un nœud, dont la connexion principale à la liaison s'effectue par le biais de la variante de PhL du NAP, doit être considéré comme un nœud réseau transitoire. Un nœud, dont la connexion principale à la liaison s'effectue par toute autre variante de PhL, doit être considéré comme un nœud de réseau permanent. Un nœud transitoire doit communiquer avec un autre nœud transitoire ou permanent à l'aide du support NAP. Le nœud permanent doit utiliser la fonctionnalité machine répéteur (RM) (voir l'Annexe G) contenue dans la DLL de ce nœud pour permettre au nœud transitoire de communiquer avec d'autres nœuds permanents, comme cela est représenté à la Figure 111. Un nœud permanent doit fonctionner comme un nœud transitoire lorsqu'aucun autre support PhL n'est connecté, comme cela est représenté à la Figure 111.

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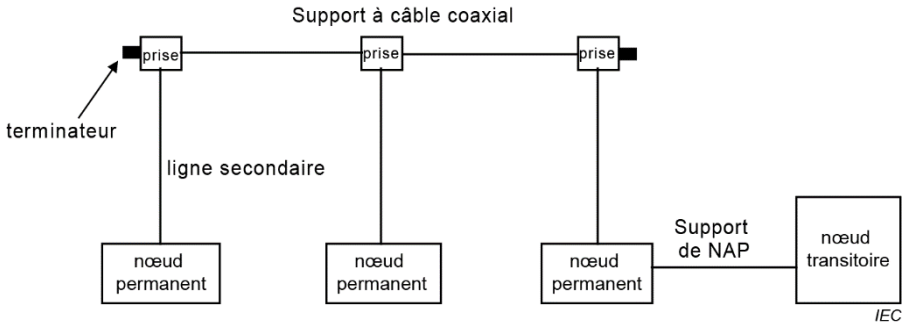


**Figure 111 – Exemples de nœuds transitoires et permanents**

Cette variante de PhL peut être associée à d'autres variantes de PhL sur le même nœud, ou sur des nœuds différents, au moyen de la RM (machine répéteur) et/ou des appareils répéteurs de PhL (voir l'Annexe G).

### 20.2 Signalisation

Les exigences de signalisation pour l'accès NAP doivent être telles qu'elles sont présentées dans le Tableau 134.

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**Tableau 134 – Exigences du NAP**

| Spécification d'interface NAP | Spécification de conception | Commentaires |
|---|---|---|
| **Interface NAP – Généralités** | | |
| Couplage | Courant continu | Isolateur optique exigé pour la programmation des nœuds |
| Configuration de la liaison | Deux, paire TIA-422-B unidirectionnelle | Une Rx, une Tx |
| Connecteur | RJ-45 blindé | Voir Annexe F |
| Terminaison | 100 Ω interne, uniquement sur /RxPTC | |
| **NAP – Transmission** | | |
| Niveau de sortie au niveau du support NAP avec /TxPTC = vrai | 2,5 V min. | Mesuré entre Tx_H et broche GND REF, avec une charge de réception NAP connectée de 100 Ω (voir le ) |
| Niveau de sortie au niveau du support NAP avec /TxPTC = faux | 2,5 V min. | Mesuré entre Tx_L et broche GND REF, avec une charge de réception NAP connectée de 100 Ω (voir le ) |
| Niveau de sortie au niveau du support NAP avec /TxPTC = vrai | 0,5 V max. | Mesuré entre Tx_L et broche GND REF, avec une charge de réception NAP connectée de 100 Ω (voir le ) |
| Niveau de sortie au niveau du support NAP avec /TxPTC = faux | 0,5 V max. | Mesuré entre Tx_H et broche GND REF, avec une charge de réception NAP connectée de 100 Ω (voir le ) |
| Niveau de sortie au niveau du support NAP avec /TxPTC = données | 4,0 V min. | (Tx_H – Tx_L) mesuré de crête à crête, avec une charge de 100 Ω (voir le ) |
| Instabilité de transmission totale | ± 5 ns max. | |
| Terminaison | Aucun | |
| **NAP – Réception** | | |
| Niveau de réception au niveau du support NAP avec /TxPTC = données | 2,5 V min. | (Rx_H – Rx_L) mesuré de crête à crête (voir le ) |
| Instabilité en réception | ± 15 ns max. | |
| Terminaison | 100 Ω avec une tolérance de ± 10 % | Entre lignes différentielles |
| Signal de réception de défauts | `/RxPTC` = vrai | Si le support est déconnecté, en court-circuit, avec le récepteur hors-tension ou désactivé, /RxPTC doit être "vrai" |

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## 20.3 Émetteur-récepteur

Le diagramme de la MAU du NAP de la Figure 112 représente les applications isolées et non isolées. Le NAP isolé doit être utilisé sur des nœuds transitoires. L'isolation optique doit être assurée pour éviter que des courants de boucle de masse ne circulent entre nœuds avec des potentiels de terre différents. L'isolation optique ne doit pas être exigée si le nœud est autoalimenté et qu'il n'est pas mis à la masse. Le NAP non isolé doit être utilisé sur des nœuds permanents.

NOTE 1 Un nœud transitoire est défini comme un nœud avec une connexion principale et ordinaire au réseau par l'intermédiaire du NAP d'un autre nœud. Cela comprend, entre autres, des cartes d'interface informatiques, des nœuds de configuration, ainsi que d'autres nœuds qui sont des connexions transitoires ou temporaires au réseau.

NOTE 2 Un nœud permanent est défini comme un nœud avec une connexion principale et ordinaire au réseau par l'intermédiaire d'une PhL autre que le NAP. Cela comprend, entre autres: les automates programmables, les adaptateurs de châssis E/S, les appareils de commande, les robots, les soudeuses et autres nœuds qui sont connectés au réseau de manière quasi-permanente.

Si un nœud peut être utilisé à la fois comme nœud transitoire et permanent, il doit inclure une isolation optique dans la conception du NAP (à moins qu'il ne soit autoalimenté et qu'il ne puisse pas être mis à la terre).

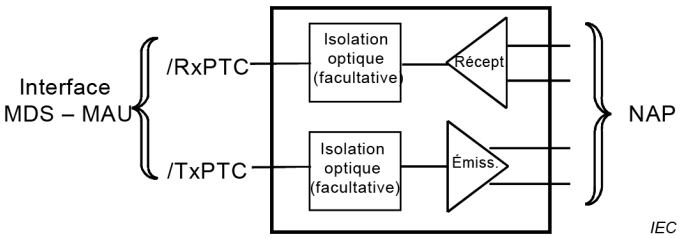



**Figure 112 – Émetteur-récepteur NAP**

NOTE 3 Un exemple de modèle de référence d'une MAU de port d'accès au réseau est présenté à l'Article H.2.

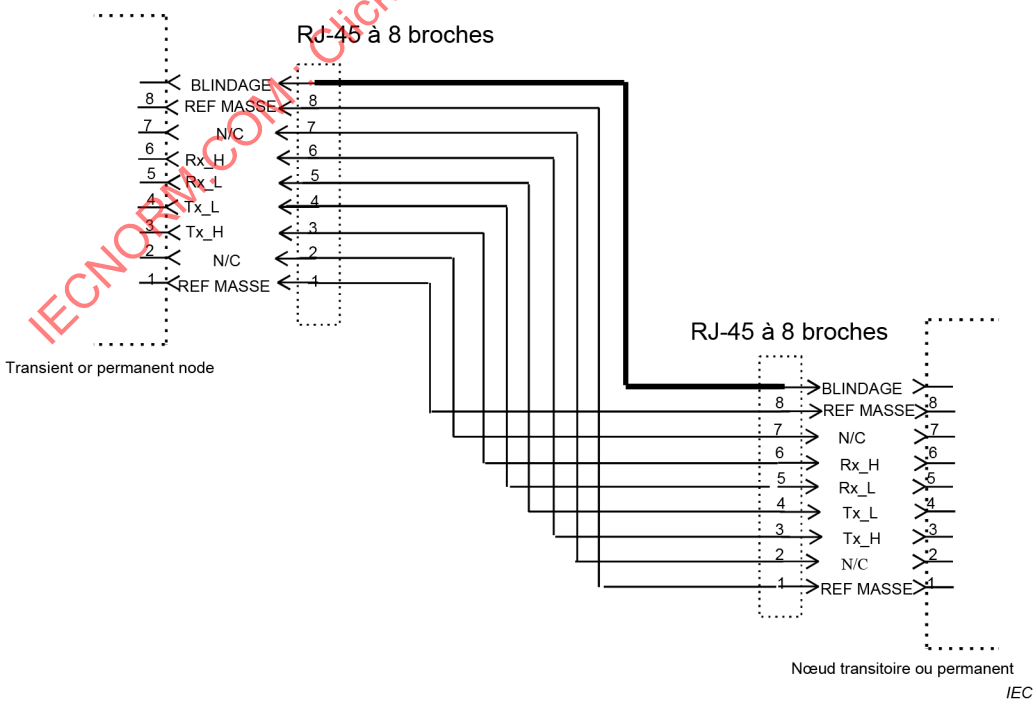
### 20.4 Connecteur

Le connecteur utilisé aux deux extrémités d'une connexion NAP doit être du type RJ-45 à 8 broches, blindé, comme cela est spécifié à l'Annexe F.

### 20.5 Câble

Le câble NAP doit contenir 8 conducteurs et un blindage global. Le blindage doit être conçu de manière à réduire le plus possible les perturbations électromagnétiques. Les broches du connecteur du câble doivent être telles qu'elles sont présentées dans le .

Sachant que le connecteur du NAP et les connexions des broches sont identiques pour les nœuds transitoires et permanents, le câble doit être conçu de manière à permettre les connexions correctes des données de transmission et de réception. Cela doit être obtenu par inversion de la connexion à une extrémité du câble NAP, comme cela est représenté à la Figure 113.




NOTE Les connecteurs du câble NAP sont montés de sorte que les lignes de signaux soient inversées pour permettre une connexion correcte. Ainsi, l'équipement peut utiliser la même configuration de broches indépendamment de la fonction.

**Figure 113 – Câble de NAP**

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Le câble de NAP doit satisfaire aux exigences suivantes:

a) caractéristiques des paires de lignes = 100 Ω;
b) résistance (à 0 Hz) = 0,122 Ω/m;
c) calibre du fil = 26 (7 brins, diamètre 0,16 mm);
d) conducteurs = 8 plus blindage global;
e) longueur maximale du câble = 10 m.

## 21 Type 3: Unité de liaison au support: Transmission synchrone, 31,25 kbit/s, mode tension, support câblé

### 21.1 Généralités

La MAU 31,25 kbit/s en mode tension fournit simultanément l'accès à un réseau de communication et à un réseau de distribution d'énergie facultatif. Les appareils raccordés au réseau communiquent par l'intermédiaire du support et peuvent ou non être alimentés par ce support. Si l'alimentation s'effectue par le bus, elle est distribuée en tension directe et en courant continu et des signaux de communication sont superposés sur l'alimentation en courant continu. Dans les applications de sécurité intrinsèque, la puissance disponible peut limiter le nombre d'appareils.

Le support réseau est constitué d'un câble à paire torsadée. Indépendamment de la topologie, tous les appareils connectés, sauf éventuellement l'appareil de transmission, présentent une haute impédance pour éviter une surcharge importante du réseau. Les formes d'onde trapézoïdales sont utilisées pour réduire les émissions électromagnétiques.

Des topologies en bus et arborescentes sont prises en charge. Quelle que soit la topologie, un réseau comporte un câble de ligne principale qui comporte des terminaisons aux deux extrémités. Dans la topologie de bus linéaire, les lignes secondaires sont réparties sur la longueur de la ligne principale. Dans la topologie arborescente, les lignes secondaires sont concentrées à une extrémité de la ligne principale. Une ligne secondaire peut connecter plusieurs appareils au réseau et le nombre d'appareils sur une ligne secondaire donnée dépend de la longueur de cette ligne.

À la fréquence industrielle (courant continu), les appareils apparaissent pour le réseau comme des absorbeurs de courant avec un taux de variation limité du courant d'alimentation prélevé du support. Cela permet d'éviter que les modifications transitoires du courant de charge n'interfèrent avec les signaux de communication.

### 21.2 Débit binaire de transmission

Voir 12.2.

### 21.3 Spécifications du réseau

#### 21.3.1 Composants

Le paragraphe 12.3.1 s'applique.

Lors de la sélection des différentes composantes, vérifier que toutes satisfont aux exigences du modèle FISCO. Seules les composantes identifiées comme matériel électrique de sécurité intrinsèque ou matériel électrique associé, conformément à l'IEC 60079-11, peuvent être installées sur des segments de bus de terrain de sécurité intrinsèque. Pour satisfaire aux exigences du 12.2.5.1 de l'IEC 60079-14:xxx, les valeurs admises des paramètres d'entrée $U_I$, $I_I$ et $P_I$ d'un matériel de sécurité intrinsèque (par exemple, des appareils de terrain) ne doivent pas être inférieures aux valeurs maximales certifiées des paramètres de sortie $U_0$, $I_0$ et $P_0$ de l'appareil d'alimentation correspondant. Des restrictions supplémentaires, applicables aux

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composantes individuelles (par exemple, limitation de la puissance d'alimentation ≤ 1,2 W) doivent être également prises en compte.

Le Tableau 135 énumère les combinaisons possibles d'appareils de différentes catégories de systèmes.

**Tableau 135 – Combinaison d'appareils de différentes catégories**

| Protection du segment de bus contre l'explosion | Protection de l'appareil d'alimentation contre l'explosion | Protection de l'appareil de terrain contre l'explosion | | | | | |
|---|---|---|---|---|---|---|---|
| | | EEx ia | | | EEx ib | | |
| | | IIC | IIB | IIC/IIB | IIC | IIB | IIC/IIB |
| EEx ia IIC (Groupe IIC) | [EEx ia] IIC | x | | x | | | |
| EEx ia IIB | [EEx ia] IIB | x | x | x | | | |
| (Groupe IIB) | [EEx ia] IIC | x | x | x | | | |
| EEx ib IIC | [EEx ib] IIC | x | | x | x | | x |
| (Groupe IIC) | [EEx ia] IIC | x | | x | x | | x |
| EEx ib IIB (Groupe IIC) | [EEx ib] IIB | (x)[a] | x | x | (x)[a] | x | x |
| | [EEx ib] IIC | x | x | x | x | x | x |
| | [EEx ia] IIB | (x)[a] | x | x | (x)[a] | x | x |
| | [EEx ia] IIC | x | x | x | x | x | x |
| Quelle que soit la combinaison choisie, il faut vérifier que les valeurs maximales absolues des caractéristiques assignées d'entrée de l'appareil de terrain correspondent aux caractéristiques de sortie de l'appareil d'alimentation<br>$U_I \geq U_O$<br>$I_I \geq I_O$<br>$P_I \geq P_O$ | | | | | | | |
| [a] Ces combinaisons sont possibles en théorie, mais elles ne sont pas pertinentes en pratique, car les appareils de terrain peuvent être certifiés pour le groupe IIC et pour le groupe IIB également (voir la colonne IIC/IIB). | | | | | | | |

Des appareils alimentés par le bus et des appareils alimentés localement sur un bus de terrain de sécurité intrinsèque peuvent être connectés si les appareils alimentés localement sont équipés d'une isolation appropriée conforme à l'IEC 60079-11.

Bien que la connexion d'une station de bus de terrain (par exemple, un appareil de terrain, un terminal portatif et un coupleur pour le maître du bus) avec inversion des pôles n'affecte pas la fonctionnalité des autres appareils connectés au bus de terrain, une station de bus installée de manière incorrecte et qui n'est pas équipée d'une détection automatique de la polarité n'est pas alimentée en énergie ou ne peut pas émettre et recevoir. Les stations qui sont équipées d'une détection automatique de la polarité fonctionnent correctement quelle que soit l'attribution des bornes d'entrée aux conducteurs.

### 21.3.2 Topologies

Une MAU câblée doit fonctionner sur un réseau de topologie de bus linéaire constitué d'une ligne principale, terminée à chaque extrémité comme cela est spécifié au 21.8.5, et à laquelle des éléments de communication sont connectés par l'intermédiaire de coupleurs et de lignes secondaires.

Le coupleur et l'élément de communication peuvent être intégrés dans un seul appareil (c'est-à-dire une ligne secondaire de longueur zéro).

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Une topologie arborescente dont tous les éléments de communication sont placés aux extrémités de la ligne principale est considérée comme un cas particulier de bus aux fins de l'Article 21.

Plusieurs éléments de communication peuvent être connectés à la ligne principale en un point donné, au moyen d'un coupleur multivoies. Un coupleur actif peut être utilisé pour étendre une ligne secondaire sur une longueur qui exige une terminaison afin d'éviter les réflexions et distorsions. Des répéteurs actifs peuvent être utilisés pour étendre la longueur de la ligne principale au-delà d'un segment unique comme le permettent les règles de configuration du réseau.

### 21.3.3 Règles de configuration du réseau

Une MAU de 31,25 kbit/s en mode tension doit satisfaire aux exigences de l'Article 21 lorsqu'elle est utilisée sur un réseau qui satisfait aux présentes règles.

**Règle 1:** Un bus de terrain doit être capable d'assurer la communication entre les nombres d'appareils indiqués ci-après, qui fonctionnent tous au même débit binaire:

a) pour un bus de terrain non IS sans alimentation par les conducteurs de signaux: entre deux et 32 appareils;

b) pour un bus de terrain non IS avec alimentation par l'intermédiaire de conducteurs de signaux: entre deux et le nombre d'appareils qui peuvent être alimentés par l'intermédiaire des conducteurs de signaux, sur la base de l'hypothèse selon laquelle au moins 120 mA doivent être mis à la disposition des appareils à l'extrémité distante de l'alimentation et en sachant que la communication avec un appareil à l'extrémité de l'alimentation consomme 10 mA;

c) pour un bus de terrain IS: entre deux et le nombre d'appareils qui peuvent être alimentés par l'intermédiaire des conducteurs de signaux, sur la base de l'hypothèse selon laquelle au moins 40 mA doivent être mis à la disposition des appareils dans la zone dangereuse.

NOTE 1 La règle 1 n'exclut pas l'utilisation d'un nombre d'appareils supérieur à celui spécifié dans un système installé. Étant donné que la consommation d'énergie de l'appareil n'est pas spécifiée, le nombre d'appareils alimentés par le bus ne peut pas être spécifié. Le point b) prend pour hypothèse que la tension minimale d'alimentation est de 20 V en courant continu. Le point c) prend pour hypothèse que la barrière IS fonctionne avec une sortie de 19 V en courant continu.

**Règle 2:** La longueur totale de câble entre deux appareils quelconques, y compris les lignes secondaires, d'un segment de bus de terrain de 31,25 kbit/s en mode tension, à pleine charge (comportant le nombre maximal d'appareils connectés) doit être de 1 900 m au plus.

NOTE 2 Cette longueur maximale du câble de 1 900 m est l'exigence de conformité à l'Article 21, mais n'exclut pas l'utilisation de longueurs supérieures dans un système installé.

**Règle 3:** Le nombre total de régénérations de forme d'onde par des répéteurs et des coupleurs actifs entre deux appareils quelconques ne doit pas être supérieur à quatre.

**Règle 4:** Le délai maximal de propagation entre deux appareils quelconques ne doit pas dépasser 20 Tbit.

Pour que le réseau fonctionne efficacement, il convient que cette partie du temps de retournement de tout appareil du réseau, générée par une PhE entre la fin d'une trame reçue et le début d'une trame émise qui contient une réponse immédiate associée, ne dépasse pas 5 temps binaires, dont il convient que 2 temps binaires au plus soient dus à la MAU.

NOTE 3 Sachant qu'il n'est pas obligatoire d'exposer l'interface DLL – PhL ou l'interface MDS – MAU, cette partie du temps de retournement d'un appareil de bus de terrain due à la PhL ou à la MAU n'est pas spécifiée et donc non disponible pour des essais de conformité.

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**Règle 5:** Le bus de terrain doit pouvoir fonctionner en continu lorsqu'un appareil y est connecté ou déconnecté. Les erreurs de données générées lors de la connexion ou de la déconnexion doivent être détectées.

**Règle 6:** La défaillance d'un quelconque élément de communication ou d'une ligne secondaire (à l'exception d'un court-circuit, d'une faible impédance ou d'un bavardage) ne doit pas interférer avec des transactions entre d'autres éléments de communication pendant plus de 1 ms.

**Règle 7:** Dans des systèmes polarisés, les paires torsadées du support doivent être distinctement repérées afin d'identifier de manière unique chaque conducteur individuel. La polarisation doit être maintenue en tout point de raccordement.

**Règle 8:** La dégradation des caractéristiques électriques du signal, entre deux appareils quelconques, due à l'affaiblissement, à la distorsion d'affaiblissement et à la désadaptation, doit être limitée aux valeurs indiquées ci-dessous.

a) Affaiblissement du signal: La configuration du bus (longueurs de la ligne principale et des lignes secondaires, nombre d'appareils, barrières IS, sectionneurs galvaniques et éventuels appareils d'adaptation) doit être telle que l'affaiblissement entre deux appareils quelconques, à la fréquence qui correspond au débit binaire, ne doit pas dépasser 10,5 dB.

b) Distorsion d'affaiblissement: La configuration du bus (longueurs de ligne principale et de lignes secondaires, nombre d'appareils, barrières IS et sectionneurs galvaniques) doit être telle qu'entre deux appareils quelconques:

   [Affaiblissement (1,25 $f_r$) – Affaiblissement (0,25 $f_r$)] ≤ 6 dB

   Affaiblissement (1,25 $f_r$) ≥ Affaiblissement (0,25 $f_r$)

   où $f_r$ est la fréquence qui correspond au débit binaire. L'affaiblissement doit être monotonique pour toutes les fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz).

c) Distorsion de désadaptation: La désadaptation (due à des lignes secondaires ou à tout autre effet, y compris une ligne secondaire en circuit ouvert de longueur maximale) sur le bus doit être telle qu'en tout point sur la ligne principale dans la bande de fréquence comprise entre 0,25 $f_r$ et 1,25 $f_r$ (7,8 kHz à 39 kHz):

   $|Z - Zf_r| / |Z + Zf_r| \leq 0,2$

   où $Z_o$ est l'impédance caractéristique du câble de ligne principale et Z est la combinaison parallèle de $Z_o$ et de l'impédance de charge au niveau du coupleur.

La concentration des coupleurs doit être inférieure à 15 pour 250 m.

NOTE 4 La règle 8 permet de réduire le plus possible les restrictions, en matière de longueurs de la ligne principale et des lignes secondaires ainsi qu'en matière de nombre d'appareils, etc. en ne spécifiant que les limites de transmission imposées par des combinaisons de ces facteurs. Il est possible d'utiliser différentes combinaisons en fonction des besoins de l'application.

**Règle 9:** Les règles suivantes doivent s'appliquer aux systèmes mis en œuvre avec des supports redondants:

a) chaque canal (câble) doit satisfaire aux règles de configuration du réseau;

b) il ne doit pas y avoir de segment non redondant entre deux segments redondants;

c) les répéteurs doivent également être redondants;

d) si le système est configuré (par la Gestion systèmes) pour émettre sur plusieurs canaux simultanément, alors la différence de délai de propagation entre deux appareils quelconques sur deux canaux quelconques ne doit pas dépasser cinq temps binaires;

e) les numéros de canaux doivent être maintenus sur l'ensemble des bus de terrain, c'est-à-dire que les canaux 1, 2, 3… en provenance de la Gestion systèmes doivent toujours être connectés aux canaux physiques 1, 2, 3…

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### 21.3.4 Règles de distribution de l'alimentation pour la configuration du réseau

Voir 12.3.4.

## 21.4 Spécification du circuit de transmission pour la MAU 31,25 kbit/s en mode tension

### 21.4.1 Récapitulatif

Pour faciliter le renvoi aux textes correspondants, les exigences définies au 21.2 et au 21.4 sont résumées dans le Tableau 98 et le Tableau 99 (voir 12.4.1).

### 21.4.2 Configuration d'essai

La Figure 79 (voir 11.4.2) représente la configuration qui doit être utilisée pour les essais.

Tension de signal en mode différentiel: $V_d = V_a - V_b$.

Résistance de la charge d'essai R = 50 Ω ($Z_o$ du câble 0,5) et C = 10 µF, sauf spécification contraire dans une exigence particulière.

### 21.4.3 Impédance

Pour les interfaces du bus (c'est-à-dire la MAU – unité de liaison au support) des appareils de terrain et des éléments de couplage, ainsi que pour les alimentations, le 11.4 exige que l'impédance d'entrée (peut être mesurée à partir de la ligne de bus) dans la plage de fréquences des signaux (7,8 kHz à 39 kHz) ne descende pas sous une valeur minimale en fonctionnement normal. À l'exception des premières 10 ms qui suivent la connexion d'un appareil de terrain à une alimentation, cette exigence s'applique à tous les aspects du fonctionnement. Le Tableau 136 donne les impédances d'entrée des interfaces de bus et des alimentations.

**Tableau 136 – Impédances d'entrée des interfaces de bus et des alimentations**

| | Impédance | Plages de tension | Plages de courant |
|---|---|---|---|
| Interface de bus (par exemple, appareil de terrain) | ≥ 3 kΩ | 9 V à 32 V | Pour le courant de fonctionnement |
| Alimentation de bus de sécurité intrinsèque | ≥ 400 Ω | Pour la tension de service | 0 à IMax |
| Alimentation de bus non de sécurité intrinsèque | ≥ 3 kΩ | Pour la tension de service | 0 à IMax |

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L'impédance d'entrée de l'interface de bus doit être mesurée avec un signal sinusoïdal dont l'amplitude doit être supérieure à la sensibilité du récepteur et toujours inférieure à 2 Vss.

NOTE Aucun signal de mesure n'est défini pour l'alimentation.

L'impédance de l'appareil de terrain et de l'alimentation doit être déterminée au moyen du circuit de mesure représenté à la Figure 114.

L'impédance X de l'appareil à l'essai est calculée à partir du rapport des deux tensions $U_D$ et $U_R$.

$$X = R_M \times \frac{U_D}{U_R}$$

Les deux tensions mesurées représentent des valeurs complexes dont le déphasage est inclus dans le résultat. Si $U_R$ est utilisée comme référence, alors:

$$X = R_M \times \frac{|U_D|}{|U_R|} \times e^{j\varphi}$$

où

$\varphi$ est le déphasage $\varphi(U_D)$- $\varphi(U_R)$.

Cela réduit le mesurage de l'impédance à un mesurage du rapport des deux tensions et à un mesurage de la différence de phase.

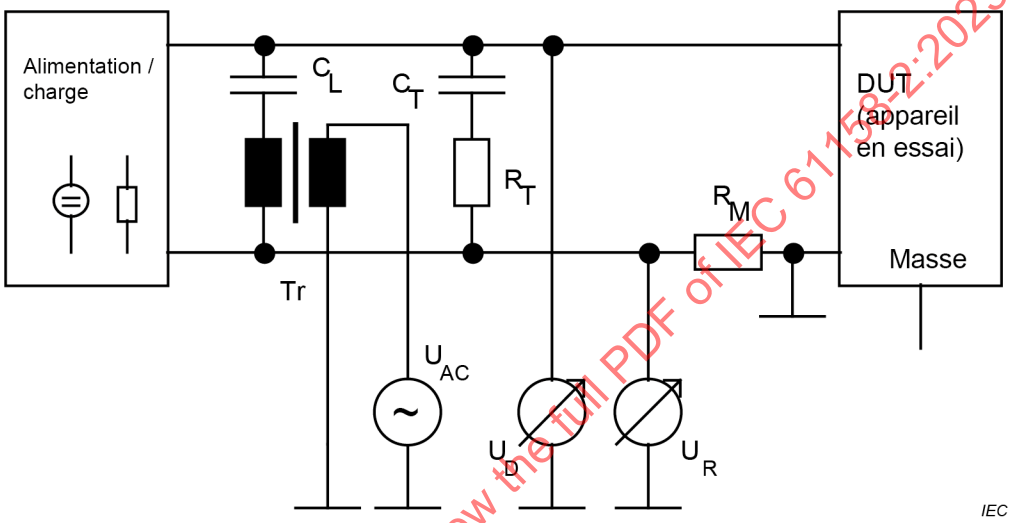


**Figure 114 – Schéma de principe de la mesure de l'impédance**

Exemple

CL = CT = 2 µF, RT = RM = 100 Ω

Le déphasage peut également être négatif. Dans ce cas, l'objet à mesurer représente une charge négative qui donne une amplification plutôt qu'un affaiblissement. Cette charge peut être omise (elle a même des effets positifs) pour la plage de fréquences des signaux de 7,9 kHz à 39 kHz tant que |X| demeure dans la plage spécifiée.

NOTE Il n'y a aucune spécification concernant l'impédance. Une valeur faible quelconque est possible. Si elle est associée à des conditions de circuit extérieur défavorables (par exemple, de longues lignes d'adaptation), une impédance négative peut créer un circuit oscillant non atténué qui transforme le système de bus en un oscillateur, même si l'objet à mesurer demeure stable dans le circuit de mesure.

Les sources d'erreurs suivantes peuvent affecter le résultat de mesure de l'impédance.

a) Distorsions non linéaires. Correction: Utiliser une méthode de mesure sélective en fréquence (c'est-à-dire, évaluer uniquement l'onde fondamentale) et surveiller le signal de mesure au moyen d'un oscillographe.

b) Asymétries du montage de mesure. Correction: Utiliser un transformateur symétrique Tr et éviter les capacités de mise à la masse. Laisser ouverte toute connexion à la masse de l'objet d'essai (due par exemple au filtre CEM) lors de la mesure de l'impédance.

c) Signaux de bruit générés par l'objet d'essai. Correction: Mesurer le bruit de fond. Il doit être ≤ 1 $mV_{eff}$ (mesuré à 50 Ω). Si cette condition est remplie, l'effet sur le mesurage de l'impédance peut être omis.

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### 21.4.4 Symétrie

Toutes les interfaces du bus doivent être isolées de la terre. La capacité dissymétrique entre les deux bornes de bus et la terre ne doit pas dépasser 250 pF. Cette disposition est également exigée pour les barrières et les alimentations.

À condition que l'impédance entre chacune des deux bornes de bus et la terre ne comporte qu'une composante capacitive, la mesure des deux capacités de terre effectives et le calcul de la différence peuvent déterminer l'asymétrie. Des composantes inductives significatives sont présentes, notamment lorsqu'il est utilisé des interfaces de bus qui ne sont pas de sécurité intrinsèque et qui peuvent être couplées au bus par l'intermédiaire d'un transformateur. Même lorsqu'il est utilisé des éléments de couplage qui ne comportent pas des composantes d'inductivité, le comportement inductif dû à des effets parasites peut être détecté, notamment aux fréquences supérieures. Au mieux, une asymétrie purement capacitive dans une plage de fréquences limitée peut uniquement être prise pour hypothèse. De ce fait, il est recommandé de déterminer le rapport de réjection en mode commun (CMRR – *Common Mode Rejection Ratio*) comme cela est défini à la Figure 115 pour évaluer les caractéristiques de symétrie.

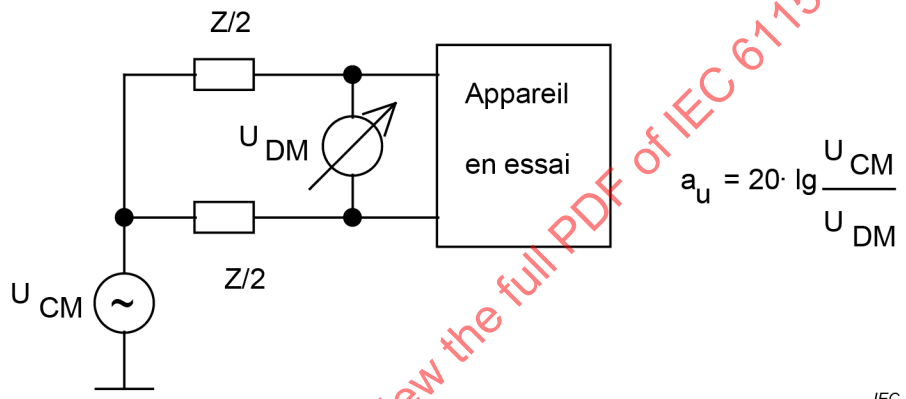


**Figure 115 – Définition du CMRR**

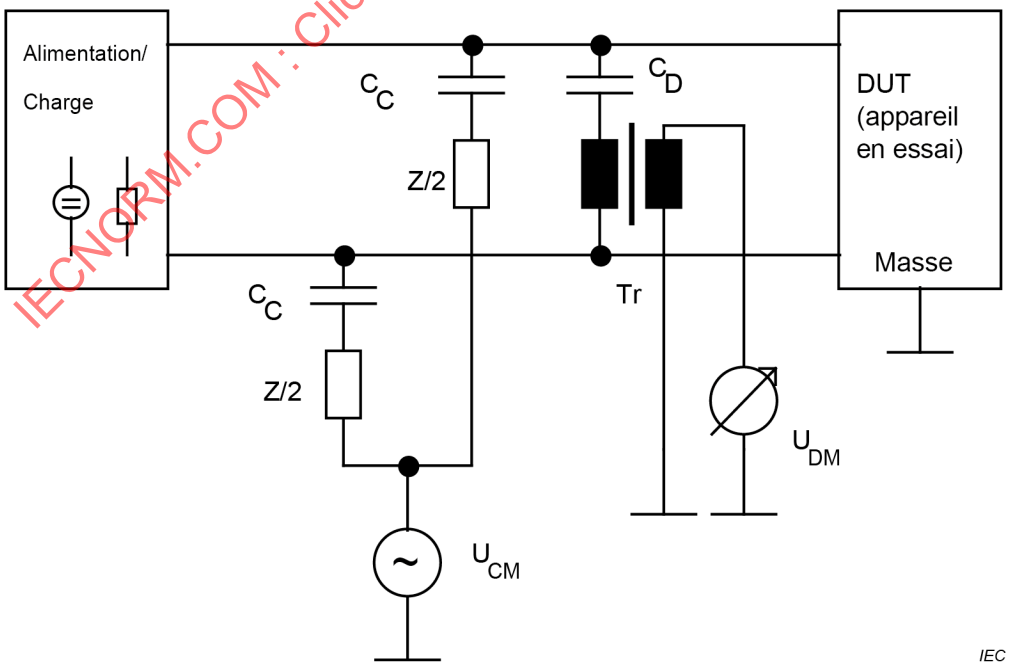


**Figure 116 – Schéma de principe de mesure du CMRR**

EXEMPLE

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$C_C = C_D$ = 2 µF, Z/2 = 25 Ω avec une tolérance de ± 0,1 %.

L'appareil de terrain, la barrière ou l'alimentation doit satisfaire au CMRR exigé dans le Tableau 137. En ce qui concerne la capacité dissymétrique, le CMRR doit être plus élevé que les valeurs énumérées dans le Tableau 137. Le CMRR de l'instrument de mesure (par exemple, comme cela est représenté à la Figure 116) sans l'appareil en essai (DUT – *Device under test*) doit être d'au moins 10 dB supérieur aux valeurs indiquées.

**Tableau 137 – CMRR exigé**

| Fréquence | kHz | ≤ 40 | 120 | 400 | 1 200 |
|---|---|---|---|---|---|
| CMRR | dB | ≥ 50 | ≥ 40 | ≥ 30 | ≥ 20 |

### 21.4.5 Exigences de niveau de sortie

Voir 12.4.3.

### 21.4.6 Exigences de temporisation des sorties

Voir 12.4.4.

### 21.4.7 Polarité du signal

Voir 11.4.5.

## 21.5 Spécification du circuit de réception pour la MAU 31,25 kbit/s en mode tension

Voir 12.5.

## 21.6 Inhibition du bavardage

Voir 12.6.

## 21.7 Distribution de l'alimentation

### 21.7.1 Généralités

Un appareil peut, facultativement, recevoir son alimentation par l'intermédiaire des conducteurs de signaux ou être alimenté de manière séparée.

Un appareil peut être certifié comme étant de sécurité intrinsèque quelle que soit la méthode d'alimentation.

NOTE Le présent document n'inclut pas d'exigences pour la certification IS, mais cherche à exclure des conditions ou situations qui empêchent la certification IS.

Un appareil à alimentation séparée peut être connecté à un bus de terrain alimenté.

Pour faciliter le renvoi aux textes correspondants, les exigences définies au 21.7 sont résumées dans le Tableau 138 et Tableau 139.

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**Tableau 138 – Caractéristiques des appareils alimentés par le réseau pour la MAU de 31,25 kbit/s en mode tension**

| Caractéristiques des appareils alimentés par le réseau | Limites pour 31,25 kbit/s |
|---|---|
| Tension de service | 9,0 V courant continu à 32,0 V courant continu |
| Tension de tenue minimale, quelle que soit la polarité, sans dommage | 35 V |
| Taux de variation maximal du courant passif (pas de transmission); cette exigence ne s'applique pas au cours des 10 premières ms après connexion de l'appareil à un réseau opérationnel ou dans les 10 premières ms après mise sous tension du réseau | 1,0 mA/ms |
| Courant maximal; cette exigence s'applique au cours de l'intervalle de temps de 100 µs à 10 ms après connexion de l'appareil à un réseau opérationnel ou 100 µs à 10 ms après mise sous tension du réseau (voir Note) | Courant passif assigné □ plus 10 mA |
| NOTE Les premières 100 µs sont exclues pour permettre le chargement des filtres RFI et autres capacités de l'appareil. La spécification du taux de variation s'applique après 10 ms. | |

**Tableau 139 – Exigences d'alimentation réseau pour la MAU de 31,25 kbit/s en mode tension**

| Exigences d'alimentation réseau | Limites pour 31,25 kbit/s |
|---|---|
| Tension de sortie, non IS | ≤ 32 VDC |
| Tension de sortie, IS | En fonction des caractéristiques assignées de la barrière |
| Ondulation de sortie et bruit | Voir la Figure 117 |
| Impédance de sortie, non IS, mesurée sur la plage de fréquences 0,25 fr à 1,25 fr | ≥ 3 kΩ |
| Impédance de sortie, IS, mesurée sur la plage de fréquences 0,25 fr à 1,25 fr | ≥ 400 Ω (Voir Note) |
| NOTE 2 Par hypothèse, l'alimentation IS comprend une barrière IS. | |

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### 21.7.2 Tension d'alimentation

Un appareil de bus de terrain qui comprend une MAU de 31,25 kbit/s en mode tension, doit pouvoir fonctionner dans une plage de tension de 9 V à 32 V en courant continu entre les deux conducteurs, y compris l'ondulation. L'appareil doit résister à une tension minimale de ±35 V DC sans aucun dommage.

NOTE 1 Pour des systèmes IS, la tension de service peut être limitée par les exigences de certification. Dans ce cas l'alimentation est placée dans la zone de sécurité et sa tension de sortie est atténuée par une barrière de sécurité ou composante équivalente.

Un appareil de bus de terrain qui comprend une MAU de 31,25 kbit/s en mode tension doit satisfaire aux exigences de l'Article 21 lorsqu'il est alimenté par une source ayant les spécifications suivantes.

a) La tension de sortie maximale de l'alimentation, pour des réseaux non IS, doit être de 32 V courant continu, y compris l'ondulation.

b) L'impédance de sortie de l'alimentation, pour des réseaux non IS, doit être 3 kΩ sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz). Cette exigence ne s'applique pas dans les 10 ms après connexion ou retrait d'un appareil de terrain.

c) L'impédance de sortie d'une alimentation IS doit être 400 Ω sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz).

NOTE 2 Par hypothèse, l'alimentation IS comprend une barrière IS.

d) Les exigences de claquage de l'isolation du circuit de signaux et du circuit de distribution de l'alimentation par rapport à la masse et par rapport à l'autre circuit doivent être conformes à l'IEC 61131-2.

La tension d'essai équivalente doit être appliquée entre circuits isolés indépendants ou entre circuits isolés et parties conductrices accessibles.

NOTE 3 Pour des circuits de tension nominale50 V en courant continu ou efficace, les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 444 V eff., 635 V en courant continu et 635 V crête. Pour des circuits de tension nominale comprise entre 150 V eff. et 300 V eff., les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 2 260 V eff., 3 175 V en courant continu et 3 175 V crête.

### 21.7.3 Alimentation par l'intermédiaire de conducteurs de signaux

Un appareil de bus de terrain qui comprend une MAU de 31,25 kbit/s en mode tension et qui est alimenté par les conducteurs de signaux doit satisfaire aux exigences de l'Article 21 lorsqu'il fonctionne à des valeurs maximales d'ondulation et de bruit de l'alimentation, de la manière suivante:

a) 16 mV crête à crête sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz);

b) 2,0 V crête à crête sur la plage de fréquences de 47 Hz à 63 Hz pour des applications non IS;

c) 0,2 V crête à crête sur la plage de fréquences de 47 Hz à 625 Hz pour des applications IS;

d) 1,6 V crête à crête à des fréquences supérieures à 125 $f_r$, jusqu'à une fréquence maximale de 25 MHz;

e) des niveaux, à des fréquences intermédiaires, généralement conformes à la Figure 117.

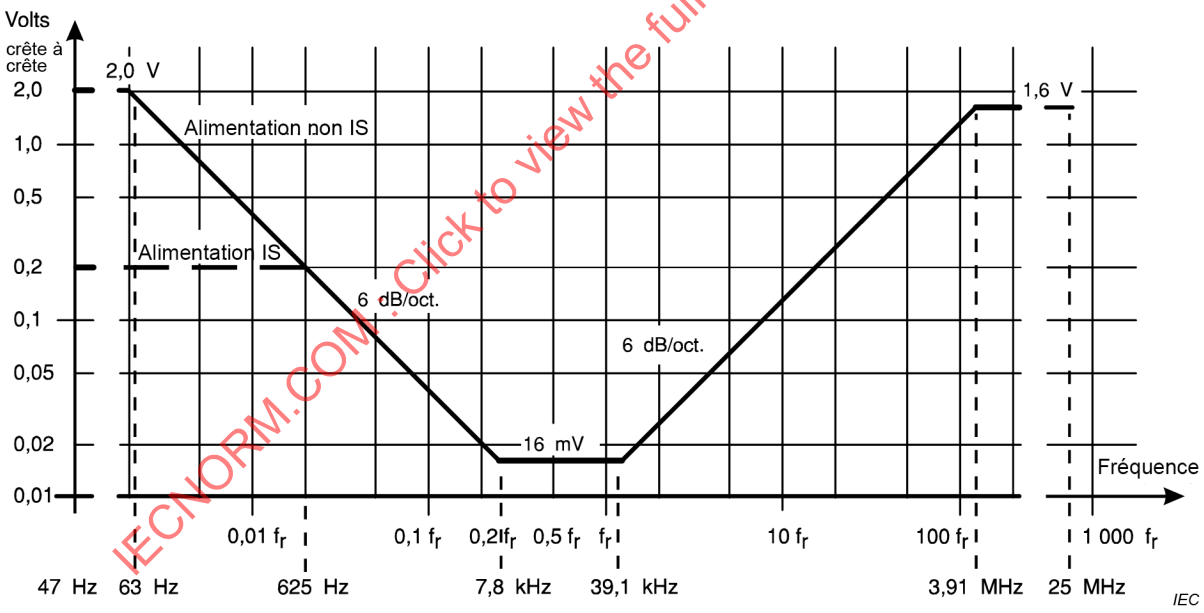


**Figure 117 – Ondulation et bruit de l'alimentation**

Un appareil de bus de terrain qui comprend une MAU de 31,25 kbit/s en mode tension et qui est alimenté par les conducteurs de signaux doit présenter un taux maximal de variation du courant prélevé du réseau de 1 mA/ms. Cette exigence ne s'applique pas:

- pendant la transmission;
- au cours des premières 10 ms après connexion de l'appareil à un réseau opérationnel;
- au cours des premières 10 ms après mise sous tension du réseau;
- lors de la déconnexion du réseau ou de la mise hors tension du réseau.

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Un appareil doit porter un marquage indiquant son courant passif assigné. Un appareil ne doit pas prélever du réseau plus de 10 mA au-dessus de son courant assigné au cours de l'intervalle de temps de 100 µs à 10 ms après connexion de l'appareil à un réseau opérationnel ou 100 µs à 10 ms après mise sous tension du réseau.

NOTE Les premières 100 µs sont exclues pour permettre le chargement des filtres RFI et autres capacités de l'appareil. La spécification du taux de variation s'applique après 10 ms.

### 21.7.4 Isolation électrique

Tous les appareils de bus de terrain utilisant un support câblé, qu'ils soient alimentés séparément ou par l'intermédiaire des conducteurs de signaux, doivent assurer une isolation basse fréquence entre la masse et le câble de ligne principale du bus de terrain.

NOTE 1 Cette isolation peut s'effectuer par isolation de l'ensemble de l'appareil de la masse ou au moyen d'un transformateur, d'un optocoupleur ou de tout autre organe d'isolation entre le câble de ligne principale et l'appareil.

Une alimentation et un élément de communication combinés ne doivent pas exiger d'isolation électrique.

Pour les câbles blindés, l'impédance d'isolation mesurée entre le blindage du câble de bus de terrain et la masse de l'appareil de bus de terrain doit être supérieure à 250 kΩ à toutes les fréquences inférieures à 63 Hz.

La capacité dissymétrique maximale par rapport à la masse de toute borne d'entrée d'un appareil ne doit pas dépasser 250 pF.

Les exigences de claquage de l'isolation du circuit de signaux et du circuit de distribution de l'alimentation par rapport à la masse et par rapport à l'autre circuit doivent être conformes à l'IEC 61131-2.

La tension d'essai équivalente doit être appliquée entre circuits isolés indépendants ou entre circuits isolés et parties conductrices accessibles.

NOTE 3 Pour des circuits de tension nominale50 V en courant continu ou efficace, les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 444 V eff., 635 V en courant continu et 635 V crête. Pour des circuits de tension nominale comprise entre 150 V eff. et 300 V eff., les tensions d'essai équivalentes au niveau de la mer correspondent à des essais de choc de 2 260 V eff., 3 175 V en courant continu et 3 175 V crête.

## 21.8 Spécifications du support

### 21.8.1 Connecteur

Le connecteur est spécifié à l'Article I.1.

### 21.8.2 Câble d'essai normalisé

Le câble utilisé pour les essais d'appareils de bus de terrain avec une MAU de 31,25 Ω en mode tension, destinés à vérifier la satisfaction aux exigences de l'Article 21, doit être un câble unique à paire torsadée, à blindage global, satisfaisant aux exigences minimales suivantes, à une température de 25 °C:

a) $Z_o$ à une fréquence de $f_r$ (31,25 kHz) = 100 Ω 20 Ω;

b) affaiblissement maximal à une fréquence de 1,25 $f_r$ (39 kHz) = 3,0 dB/km;

c) déséquilibre capacitif maximal par rapport au blindage = 2 nF/km;

d) résistance maximale en courant continu (par conducteur) = 24 Ω/km;

e) variation du délai maximal de propagation à une fréquence de 0,25 $f_r$ à 1,25 $f_r$ = 1,7 µs/km;

f) section du conducteur (dimension des fils) = 0,8 $mm^2$, valeur nominale;

g) la couverture minimale du blindage doit être de 90 %.

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La spécification ci-dessus concerne les essais de conformité d'une MAU. D'autres types de câbles peuvent être utilisés dans les installations réelles (voir l'Annexe B). Les câbles à spécifications améliorées peuvent permettre l'utilisation de longueurs de ligne principale plus importantes et/ou une meilleure immunité aux perturbations. En revanche, les câbles qui présentent des spécifications inférieures peuvent être utilisés, sous réserve d'une limitation des longueurs utilisées, tant pour les lignes principales que secondaires, à laquelle s'ajoute une éventuelle non-conformité aux exigences de susceptibilité aux perturbations radioélectriques (RFI) et électromagnétiques (EMI).

Pour les applications de sécurité intrinsèque, il convient de satisfaire aux exigences particulières, telles qu'elles sont spécifiées par les normes de sécurité intrinsèque pertinentes, par exemple l'IEC 60079-11 et l'IEC 60079-25.

### 21.8.3 Coupleur

Voir 12.8.3.

### 21.8.4 Épissures

Voir 12.8.4.

### 21.8.5 Terminateur

Un terminateur doit être placé aux deux extrémités du câble de ligne principale et connecté d'un conducteur de signal à l'autre. Il ne doit y avoir aucune connexion entre le terminateur et le blindage du câble.

La valeur de l'impédance du terminateur doit être de 100 Ω ± 2 Ω sur la plage de fréquences de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz).

NOTE 1 Cette valeur correspond approximativement à la valeur moyenne de l'impédance caractéristique du câble, pour les câbles appropriés, aux fréquences pertinentes, et elle est choisie pour réduire le plus possible les réflexions de la ligne de transmission.

Le courant continu de fuite à travers le terminateur ne doit pas dépasser 100 µA. Le terminateur doit être non polarisé.

Tous les terminateurs utilisés pour les applications IS doivent satisfaire aux exigences d'isolation (lignes de fuite et distances d'isolement) en fonction de l'homologation IS exigée. L'homologation IS ne doit pas être exigée pour des terminateurs destinés à des applications non IS.

NOTE 2 Il est acceptable que les fonctions de l'alimentation, de la barrière de sécurité et du terminateur soient combinées de différentes manières, tant que l'impédance de la combinaison obtenue soit équivalente à l'impédance parallèle d'appareils indépendants qui satisfont aux exigences de l'Article 21 et si les règles de configuration du réseau du 21.3.3 sont respectées.

### 21.8.6 Règles de blindage

Voir 12.8.6.

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### 21.8.7 Règles de mise à la masse

NOTE 1 Mise à la masse signifie une connexion permanente à la terre par l'intermédiaire d'une impédance suffisamment basse et ayant un courant admissible suffisant pour prévenir un amorçage en tension qui peut entraîner un danger excessif pour le matériel connecté ou les personnes. Les lignes de tension zéro (commun) peuvent être reliées à la masse lorsqu'elles sont galvaniquement isolées de la ligne principale du bus de terrain.

Les appareils de bus de terrain doivent fonctionner conformément aux exigences de l'Article 21, le point médian d'un terminateur ou d'un coupleur inductif étant directement connecté à la masse.

Les appareils de bus de terrain ne doivent pas raccorder l'un des conducteurs de la paire torsadée à la masse, quel que soit le point du réseau. Les signaux doivent être appliqués et préservés de manière différentielle sur l'ensemble du réseau.

Les meilleures pratiques consistent à mettre effectivement à la masse le blindage du câble de ligne principale de bus de terrain (le cas échéant) en plusieurs points sur la longueur du câble. Il convient néanmoins que les appareils de bus de terrain permettent une isolation en courant continu du blindage du câble par rapport à la masse.

La pratique courante est également de raccorder les conducteurs de signaux à la masse de manière symétrique, en un point central de mise à la masse, en utilisant par exemple la prise centrale d'un terminateur ou d'un transformateur de couplage. Pour des systèmes alimentés par le bus, il convient que la mise à la masse du blindage et des conducteurs de signaux équilibrés soit proche de l'unité d'alimentation. Pour les systèmes IS, il convient que la mise à la masse soit conforme aux normes de sécurité intrinsèque correspondantes, par exemple l'IEC 60079-11 et l'IEC 60079-25.

### 21.8.8 Couleurs du câblage

Voir 12.8.8.

## 21.9 Sécurité intrinsèque

### 21.9.1 Généralités

Le présent document n'a pas pour objet d'énumérer les exigences par lesquelles un équipement peut être certifié comme étant de sécurité intrinsèque et n'exige pas non plus que l'équipement soit de sécurité intrinsèque. Il cherche plutôt à exclure les conditions ou situations qui peuvent empêcher la certification IS.

### 21.9.2 Barrière de sécurité intrinsèque

L'impédance de la barrière doit être supérieure à 460 Ω, à toute fréquence dans une plage de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz). La spécification de l'impédance de la barrière IS doit s'appliquer à toutes les barrières utilisées comme parties de PhL, qu'elles soient installées comme un élément séparé de matériel de réseau ou intégrées dans une carte d'alimentation. L'impédance de la barrière doit être mesurée entre les bornes des deux côtés de la barrière. L'impédance de la barrière doit être mesurée avec l'alimentation réseau réglée à la tension de service assignée (et non la tension de sécurité) de la barrière.

NOTE Il est acceptable que les fonctions de l'alimentation, de la barrière de sécurité et du terminateur soient combinées de différentes manières, tant que l'impédance de la combinaison obtenue est équivalente à l'impédance parallèle d'appareils indépendants qui satisfont aux exigences de l'Article 21 et si les règles de configuration du réseau du 21.3.3 sont respectées.

À la tension de service assignée de la barrière et à toute fréquence dans une plage de 0,25 $f_r$ à 1,25 $f_r$ (7,8 kHz à 39 kHz), la capacité mesurée à la borne positive du réseau "+" (côté dangereux) et la masse ne doit pas s'écarter de plus de 250 pF par rapport à la capacité mesurée entre la borne négative du réseau "-" (côté dangereux) et la masse.

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### 21.9.3 Mise en place de barrières et de terminateurs

Une barrière doit être séparée du terminateur le plus proche de 100 m de câble au plus.

NOTE La barrière peut apparaître comme une impédance en dérivation de valeur aussi faible que 460 Ω aux signalisations de fréquences. La résistance du terminateur est suffisamment basse pour que, lorsqu'elle est mise en parallèle avec l'impédance de la barrière, l'impédance résultante soit presque totalement résistive (non réactive).

## 21.10 Sectionneurs galvaniques

Les caractéristiques de communication des sectionneurs galvaniques utilisés sur le bus de terrain doivent satisfaire aux spécifications du 21.9.

## 21.11 Éléments de couplage

### 21.11.1 Généralités

Les éléments de couplage sont utilisés pour connecter différents segments de Type 3 à la même PhL ou à une PhL différente.

À l'exception des niveaux de signaux, le présent document ne décrit pas les caractéristiques exigées d'un élément de couplage. En d'autres termes, il incombe au planificateur de système d'assurer que la norme relative aux "Règles de configuration du réseau" est respectée lorsque des éléments de couplage sont utilisés. Les spécifications suivantes sont importantes.

- Retard maximal du signal;
- Écart maximal par rapport au passage par zéro du signal nominal (instabilité du signal).

Deux types d'éléments de couplage peuvent être utilisés:

- des répéteurs MBP-IS;
- des coupleurs de signaux MBP-IS/RS 485.

### 21.11.2 Répéteur MBP-IS

Un répéteur MBP-IS est connecté à deux segments MBP-IS. Il comporte une MAU sur chaque segment et une isolation galvanique entre les deux MAU. Les caractéristiques électriques présentées dans le Tableau 140 sont obligatoires pour les deux interfaces de bus de terrain. Les exigences concernant la MAU de l'Article 12 et du 21.1 au 21.10 s'appliquent également aux répéteurs.

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**Tableau 140 – Caractéristiques électriques des interfaces de bus de terrain**

| Paramètre | Valeurs | Paragraphe du présent document |
|---|---|---|
| Codage du signal | Manchester II | 9.2.2 |
| Délimiteur de début | 1, N+, N-, 1, 0, N-, N+, 0 (Note 1) | 9.2.4 |
| Délimiteur de fin | 1, N+, N-, N+, N-,1, 0, 1 (Note 1) | 9.2.5 |
| Préambule | 1, 0, 1, 0, 1, 0, 1, 0 | 9.2.6 |
| Débit de transmission de données | 31,25 kbit/s avec une tolérance de ± 0,2 % | 21.2 |
| Niveau de sortie (crête à crête) | 0,75 V à 1 V | 21.4.5 |
| Différence maximale entre amplitudes de transmission positive et négative | ± 50 mV | 21.4.5 |
| Distorsion max. du signal de transmission (surtension, suroscillation et statisme) | ± 10 % | 21.4.5 |
| Bruit de l'émetteur | 1 mV (eff) (Note 2) | 21.4.5 |
| Impédance de sortie | ≥ 3 kΩ (Note 3) | 21.7.1 |
| Tension de service | 9 V à 32 V (Note 4) | 21.7.1 |
| Rapport de réjection en mode commun (CMRR) | ≥ 50 dB (Note 5) | |
| Courant de fuite (Note 6) | 50 µA | |
| NOTE 1 N+ et N- sont des symboles non données. | | |
| NOTE 2 Dans la plage de fréquences de 1 kHz à 100 kHz. | | |
| NOTE 3 Dans la plage de fréquences de 7,8 kHz à 39 kHz. | | |
| NOTE 4 Plage de tensions de fonctionnement. Peut être limitée de 9 V à 17,5 V ou de 9 V à 24 V pour des appareils de sécurité intrinsèque. | | |
| NOTE 5 Correspond à une capacité dissymétrique de 250 pF à une fréquence de 39 kHz. | | |
| NOTE 6 Uniquement pour sécurité intrinsèque. | | |

Des répéteurs connectés à des segments de bus de sécurité intrinsèque doivent être certifiés comme matériel de sécurité intrinsèque. Le certificat doit inclure une déclaration qui stipule que les appareils sont conformes au modèle FISCO. Les spécifications de l'IEC 60079-11 doivent être respectées en ce qui concerne l'isolation galvanique.

Pour pouvoir déterminer la conformité aux règles de configuration du réseau du 21.3.3, le planificateur de système exige des informations concernant le retard du signal dû aux répéteurs et l'écart maximal par rapport au passage par zéro du signal nominal (c'est-à-dire l'instabilité du signal). Ces informations doivent être indiquées dans la fiche technique.

Un répéteur peut être associé à une alimentation et à des terminateurs de lignes.

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### 21.11.3 Coupleur de signaux MBP-IS – RS 485

Un coupleur de signaux MBP-IS – RS 485 connecte un segment MBP-IS à un segment RS 485. Il comporte une MAU sur chaque segment, une isolation galvanique entre les deux MAU et un codage/décodage Manchester.

Les caractéristiques électriques présentées dans le Tableau 140 sont obligatoires pour l'interface MBP-IS. Les exigences concernant la MAU de l'Article 12 et du 21.1 au 21.10 s'appliquent également. L'Article 22 s'applique à la conception de l'interface de bus RS 485.

Des coupleurs de signaux connectés à des segments de bus de sécurité intrinsèque doivent être certifiés comme matériel de sécurité intrinsèque. Le certificat doit inclure une déclaration qui stipule que les appareils sont conformes au modèle FISCO. Les spécifications de l'IEC 60079-11 doivent être respectées en ce qui concerne l'isolation galvanique (voir 21.10).

Pour pouvoir déterminer la conformité aux règles de configuration du réseau du 21.3.3, le planificateur de système exige des informations concernant le retard du signal dû aux répéteurs et l'écart maximal par rapport au passage par zéro du signal nominal (c'est-à-dire l'instabilité du signal). Ces informations doivent être indiquées dans la fiche technique d'un coupleur de signaux.

Un coupleur de signaux peut être associé à une alimentation et à un terminateur de bus.

NOTE Un tel appareil est généralement appelé coupleur de segment.

## 21.12 Alimentation

### 21.12.1 Généralités

Une alimentation doit être connectée au bus pour fournir de l'énergie aux appareils de terrain. La tension d'alimentation dépend des exigences de l'application particulière.

L'alimentation d'un bus de sécurité intrinsèque peut être fournie soit par une alimentation à sortie de sécurité intrinsèque, soit par une alimentation qui n'est pas de sécurité intrinsèque complétée par une barrière.

Pour éviter tout effet sur la transmission des données, les caractéristiques électriques de l'Article 21 du présent document, énumérées dans le Tableau 141, sont obligatoires pour toutes les alimentations.

Les bornes de sortie d'une alimentation doivent être clairement marquées "+" et "-".

Même si une alimentation isolée par rapport à la terre n'est pas spécifiquement exigée, une mise à la masse asymétrique des conducteurs du câble de bus n'est pas admise. Il est essentiel que toute connexion entre les conducteurs et la terre soit symétrique. Pour plus de précisions, voir 21.8.7.

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**Tableau 141 – Caractéristiques électriques des alimentations**

| | Non de sécurité intrinsèque | Sécurité intrinsèque, IIC FISCO [a] | Sécurité intrinsèque, IIB FISCO [a] | Sécurité intrinsèque, barrière linéaire IIC [b] |
|---|---|---|---|---|
| Selon le modèle FISCO | non | oui | oui | |
| Tension maximale d'alimentation en courant continu $U_0$ | ≤ 32 V | ≤ 17,5 V | ≤ 17,5 V | ≤ 24 V |
| Courant maximal de court-circuit en courant continu $I_0$ | | ≤ 360 mA | ≤ 380 mA [g] | ≤ 250 mA |
| Puissance de sortie maximale $P_0$ | | ≤ 2,52 W | ≤ 5,32 W | ≤ 1,2 W |
| Ondulation, bruit | ≤ 16 mV [c] | ≤ 16 mV [c] | ≤ 16 mV [c] | ≤ 16 mV [c] |
| Impédance de sortie [g] | ≥ 3 k Ω [c d] | ≥ 400 Ω [c d] | ≥ 400 Ω [c d] | ≥ 400 Ω [c d e] |
| Ondulation, bruit | ≤ 16 mV [c] | | | |
| Affaiblissement par asymétrie | ≥ 50 dB [f] | | | ≥ 50 dB [e f] |

| | |
|---|---|
| [a] | Alimentation à caractéristique rectangulaire ou trapézoïdale, conformément au modèle FISCO. |
| [b] | Alimentation ou barrière à caractéristique linéaire. |
| [c] | Dans la plage de fréquences de 7,8 kHz à 39 kHz. Sinon, voir la Figure 117. |
| [d] | Avec terminateur de ligne intégré: 100 Ω avec une tolérance de ± 2 %. Il est recommandé d'équiper chaque alimentation d'une résistance de terminaison. |
| [e] | Y compris une barrière, si cela est exigé. |
| [f] | Aucune spécification obligatoire dans la norme, mais exigé du point de vue fonctionnel. |
| [g] | La limite de courant résulte d'une caractéristique rectangulaire. |

Les alimentations utilisées pour fournir de l'énergie aux appareils de terrain situés dans des zones explosibles doivent être certifiées en tant que matériel associé de sécurité intrinsèque destiné à une utilisation dans des lieux dangereux.

### 21.12.2 Alimentation non de sécurité intrinsèque

Les alimentations qui ne sont pas de sécurité intrinsèque doivent avoir les caractéristiques techniques définies dans le Tableau 141.

Les alimentations qui ne sont pas de sécurité intrinsèque peuvent être utilisées avec une barrière homologuée pour fournir de l'énergie à un bus de sécurité intrinsèque.

### 21.12.3 Alimentation de sécurité intrinsèque

Pour alimenter des appareils de terrain dans des zones explosibles, une alimentation à sortie de sécurité intrinsèque peut être connectée au bus en lieu et place d'une combinaison d'alimentation non de sécurité intrinsèque et de barrière. Cet appareil est en général placé à l'extérieur de la zone dangereuse, dans la salle de commande. Au sens de l'IEC 60079-11, il s'agit d'un matériel associé car, même s'il n'est pas protégé contre l'explosion proprement dite, il génère effectivement un circuit électrique de sécurité intrinsèque qui mène à la zone explosible.

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Outre les exigences de l'Article 21, notamment dans le Tableau 141, des alimentations de sécurité intrinsèque doivent satisfaire aux exigences de sécurité établies dans l'IEC 60079-14 et l'IEC 60079-11.

Si l'alimentation se situe dans la zone dangereuse, un type de protection normalisée supplémentaire doit être prévu (par exemple, installation dans un boîtier de protection de type "enveloppe antidéflagrante d").

Des alimentations de sécurité intrinsèque peuvent faire partie d'autres composantes de bus de terrain (par exemple, des coupleurs de segments, voir 21.11).

Le modèle FISCO repose sur une tension continue assignée de 13,5 V. Les courbes d'inflammation des alimentations à caractéristique rectangulaire indiquent que la puissance maximale admissible diminue considérablement si la tension augmente. D'autre part, une alimentation basse tension provoque une chute de tension plus élevée de la ligne de transmission. Par conséquent, la tension de 13,5 V semble être un compromis acceptable.

Du fait des tolérances et afin de disposer d'une marge d'amplitude du signal, la tension de sortie maximale $U_0$ d'un appareil d'alimentation doit être supérieure à la tension de sortie assignée. L'amplitude du signal est ≤ 1 $V_{PP}$; par conséquent une marge de 0,5 V est nécessaire. Si les tolérances sont par hypothèse ≤ 1V, le calcul donne une tension de sortie maximale garantie $U_0$ = 15 V. Le courant de sortie maximal admissible (courant de court-circuit), en fonction du groupe de gaz, peut être extrait des courbes d'inflammation disponibles ou peut être déduit à partir d'essais d'inflammation. Dans le groupe IIC, le courant de sortie admis est $I_0$ = 128 mA. D'autres combinaisons tension/courant, conformes au FISCO, peuvent être sélectionnées.

La conception et la mise en œuvre de la tension relative à la sécurité et des limiteurs de courant dépendent de la catégorie choisie de circuit de sécurité intrinsèque ("ia" ou "ib"). Les valeurs maximales des paramètres de sortie doivent satisfaire aux exigences du FISCO.

Un certificat de contrôle doit être obtenu pour l'alimentation du bus en tant que "matériel associé", au sens de l'IEC 60079-11. Ce certificat doit déclarer que l'alimentation est conforme au modèle FISCO.

Outre les données habituelles (c'est-à-dire les valeurs maximales des paramètres de sortie), le certificat peut également contenir des spécifications fondamentales applicables à la configuration de bus de terrain admissible.

NOTE En général, les valeurs limites d'inductance La et de capacité Ca externes maximales admissibles ne sont pas exigées. Si ces valeurs avaient été incluses, elles donneraient l'impression que La et Ca sont présentes dans le circuit de sécurité intrinsèque en tant qu'inductivité et capacité non protégées, ce qui n'est pas le cas pour le modèle FISCO. Le câble n'est pas considéré ici comme une inductivité et une capacité concentrées tant que les paramètres du système demeurent dans la plage des limites définies du modèle FISCO.

### 21.12.4 Alimentation de catégorie "ib"

NOTE 1 Étant donné qu'il convient que le circuit du courant de sortie de l'alimentation ait une résistance interne faible en courant continu, l'utilisation de l'alimentation avec un régulateur de tension et une commande de courant active (c'est-à-dire une limitation électronique du courant) vient à l'esprit. Par exemple, il est possible d'obtenir une résistance interne ≥ 400 Ω dans la plage de fréquences des signaux conformément au Tableau 141 en utilisant par exemple une contre-réaction en fonction de la fréquence.

La courbe de sortie caractéristique théorique d'une alimentation (c'est-à-dire la caractéristique courant/tension) est rectangulaire (voir la Figure 118). Lorsque le courant de sortie augmente, la tension de sortie reste constante jusqu'à ce que le courant atteigne une certaine limite. L'IEC 60079-11 permet d'utiliser une telle solution dans l'hypothèse selon laquelle une limitation redondante du courant et de la tension a été établie, ainsi qu'une isolation galvanique (facultative) fiable par rapport aux circuits électriques qui ne sont pas de sécurité intrinsèque.

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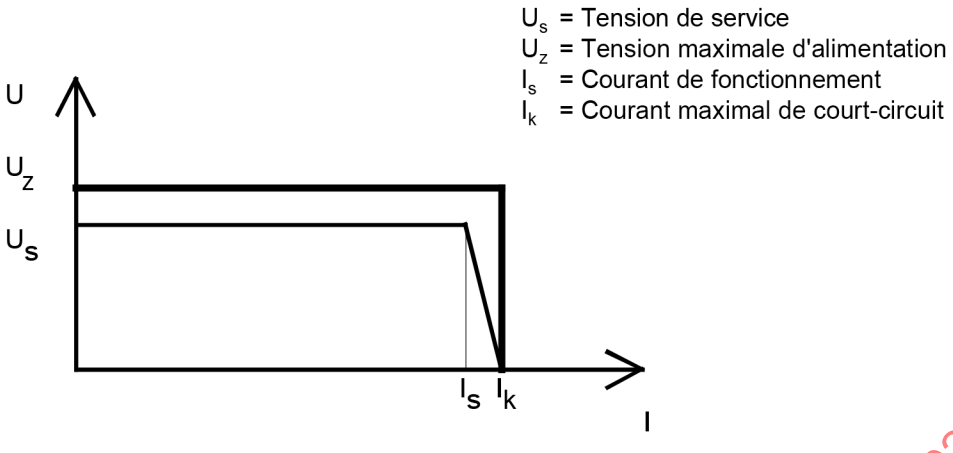


**Figure 118 – Courbe de sortie caractéristique d'une alimentation de catégorie EEx ib**

NOTE 2 Une tension de 13,5 V en courant continu semble réaliste, puisque des tensions plus élevées restreignent la puissance disponible. Les courbes de limite d'explosivité pour des sources dont la courbe de sortie caractéristique est de forme carrée démontrent que la puissance admissible décroît de manière significative lorsque la tension augmente.

### 21.12.5 Alimentation de catégorie "ia"

Les alimentations qui présentent une limitation électronique de courant doivent être certifiées conformément à l'IEC 60079-11 pour la catégorie "ib".

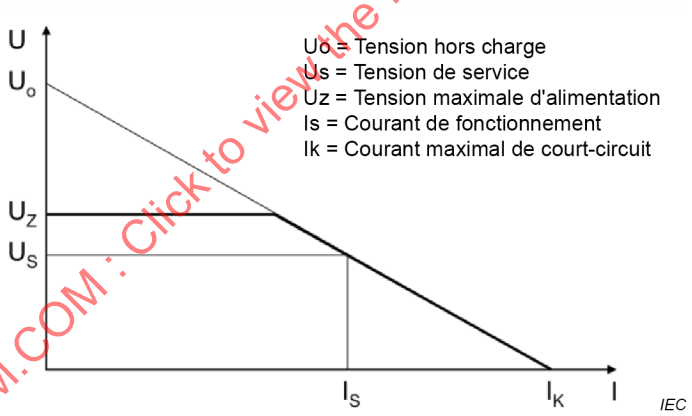


**Figure 119 – Courbe de sortie caractéristique d'une alimentation de catégorie EEx ia**

L'alimentation ia doit être conforme au modèle FISCO. Le courant de sortie maximal IK de la Figure 118 correspond au courant IZul (à U = Uz) de la Figure 119.

Exemple

Un exemple d'alimentation appropriée pour la catégorie "ia" comporte les éléments de sécurité suivants: Source de tension Uo = 34 V, résistance fixe R = 158 Ω, et diodes Zener UZD = 15 V (valeur maximale). Un tel circuit a une courbe de sortie caractéristique trapézoïdale, comme cela est représenté à la Figure 119. Les valeurs opérationnelles approchées qui peuvent être obtenues pour l'alimentation sont énumérées ci-dessous.

U = 13,5 V

I = 120 mA

P = 1,7 W

$$P_{v\,max} = \frac{U_0^2}{Rv} = 7{,}32\ \text{W}$$

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NOTE 1 Ainsi, les valeurs opérationnelles sont comparables à celles du concept "ib" avec limitation électronique du courant. Cette situation présente cependant un inconvénient: l'exigence d'une contrainte thermique relativement élevée de la résistance série et la perte de puissance de la résistance série qui est toujours présente dans des conditions opérationnelles.

Si un facteur de sécurité de 1,5 est appliqué, la puissance dissipée admise de la résistance doit être de 11 W.

NOTE 3 L'utilisation de deux résistances en série peut être utile.

La puissance dissipée maximale des diodes Zener est de 1,8 W.

$$P_{vmax} = \frac{U_o - U_z}{R_v} \times 15\ V = \frac{34\ V - 15\ V}{158\ \Omega} \times 15\ V = 1{,}8\ W$$

Compte tenu du facteur de sécurité, les diodes Zener doivent permettre une puissance dissipée maximale de 2,7 W.

NOTE 4 L'utilisation de deux diodes en série est également possible dans ce cas.

L'IEC 60079-14 et l'IEC 60079-11 s'appliquent.

#### 21.12.6 Retour de puissance

À l'exception d'une alimentation par segment, le modèle FISCO ne permet pas à des appareils connectés au bus de terrain de sécurité intrinsèque de retourner l'alimentation vers le bus de terrain, même en cas de court-circuit sur la ligne de bus de terrain. Cela est en général assuré par la connexion en série de deux (pour la catégorie EEx ib) ou de trois (pour la catégorie EEx ia) diodes au silicium ou Schottky dans le circuit électrique d'entrée. L'appareil de terrain est conforme au modèle FISCO lorsque le courant de fuite de ces diodes (jusqu'à la valeur maximale de tension inverse dans la plage de températures admissible) ne dépasse pas 50 µA. Ici, outre un facteur de sécurité, les spécifications des fabricants de diodes (c'est-à-dire les valeurs types des fiches techniques) s'appliquent généralement.

La décision finale concernant ces mesures incombe à l'autorité de certification qui réalise les essais de sécurité et la certification de l'appareil de terrain particulier.

## 22 Type 3: Unité de liaison au support: transmission asynchrone, support câblé

### 22.1 Unité de liaison au support non IS

#### 22.1.1 Caractéristiques

Cette spécification de MAU décrit une transmission sur ligne symétrique correspondant à TIA-485-A:1998. Les terminateurs, placés aux deux extrémités du câble à paire torsadée permettent à la PhL de prendre notamment en charge des vitesses de transmission plus élevées. La longueur maximale du câble est de 1 200 m pour des débits de données ≤ 93,75 kbit/s. Pour un débit de 1 500 kbit/s, la longueur maximale du câble est réduite à 70 m pour le type B et à 200 m pour le type A. Pour un débit de 12 Mbit/s, elle est de 100 m (câble de type A uniquement, voir 22.1.2.2).

Le codage binaire NRZ est associé à la signalisation TIA-485-A:1998 avec pour objectif des coupleurs de ligne à faible coût qui peuvent ou non isoler la station de la ligne (isolation galvanique). Des terminateurs de ligne sont exigés, notamment pour les débits de données les plus élevés (jusqu'à 12 Mbit/s).

Les caractéristiques exigées sont présentées dans le Tableau 142.

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**Tableau 142 – Caractéristiques non de sécurité intrinsèque**

| Caractéristique | Contraintes |
|---|---|
| Topologie: | Bus linéaire, terminé aux deux extrémités, lignes d'adaptation ≤ 0,3 m, pas de dérivations; voir la Note.<br>La longueur totale de la ligne inclut la somme des longueurs de lignes d'adaptation. |
| Support: | Câble à paire torsadée blindé recommandé, voir 22.1.2 "Spécifications du support" |
| Longueur de ligne:[a] | ≤ 1 200 m, en fonction du débit de données et du type de câble |
| Nombre de stations:[a] | 32 (stations maître, stations esclave ou répéteurs) |
| Débits de données: | 9,6 / 19,2 / 45,45 / 93,75 / 187,5 / 500 / 1 500 / 3 000 / 6 000 / 12 000 kbit/s, d'autres débits de données peuvent être pris en charge. |
| | |
| NOTE Contrairement aux recommandations de la norme TIA-485-A:1998, les meilleures pratiques consistent à permettre des lignes d'adaptation plus longues si la valeur totale des capacités de toutes les lignes d'adaptation (Cstges) ne dépasse pas les valeurs suivantes:<br>0,05 nF à 3 Mbit/s, 6 Mbit/s et 12 Mbit/s.<br>0,2 nF à 1,5 Mbit/s.<br>0,6 nF à 500 kbit/s.<br>1,5 nF à 187,5 kbit/s.<br>3,0 nF à 93,75 kbit/s.<br>15 nF à 9,6 kbit/s et 19,2 kbit/s. | |
| [a] Le répéteur étend à la fois la longueur de la ligne et le nombre de stations, voir le Tableau 143. | |

La longueur de la ligne et le nombre de stations connectées peuvent être augmentés par l'utilisation de répéteurs. 3 répéteurs au plus peuvent être utilisés entre deux stations. Si le débit de données est ≤ 93,75 kbit/s et si les sections liées constituent une chaîne (topologie en bus linéaire, pas d'étoile active, par exemple, comme à la Figure 120) et en prenant pour hypothèse une section du conducteur de 0,22 mm$^2$, la topologie maximale admissible est telle qu'elle est présentée dans le Tableau 143.

**Tableau 143 – Caractéristiques avec utilisation de répéteurs**

| Nombre de répéteurs | Caractéristique | Contraintes |
|---|---|---|
| 1 | Longueur de ligne | < 2,4 km |
| | Nombre de stations | 62 (stations maître, stations esclave ou répéteurs) |
| 2 | Longueur de ligne | < 3,6 km |
| | Nombre de stations | 92 (stations maître, stations esclave ou répéteurs), voir la |
| 3 | Longueur de ligne | < 4,8 km |
| | Nombre de stations | 122 (stations maître, stations esclave ou répéteurs) |

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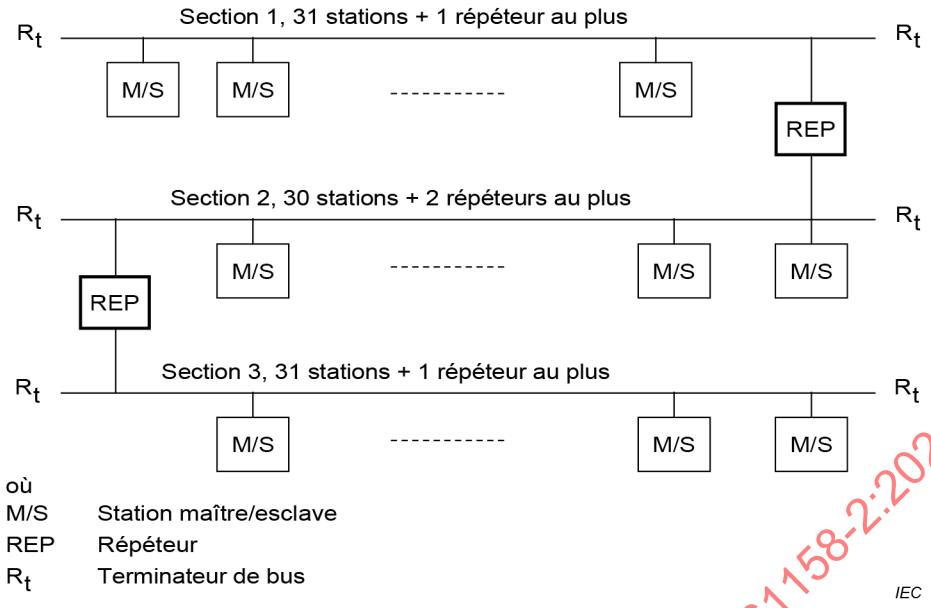


**Figure 120 – Répéteur en topologie en bus linéaire**

Dans une topologie arborescente, comme à la Figure 121, plus de 3 répéteurs peuvent être utilisés et plus de 122 stations peuvent être connectées, par exemple 5 répéteurs et 127 stations. Une zone étendue peut être couverte par cette topologie, par exemple une longueur de 4,8 km à un débit de données inférieur à 93,75 kbit/s et une section de conducteur de 0,22 $mm^2$.

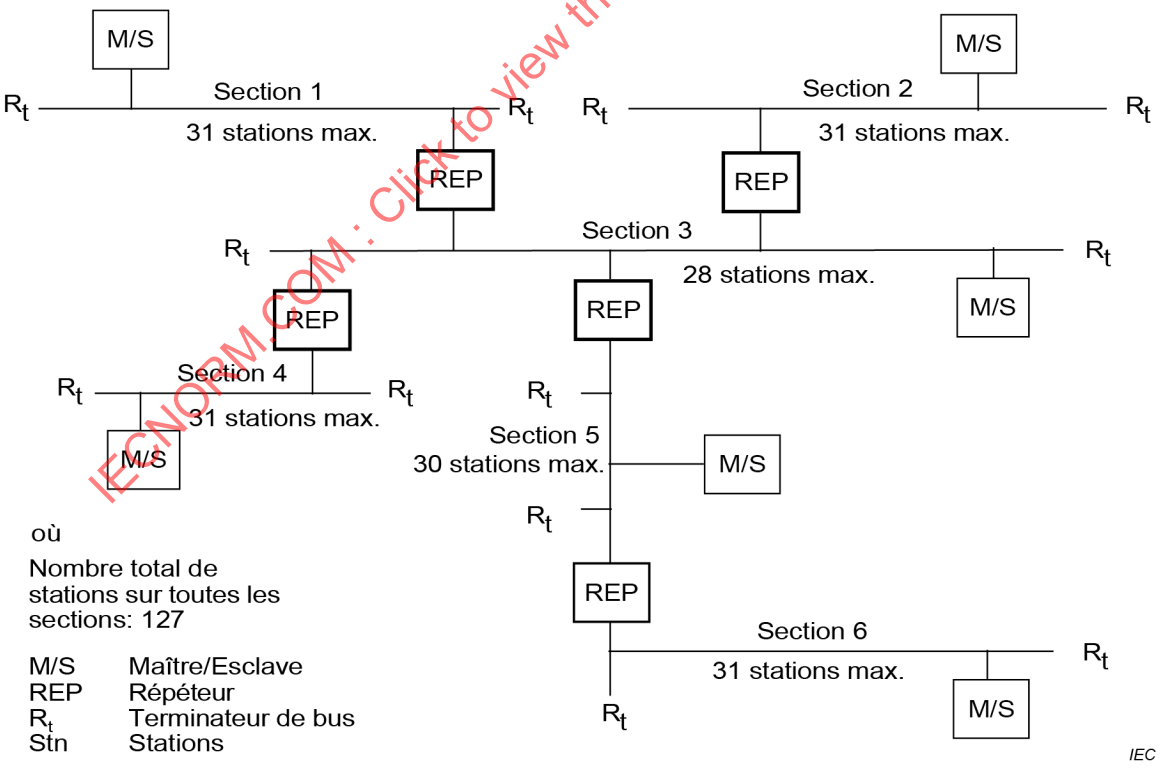


**Figure 121 – Répéteur en topologie arborescente**

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### 22.1.2 Spécifications du support

#### 22.1.2.1 Connecteur

Le connecteur est spécifié au I.2.1.

#### 22.1.2.2 Câble

Le support de bus est un câble à paire torsadée blindé. Le blindage permet d'améliorer la compatibilité électromagnétique (CEM). Des paires torsadées non blindées peuvent être utilisées en l'absence de perturbations électromagnétiques (EMI) sévères.

L'impédance caractéristique du câble doit se situer dans une plage comprise entre 100 Ω et 220 Ω. Il convient que la capacité du câble (entre conducteurs) soit inférieure à 60 pF/m et il convient que la section du conducteur soit supérieure ou égale à 0,22 mm$^2$. Des critères de sélection du câble sont donnés à l'annexe de la norme TIA-485-A:1998.

Deux types de câbles sont définis, comme cela est spécifié dans le Tableau 144.

**Tableau 144 – Spécifications du câble**

| Paramètre du câble | Type A | Type B |
|---|---|---|
| Impédance | (135 à 165) Ω<br>(f = 3 MHz à 20 MHz) | (100 à 130) Ω<br>(f> 100 kHz) |
| Capacité | < 30 pF/m | < 60 pF/m |
| Résistance | < 110 Ω/km | non spécifiée |
| Section du conducteur | ≥ 0,34 mm$^2$ | ≥ 0,22 mm$^2$ |
| Couleur de gaine non IS | Violette | Non spécifiée |
| Couleur du conducteur intérieur du câble A (RxD/TxD-N) | Verte | Non spécifiée |
| Couleur du conducteur intérieur du câble B (RxD/TxD-P) | Rouge | Non spécifiée |

Le Tableau 145 présente la longueur maximale du câble de type A et du câble de type B pour les différentes vitesses de transmission.

**Tableau 145 – Longueur maximale du câble pour les différentes vitesses de transmission**

| Élément | Unité | Valeur | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Débit de données** | kbit/s | 9,6 | 19,2 | 93,75 | 187,5 | 500 | 1 500 | 3 000 | 6 000 | 12 000 |
| **Câble de type A** | m | 1 200 | 1 200 | 1 200 | 1 000 | 400 | 200 | 100 | 100 | 100 |
| **Câble de type B** | m | 1 200 | 1 200 | 1 200 | 600 | 200 | 70 | Non admissible | | |

Pour des débits de données inférieurs ou égaux à 1 500 kbit/s, la somme des longueurs de lignes d'adaptation (les capacités totales de toutes les lignes d'adaptation (Cstges)) est spécifiée au 22.1. Par exemple, à 1 500 kbit/s, la longueur maximale d'une ligne d'adaptation pour le type de câble A est de 6,6 m.

À des débits de données de 3 Mbit/s et plus, les capacités totales de toutes les lignes d'adaptation doivent être inférieures à 0,05 nF. Par conséquent, pour le câble de type A, la longueur totale de ligne d'adaptation est de 1,6 m. À ce débit de données, il est nécessaire d'intégrer l'impédance dans le câblage pour éviter les réflexions.

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L'exemple suivant (Figure 122) représente l'intégration des inductances L1 à L4 dans le connecteur.

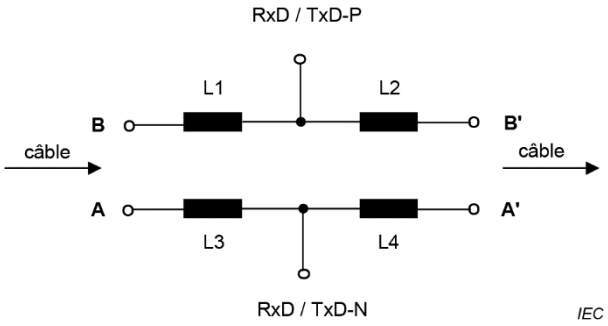


**Figure 122 – Exemple d'un connecteur avec inductance intégrée**

Pour des câbles de type A, les inductances L1 à L4 doivent avoir une valeur de (110 ± 22) nH avec la contrainte suivante:

La résistance entre A et A' ainsi qu'entre B et B' doit être ≤ 0,35 Ω.

La capacité type de chaque station connectée (connecteur, câble pour émetteurs-récepteurs de la norme TIA-485-A, émetteurs-récepteurs proprement dits et autres composantes) doit être la suivante: (15 à 25) pF.

NOTE 1 Le calcul de l'inductance comprend la contribution de la station connectée. En cas de débranchement de ces connecteurs, des réflexions dues au câblage peuvent apparaître et entraîner des distorsions sur le bus.

La dépendance du débit de données admissible sur l'extension de la liaison locale (distance maximale entre deux stations) est représentée à la Figure 2-A.1 de la norme TIA-422-B (également incluse dans le document UIT-T V.11).

NOTE 5 Les recommandations concernant la longueur de la ligne supposent un affaiblissement maximal du signal de 6 dB. L'expérience démontre que les distances sont éventuellement doublées s'il est utilisé des conducteurs d'une section ≥ 0,5 mm$^2$.

Le câblage minimal entre deux stations est représenté à la Figure 123.

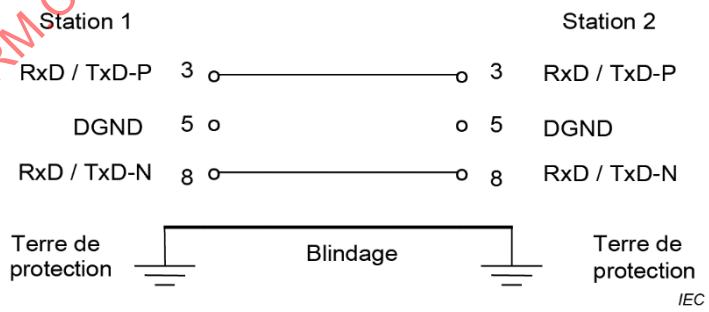


**Figure 123 – Câblage d'interconnexion**

Le câblage représenté à la Figure 123 permet d'obtenir une tension en mode commun entre les deux stations (c'est-à-dire la différence de tension entre les masses de protection) de ± 7 V au plus. S'il est prévu une tension en mode commun supérieure, un conducteur de compensation doit être placé entre les points de mise à la masse.

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#### 22.1.2.3 Règles de mise à la masse et de blindage

S'il est utilisé un câble à paire torsadée blindé, il est recommandé de connecter le blindage à la terre de protection aux deux extrémités du câble, au moyen de connexions à faible impédance (c'est-à-dire à faible inductance). Cette opération est nécessaire pour obtenir une compatibilité électromagnétique raisonnable.

Il convient de préférence de réaliser les branchements entre le blindage du câble et la terre de protection (par exemple, le boîtier métallique de l'appareil) par l'intermédiaire des boîtiers métalliques et des vis de fixation métalliques des connecteurs sub-D. Si cette connexion n'est pas réalisable, la broche 1 des connecteurs peut être utilisée.

#### 22.1.2.4 Terminateur de bus

Le câble de bus de Type A et de Type B doit être terminé aux deux extrémités par les résistances $R_{tA}$ et $R_{tB}$ respectivement. La résistance de terminaison $R_t$, spécifiée dans la norme TIA-485-A:1998 doit être complétée par une résistance de rappel vers le niveau bas $R_d$ (connectée à la masse des données DGND) et par une résistance de rappel vers le niveau bas $R_u$ (connectée au Plus de la tension VP), comme cela est représenté à la Figure 124. Ce complément force la tension en mode différentiel (c'est-à-dire la tension entre les conducteurs) à une valeur bien définie, lorsqu'aucune station n'émet (au cours des périodes de repos).

Chaque station qui termine la ligne (en association avec un terminateur de bus) doit mettre à disposition le Plus de la tension (+ 5 V ± 0,25 V, par exemple) au niveau de la broche 6 du connecteur de bus.

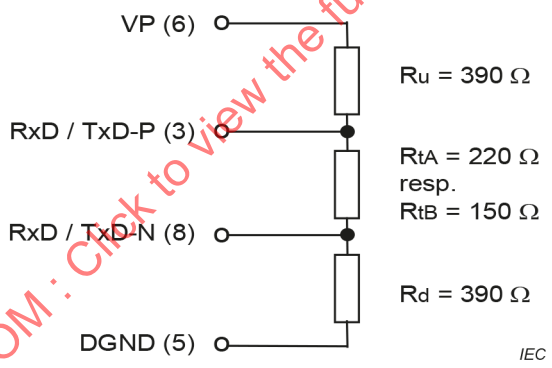


**Figure 124 – Terminateur de bus**

En prenant pour hypothèse une tension d'alimentation de +5 V ± 0,25 V, les valeurs de résistance suivantes sont recommandées:

$R_{tA}$ = 220 Ω ± 4,4 Ω, min. 1/4 W;

$R_{tB}$ = 150 Ω ± 3 Ω, min. 1/4 W;

$R_u = R_d$ = 390 Ω ± 7,8 Ω, min. 1/4 W

La source qui alimente la broche 6 (VP) doit pouvoir livrer un courant d'au moins 10 mA dans les limites spécifiées de tolérances de tension.

Les deux types de câbles et résistances de terminaisons du câblage peuvent être combinés, comme cela est décrit ci-dessus. Cependant, la longueur maximale de la ligne doit être réduite à la moitié des valeurs fixées ci-dessus si la terminaison de la ligne et l'impédance de la ligne ne sont pas en correspondance.

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### 22.1.3 Méthode de transmission

#### 22.1.3.1 Codage binaire

Les données codées NRZ (non-return-to-ZÉRO) en provenance de la DLL sont transmises par l'intermédiaire d'un câble à paire torsadée. Un "1" binaire (DL_symbol = "UN") est représenté par une tension différentielle positive constante entre la broche 3 (RxD/TxD-P) et la broche 8 (RxD/TxD-N) du connecteur de bus; un "0" binaire (DL_symbol = "ZÉRO") est représenté par une tension différentielle négative constante.

#### 22.1.3.2 Commande de l'émetteur-récepteur

Lorsqu'une station n'est pas en émission, la sortie de l'émetteur doit être désactivée (DL_symbol = "SILENCE"). Elle doit présenter une impédance élevée par rapport à la ligne. Au cours des périodes de repos, c'est-à-dire lorsqu'aucune donnée n'est transmise par une quelconque station, le signal de la ligne de réception doit représenter une valeur binaire "1" (DL_symbol = "UN"). Par conséquent, le terminateur de bus doit forcer la tension différentielle entre la broche 3 et la broche 8 du connecteur à l'état positif lorsque tous les émetteurs sont désactivés. Les récepteurs de la ligne doivent toujours être activés et par conséquent au cours de la période de repos, le signal binaire "1" est reçu par chaque station.

### 22.2 Unité de liaison au support de sécurité intrinsèque

### 22.2.1 Caractéristiques

Cette spécification de MAU décrit une MAU de protection contre l'explosion de type Ex i, conformément à l'IEC 60079-11 et à l'IEC 60079-25, sur la base d'une transmission sur ligne symétrique correspondant à la norme TIA-485-A:1998. Les terminateurs, placés aux deux extrémités du câble à paire torsadée permettent à la PhL de prendre notamment en charge des vitesses de transmission plus élevées. La longueur maximale du câble est de 1 200 m pour des débits de données ≤ 93,75 kbit/s. Pour la vitesse maximale de transmission de 1 500 kbit/s, la longueur maximale du câble est réduite à 200 m. Seul le câble de type A (voir 22.2.2.2) doit être utilisé avec cette MAU.

Le codage binaire NRZ est associé à la signalisation de la norme TIA-485-A:1998 qui cible les coupleurs de ligne de moindre coût. Des terminateurs de ligne sont exigés.

Dans tous les appareils connectés aux bus de terrain, le circuit d'interface du bus doit être galvaniquement isolé de tous les autres circuits électriques. Les distances de séparation et les tensions d'isolement entre circuits de sécurité intrinsèque et/ou circuits non de sécurité intrinsèque doivent satisfaire aux normes applicables pertinentes (par exemple, l'IEC 60079-11).

Les caractéristiques exigées sont présentées dans le Tableau 146.

**Tableau 146 – Caractéristiques de sécurité intrinsèque**

| Caractéristique | Contraintes |
|---|---|
| Topologie | Bus linéaire, terminé aux deux extrémités, lignes d'adaptation ≤ 0,3 m, pas de dérivations |
| Support | Câble à paire torsadée blindé recommandé, voir 22.2.2 "Spécifications du support" |
| Longueur de ligne: | ≤ 1 200 m, en fonction du débit de données |
| Nombre de stations: | 32 (stations maîtres, stations esclaves ou répéteurs d'isolation de bus de terrain et en outre 2 terminateurs de bus externes) |
| Débits de données | 9,6 kbit/s / 19,2 kbit/s / 45,45 kbit/s / 93,75 kbit/s / 187,5 kbit/s / 500 kbit/s / 1 500 kbit/s |

La structure linéaire, représentée à la Figure 125, permet la mise en place de points de connexion sur le segment de bus de terrain semblable à l'installation des circuits d'alimentation.

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Il convient que le câble de bus de terrain soit bouclé à travers les appareils de terrain individuels afin d'éviter les lignes d'adaptation.

Un répéteur d'isolation de bus de terrain ou un appareil comparable constitue normalement le début d'un segment de bus de terrain de sécurité intrinsèque. Ce répéteur d'isolation de bus de terrain connecte un segment de bus de terrain qui n'est pas de sécurité intrinsèque avec le segment de bus de terrain de sécurité intrinsèque et assure simultanément une isolation galvanique fiable entre les deux. Le segment de bus de terrain de sécurité intrinsèque est terminé aux deux extrémités par une terminaison de bus active. Jusqu'à 32 éléments de bus (appareils de terrain, répéteur d'isolation de bus de terrain, terminateurs de bus externes, etc.) peuvent être disposés sur le segment de bus de terrain. Ces éléments du bus sont connectés à un segment de bus de terrain en système électrique flottant (sans retour à la terre).

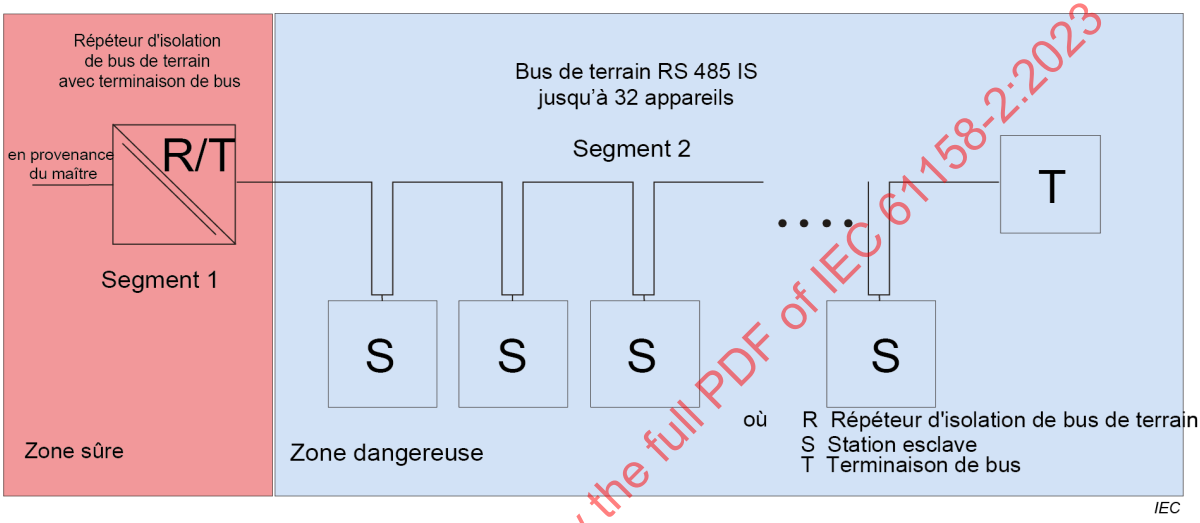


**Figure 125 – Structure linéaire d'un segment de sécurité intrinsèque**

La Figure 126 donne un exemple de montage et la segmentation d'un système de bus de terrain avec répéteurs d'isolation de bus de terrain. Le segment 2 et le segment 3 de bus de terrain sont de sécurité intrinsèque. Le répéteur d'isolation de bus de terrain, entre le segment de sécurité intrinsèque 2 et le segment de sécurité intrinsèque 3 doit maintenir l'isolation galvanique. Le nombre de répéteurs qui peuvent être connectés en cascade dépend de la distorsion du signal et du retard de signal (attention aux spécifications du fabricant).

Le segment 3 de la Figure 126 commence par un répéteur d'isolation de bus de terrain au milieu du segment 3. La terminaison de bus est assurée à une extrémité au moyen d'une terminaison de bus active et à l'autre extrémité au moyen d'un autre répéteur d'isolation de bus de terrain qui ouvre le segment 4 dans la zone de sécurité.

Les terminaisons de bus d'un segment de bus de terrain peuvent être localisées dans un répéteur d'isolation de bus de terrain, dans un appareil de terrain, dans une terminaison de bus active (en tant qu'appareil autonome) ou dans un connecteur alimenté à partir d'un répéteur d'isolation de bus de terrain ou d'un appareil de terrain.

Le répéteur entre le segment 2 et le segment 3 de la Figure 126 doit être installé à l'extérieur de la zone dangereuse, comme matériel associé. L'installation dans la zone dangereuse exige des mesures de protection supplémentaires contre l'explosion (par exemple, Ex e, Ex d, Ex I, etc., conformément à l'IEC 60079-0).

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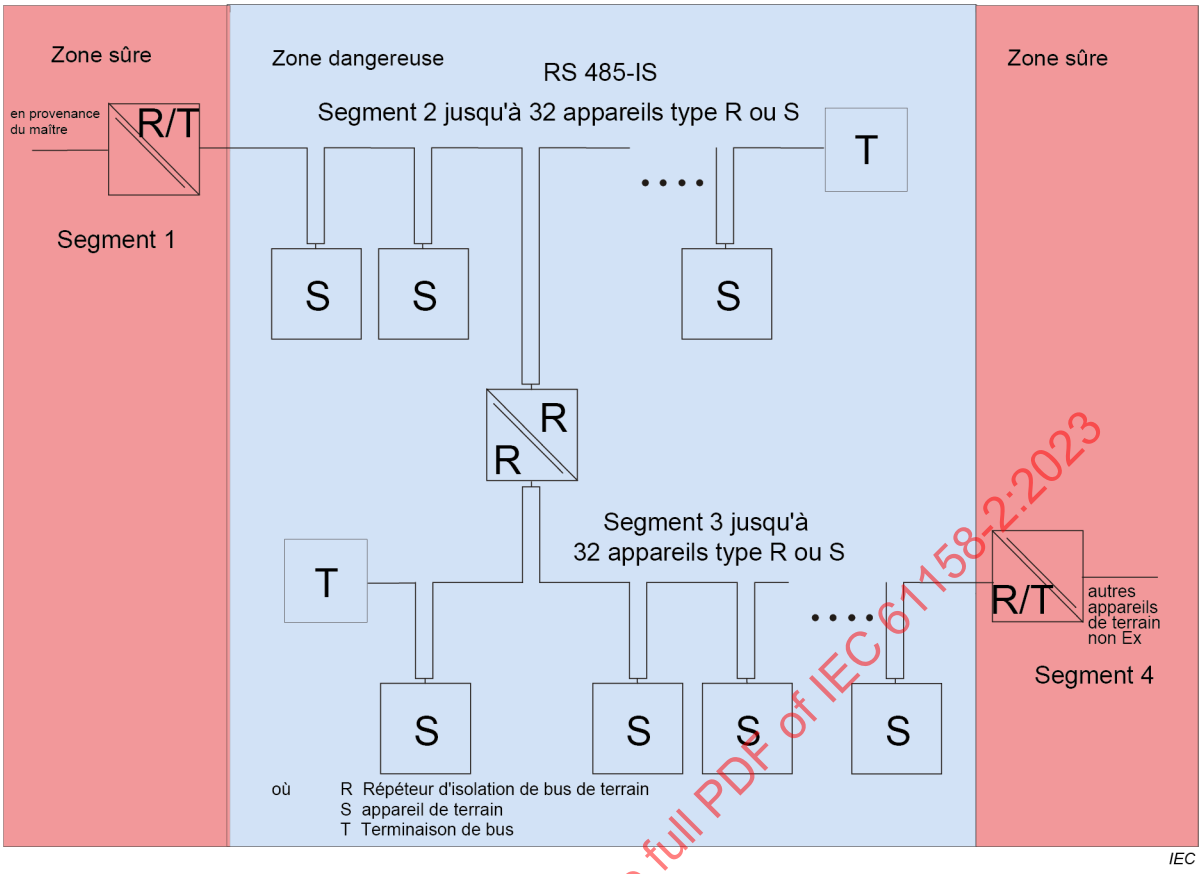


**Figure 126 – Exemple de topologie étendue par des répéteurs**

### 22.2.2 Spécifications du support

#### 22.2.2.1 Connecteur

Le connecteur est spécifié au I.2.2.

#### 22.2.2.2 Câble

Le Tableau 147 présente les paramètres spécifiés du câble compte tenu de la fonction et de la sécurité intrinsèque.

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**Tableau 147 – Spécification du câble (liée à la fonction et à la sécurité)**

| Paramètre du câble | Câble de type A [a] | Valeurs limites de sécurité |
|---|---|---|
| Impédance d'onde (Ω) | 135…165 à une fréquence de 3…20 MHz | Non applicable |
| Capacité de service (nF/km) | ≤ 30 | Non applicable |
| Diamètre du conducteur (mm) | > 0,64 | > 0,1 par fil pour un conducteur toronné à brins fins [b]<br>> 0,35 [c] |
| Section de l'âme (mm2) | > 0,34 | > 0,096 2 [c] |
| Résistance de boucle (Ω□/km) | ≤ 110 | Non applicable |
| Rapport L/R (µH/Ω) | ≤ 15 | ≤ 15 pour la température ambiante la plus basse (voir la note) |
| Couleur de gaine IS | Bleu clair | Si la couleur est utilisée pour le marquage |
| Couleur du conducteur intérieur du câble A (RxD/TxD-N) | Verte | |
| Couleur du conducteur intérieur du câble B (RxD/TxD-P) | Rouge | |

NOTE Le câble de type A satisfait à cette exigence pour une température ambiante supérieure à –40 °C.

[a] Conformément à l'IEC 60079-14. Le câble doit satisfaire aux exigences correspondantes.

[b] Conformément à l'IEC 60079-14. Les extrémités des conducteurs toronnés à brins fins doivent être protégées contre la séparation des brins élémentaires, par exemple au moyen de cosses de câbles ou de manchons d'extrémité.

[c] Cette valeur minimale s'applique à une température ambiante maximale de 40 °C et à la classe de température T6 pour une valeur totale du courant dans le câble de bus de terrain de 4,8 A au plus. Conformément à l'IEC 60079-11, les informations concernant le courant admissible à d'autres températures ambiantes doivent être déduites des exigences existantes. Dans le cas de la RS 485-IS, le courant maximal dans le câble de bus de terrain est de 4,8 A. Cette opération nécessite une section de conducteur ≥ 0,096 2 mm2 (diamètre: ≥ 0,35 mm) pour un câble utilisé en classe T6 et pour une température ambiante maximale de 40 °C. La température de surface admissible du câble ne doit pas dépasser 80 °C dans le cas de T6, et de ce fait, l'échauffement maximal est de 40 K pour 4,8 A et la section de conducteur spécifiée ci-dessus. Pour des câbles déployés en classe T4 et des températures ambiantes supérieures à 40 °C, la somme de la température ambiante et de l'échauffement du câble ne doit pas dépasser 130 °C pour un courant de 4,8 A. Dans tous les cas, l'isolation du câble doit convenir aux températures maximales prévues pour le câble.

Le Tableau 148 présente la longueur de câble maximale admissible en fonction des vitesses de transmission.

**Tableau 148 – Longueur maximale du câble pour les différentes vitesses de transmission**

| Élément | Unité | Valeur | | | | | |
|---|---|---|---|---|---|---|---|
| **Débit de données** | kbit/s | 9,6 | 19,2 | 93,75 | 187,5 | 500 | 1 500 |
| **Câble de type A** | m | 1 200 | 1 200 | 1 200 | 1 000 | 400 | 200 |

### 22.2.2.3 Règles de mise à la masse et de blindage

NOTE Mise à la masse signifie une connexion permanente à la terre par l'intermédiaire d'une impédance suffisamment basse et avec un courant admissible suffisant pour prévenir un amorçage en tension qui peut entraîner un danger excessif pour le matériel connecté ou les personnes.

Les lignes de tension zéro (commun) peuvent être reliées à la masse où elles sont galvaniquement isolées de la ligne principale du bus de terrain.

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Les appareils de bus de terrain ne doivent pas raccorder l'un des conducteurs de la paire torsadée à la masse, quel que soit le point du réseau. Les signaux doivent être appliqués et préservés de manière différentielle sur l'ensemble du réseau.

Il convient que les appareils de bus de terrain permettent une isolation en courant continu du blindage du câble par rapport à la masse.

Pour des installations de sécurité intrinsèque, la mise à la masse doit être conforme à l'IEC 60079-14.

En ce qui concerne le blindage, voir 12.8.6.

#### 22.2.2.4 Terminateur de bus

Le câble de bus de type A doit être terminé aux deux extrémités par la résistance $R_t$. La résistance de terminaison $R_t$, spécifiée dans la norme TIA-485-A:1998 doit être complétée par une résistance de rappel vers le niveau bas $R_d$ (connectée à la masse de la terminaison de bus ISGND) et par une résistance de rappel vers le niveau bas $R_u$ (connectée au Plus de la terminaison de bus ISP), comme cela est représenté à la Figure 127. Ce complément force la tension en mode différentiel (c'est-à-dire la tension entre les conducteurs) à une valeur bien définie, lorsqu'aucune station n'émet (au cours des périodes de repos).

La terminaison de cette spécification de MAU pour le type de protection contre l'explosion Ex i diffère de la spécification de la MAU qui n'est pas de sécurité intrinsèque de par la modification des caractéristiques électriques. Dans ce contexte, les valeurs de résistance de la terminaison de bus (voir la Figure 127) et la disposition modifiée de la terminaison de bus (voir I.2.2) doivent faire l'objet d'une attention particulière lorsque ces éléments sont intégrés dans des appareils de communication ou des connecteurs à fiche.

Chaque station qui termine la ligne (en association avec un terminateur de bus) doit mettre à disposition une tension d'alimentation interne U+ de + 3,3 V avec une tolérance de ± 5 %.

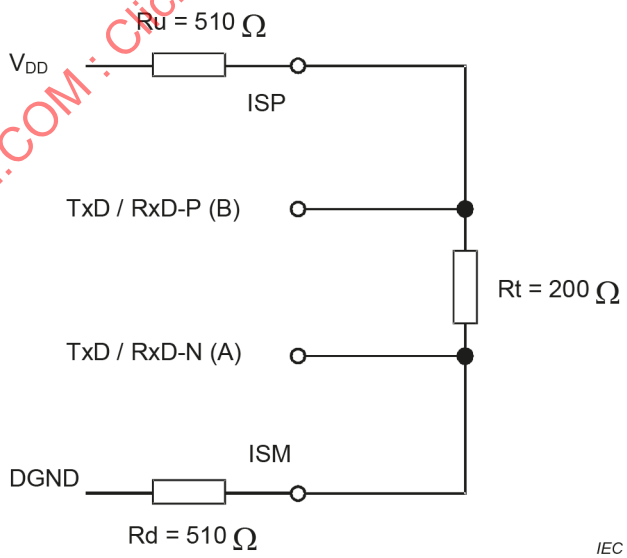


**Figure 127 – Terminateur de bus**

### 22.2.3 Méthode de transmission

#### 22.2.3.1 Codage binaire

Voir 22.1.3.1.

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#### 22.2.3.2 Commande de l'émetteur-récepteur

Voir 22.1.3.2.

#### 22.2.3.3 Caractéristiques des signaux

##### 22.2.3.3.1 Spécification des signaux

La Figure 128 représente une forme d'onde de tension type sur le bus de terrain de sécurité intrinsèque. Il est défini trois phases au cours desquelles des niveaux de signal caractéristiques sont générés sur le bus:

– état de repos avec $V_{ODidle}$

– phase basse avec $V_{ODlow}$

– phase haute avec $V_{ODhigh}$

La marge de bruit joue un rôle crucial dans la définition des niveaux de signal. La marge de bruit d'un niveau du signal est toujours la différence entre la tension correspondant à ce niveau et la tension de seuil. La tension de seuil $U_{TH}$ est un attribut du récepteur TIA-485-A et est définie dans la plage de ±0,2 V. Pour une transmission de données fiable, la marge de bruit doit être aussi grande que possible. Dans le cas d'une MAU pour bus de terrain de sécurité intrinsèque, une marge de bruit minimale de 0,2 V doit être assurée dans les conditions "les plus défavorables".

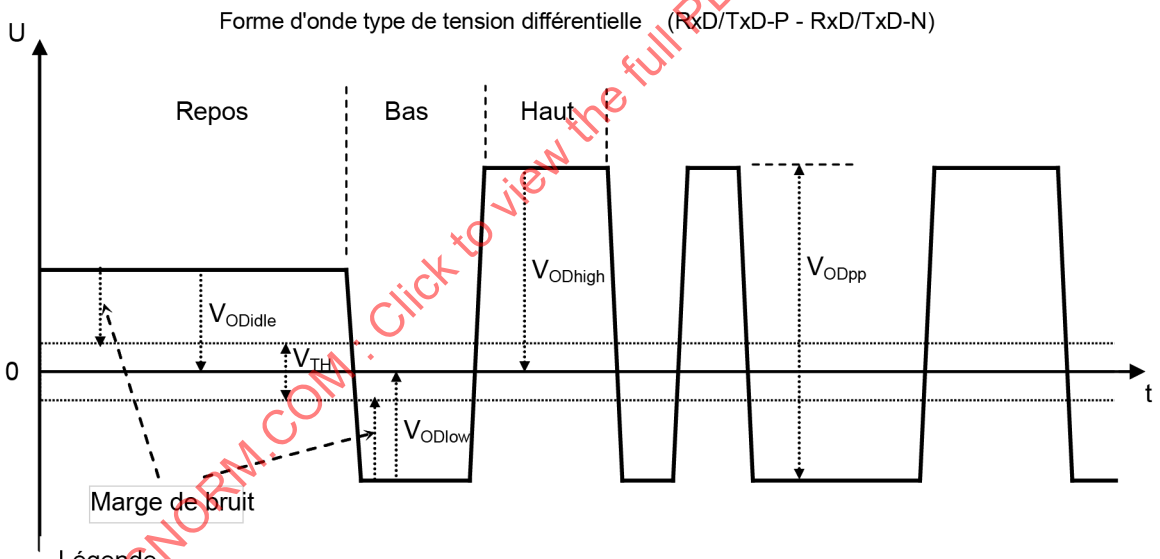


**Figure 128 – Forme d'onde de la tension différentielle**

Les paramètres définis dans le Tableau 149 sont obligatoires pour les appareils de communication.±

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**Tableau 149 – Caractéristiques électriques de l'interface de sécurité intrinsèque**

| Paramètre | Description | Valeur | Remarque |
|---|---|---|---|
| Niveau de repos minimal | $V_{ODidle}$ [V] | 0,50 | Applicable uniquement à des appareils avec une terminaison de bus intégrée ou raccordable |
| Niveau de transmission sur la connexion du bus (crête à crête) | $V_{ODss}$ [V] | ≥ 2,7 | Pour la configuration de bus la plus défavorable et une charge maximale sur l'émetteur |
| Niveau de transmission positif et négatif sur la connexion du bus | $V_{ODhigh}$ [V] | ≥ 1,5 | Pour la configuration de bus la plus défavorable et une charge maximale sur l'émetteur |
| | $V_{ODlow}$ [V] | ≤ -1,1 | |
| Niveau du signal à l'entrée du récepteur | $V_{IDhigh}$ [V] | ≥ 0,8 | Pour la configuration de bus la plus défavorable |
| | $V_{Idlow}$ [V] | ≤ -0,4 | |
| Débits de transmission de données | kbit/s | 9,6;<br>19,2;<br>45,45;<br>93,75;<br>187,5;<br>500;<br>1 500 | Un appareil de terrain peut être conçu avec un débit limité de transmission de données |
| Impédance d'entrée (récepteur) | $R_{IN}$ [kOhm]<br>$C_{IN}$ [pF]<br>$L_{IN}$ | ≥ 12<br>≤ 40<br>≈ 0 | Pour un appareil alimenté ou non alimenté |
| Tension d'alimentation du circuit d'attaque RS 485 et terminaison de bus | $V_{DD}$ [V] | 3,3 ±5 % | |

#### 22.2.3.3.2 Circuits d'essai

##### 22.2.3.3.2.1 Généralités

L'objectif de ces mesurages est de vérifier les niveaux de signal exigés par le Tableau 149. Il convient d'effectuer des mesurages statiques à un bas débit de transmission de données de sorte que les réactances existantes, telles que les capacités d'entrée, n'influencent pas les résultats de mesure. En outre, le câble de bus est remplacé par une résistance équivalente qui correspond à la résistance de boucle pour la longueur maximale du câble de bus.

NOTE Seuls les mesurages qui sont spécifiques à l'interface de sécurité intrinsèque sont décrits ici.

Par ailleurs, il convient de vérifier la conformité à la norme TIA-485-A:1998.

##### 22.2.3.3.2.2 Mesurage du niveau au repos

Ce mesurage détermine les caractéristiques de la résistance de terminaison. De ce fait, ce mesurage doit uniquement être effectué sur des appareils en essai qui sont soit équipés d'une terminaison de bus (voir la Figure 129), soit fournissent une alimentation à une terminaison de bus externe (les connexions ISM et ISP sont réalisées) (voir la Figure 130).

Il convient que les composants supplémentaires, ainsi que les commutateurs et résistances, soient directement connectés aux bornes du DUT (à une distance de 5 cm à 15 cm). Lorsqu'un câble de connexion doit être utilisé, la longueur du câble ne doit pas dépasser 1 m.

Le mesurage est effectué en deux étapes:

Étape 1: la tension en circuit ouvert V1 est mesurée; elle doit être supérieure aux valeurs spécifiées sur la ligne 1 du Tableau 149.

Étape 2: la tension V2 est mesurée dans des conditions de charge (charge de 330 Ω). V2 doit être dans une plage spécifiée (0,65 × V1 ≤ V2 ≤ 0,72 × V1). Cette disposition

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garantit une valeur de la résistance de terminaison dans une plage de 130 Ω à 180 Ω.

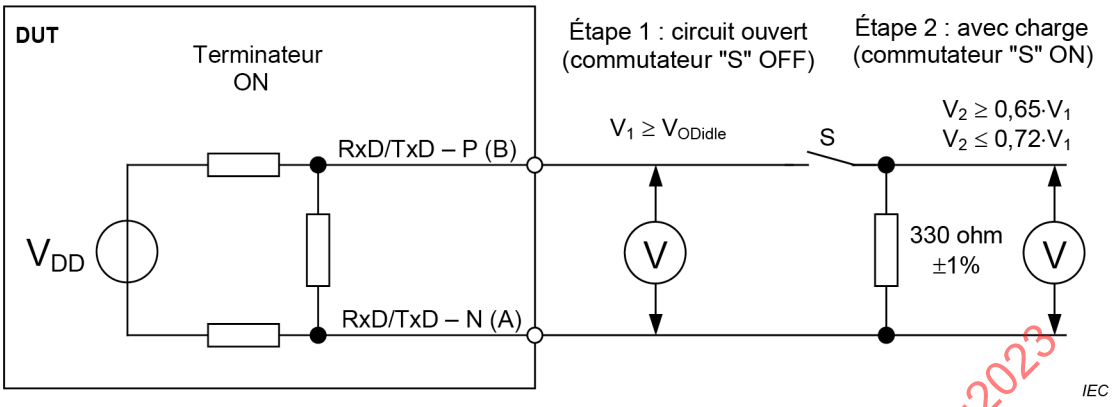


**Figure 129 – Montage d'essai pour le mesurage du niveau de repos d'appareils à résistance de terminaison intégrée**

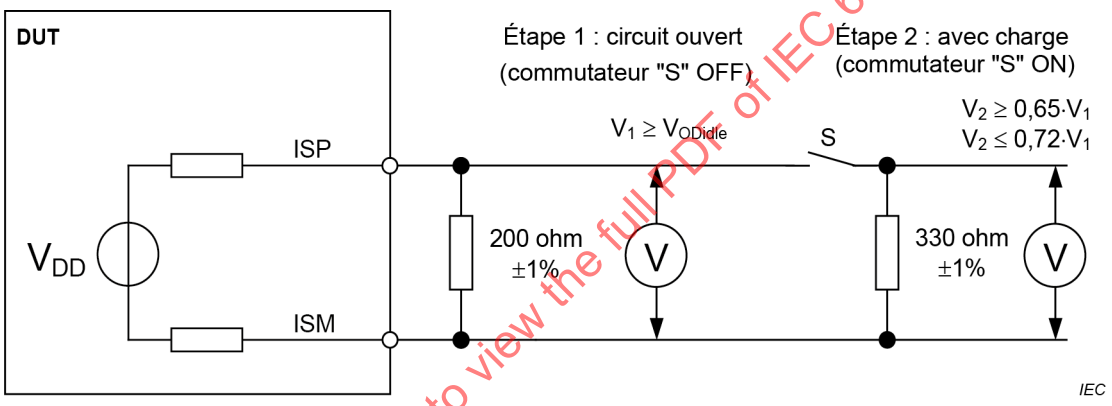


**Figure 130 – Montage d'essai pour le mesurage du niveau de repos d'appareils à résistance de terminaison raccordable**

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#### 22.2.3.3.2.3 Mesurage des niveaux de signal

Pour les montages de mesure ci-dessous, un répéteur d'isolation du bus de terrain conforme doit être utilisé pour la connexion au système maître. Au cours de l'essai, le bus de terrain de sécurité intrinsèque doit être terminé aux deux extrémités conformément au 22.2.2.4. Si la terminaison de bus n'est pas intégrée à l'appareil en essai, alors une terminaison de bus externe conforme doit être utilisée.

Pour mesurer les signaux sur le bus de terrain de sécurité intrinsèque sans influences externes, il est nécessaire de connecter un oscilloscope isolé électriquement (par exemple, un appareil portatif alimenté par batterie).

Il convient que les composants supplémentaires, ainsi que la résistance et le réseau de résistance, soient connectés sur une longueur aussi courte que possible aux bornes du DUT et au répéteur d'isolation du bus de terrain. Lorsqu'un câble de connexion doit être utilisé, la longueur totale du câblage ne doit pas dépasser 2 m. L'oscilloscope peut être connecté à toute borne appropriée en fonction du montage.

Le mesurage représenté à la Figure 131 détermine les niveaux de transmission sur les connexions de l'émetteur et pour une charge la plus défavorable. Tel est le cas d'une longueur de câble de bus de terrain égale à zéro. Dans ce cas, le niveau du courant de sortie de l'émetteur et par conséquent de la charge est maximal. Les valeurs assignées pour les niveaux de transmission sont présentées sur la ligne 2 et la ligne 3 du Tableau 149.

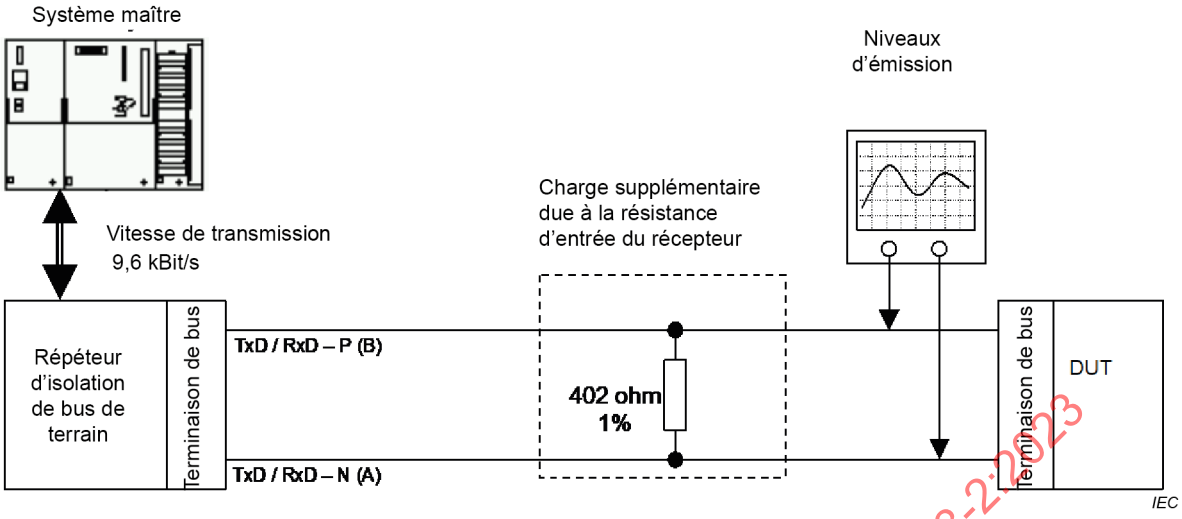


**Figure 131 – Montage d'essai pour le mesurage des niveaux de transmission**

Le mesurage représenté à la Figure 132 tente de vérifier la capacité de l'émetteur à générer un niveau suffisant pour chaque récepteur et pour la charge la plus défavorable. Pour une longueur maximale de câble de bus de terrain de 1 200 m et une charge supplémentaire, le point milieu du câble approximativement est concerné. Les valeurs de mesure doivent satisfaire aux exigences de la ligne 4 du Tableau 149.

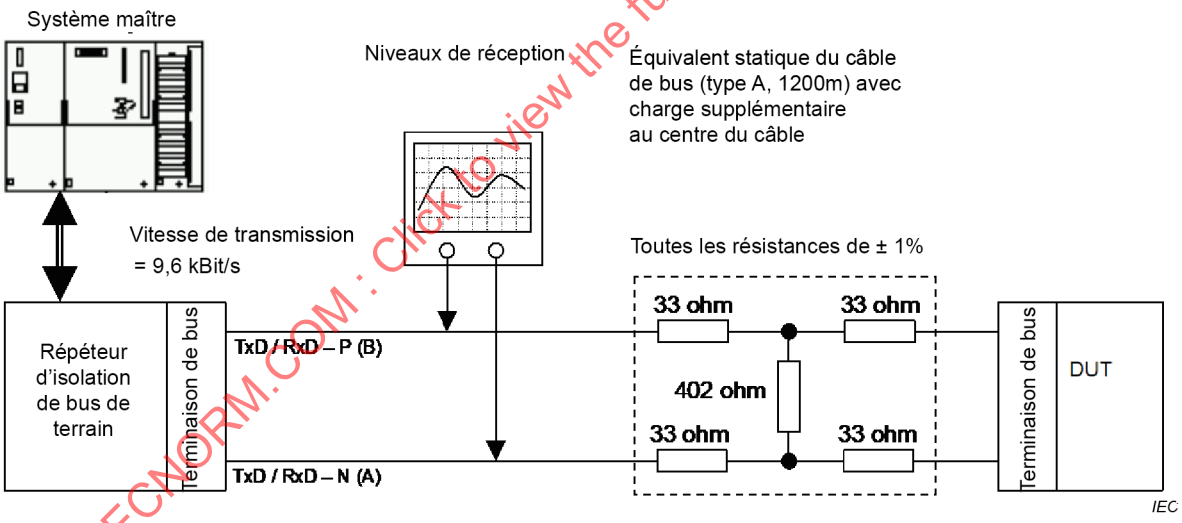


**Figure 132 – Montage d'essai pour le mesurage des niveaux de réception**

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### 22.2.4 Sécurité intrinsèque

#### 22.2.4.1 Généralités

Le présent document n'a pas pour objet d'énumérer les exigences par lesquelles un équipement peut être certifié comme étant de sécurité intrinsèque et n'exige pas non plus que l'équipement soit de sécurité intrinsèque. Il cherche plutôt à exclure les conditions ou situations qui empêchent la certification de la sécurité intrinsèque.

#### 22.2.4.2 Modèle de bus de terrain de sécurité intrinsèque

Le bus de terrain de sécurité intrinsèque repose sur un modèle dans lequel tous les appareils sont actifs. Tous les appareils sont alimentés de l'extérieur et peuvent fournir de l'énergie au bus de terrain. Dans un circuit de sécurité intrinsèque, uniquement une quantité maximale

d'énergie est admise en prenant en considération les inductances et les capacités existantes. La quantité maximale d'énergie est décrite par les courbes d'inflammation.

NOTE Le bus de terrain de sécurité intrinsèque repose sur l'analyse effectuée par le PTB (Physikalisch-Technische Bundesanstalt). PTB-Mitteilungen, 113 Jahrgang, Heft 2/2003, Die Bewertung der Zündfähigkeit eigensicherer Stromkreise anhand eines Rechenverfahrens. Abschnitt: Der eigensichere RS 485 Feldbus als Anwendungsbeispiel.

Un montage du modèle de base du bus de terrain est représenté à la Figure 133. Un répéteur d'isolation de bus de terrain est (généralement) placé dans la zone non dangereuse pour assurer en toute sécurité la séparation entre le segment de bus de sécurité intrinsèque et le segment de bus qui n'est pas de sécurité intrinsèque. D'autres appareils de communication connectés se trouvent dans la zone dangereuse. Le câble de bus est terminé aux deux extrémités par une terminaison de bus externe active ou par une terminaison de bus intégrée dans un appareil de terrain. Tous les appareils de communication sont alimentés par des sources de tension externes et possèdent les moyens de limiter en toute sécurité le courant et la tension présents sur le bus.

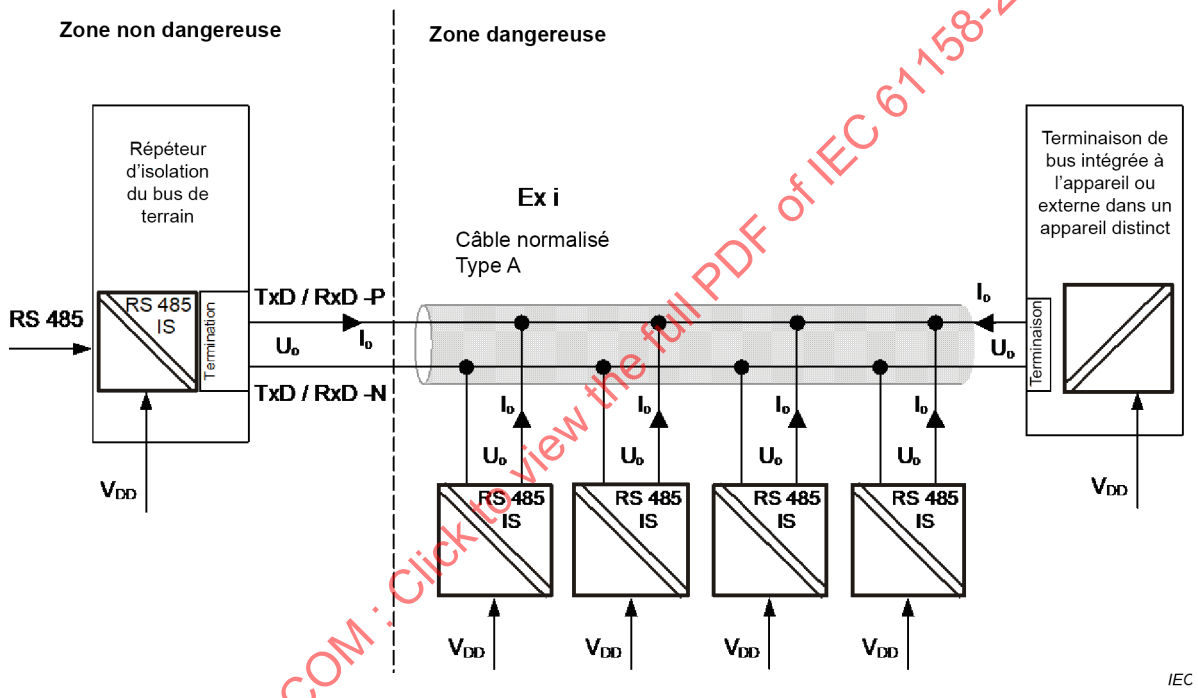


**Figure 133 – Modèle de bus de terrain de sécurité intrinsèque**

Dans certaines circonstances, les appareils installés dans la zone dangereuse doivent être protégés par des mesures de protection supplémentaires contre l'explosion (par exemple, Ex e, d ou m, conformément à l'IEC 60079-0).

### 22.2.4.3 Modèle d'appareil de communication

La Figure 134 représente un schéma de circuit de l'interface RS 485-IS. Cette interface est constituée de composants d'isolation galvanique et de limitation de la tension et du courant, ainsi que d'un émetteur-récepteur RS 485.

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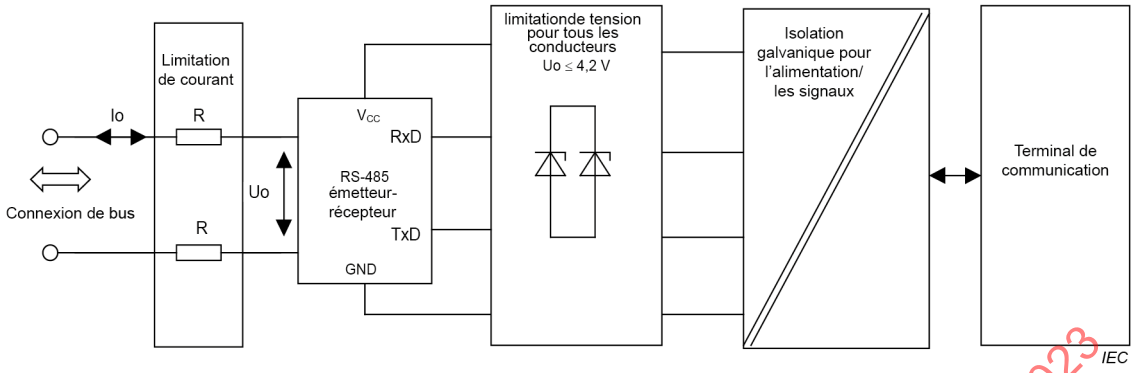


**Figure 134 – Modèle d'appareil de communication de sécurité intrinsèque**

Pour se conformer à la limite donnée pour $U_o$ dans le Tableau 150, toutes les connexions à l'interface de bus (lignes d'alimentation et de données) doivent être limitées au moyen de composants de limitation de tension appropriés. Dans ce contexte, les tolérances et les valeurs maximales de puissance assignée des composants doivent être prises en compte. Dans certaines circonstances, il convient d'intégrer au terminal de communication / à l'alimentation des mesures appropriées de limitation de puissance.

Dans tous les appareils connectés aux bus de terrain de sécurité intrinsèque, le circuit d'interface du bus doit être galvaniquement isolé de tous les autres circuits électriques.

Les distances de séparation et les tensions d'isolement entre circuits de sécurité intrinsèque et/ou circuits qui ne sont pas de sécurité intrinsèque, doivent satisfaire aux exigences de l'IEC 60079-11.

NOTE La limitation du courant est déterminée par la tension de sortie maximale et la somme des résistances internes. Les résistances internes sont constituées par les résistances série des lignes de données RxD/TxD-N et RxD/TxD-P, ainsi que par les résistances série Ru et Rd pour l'alimentation du terminateur de bus.

Dans ce contexte, les tolérances et les valeurs assignées de puissance des résistances doivent également être prises en compte. L'IEC 60079-11 fournit les exigences détaillées applicables aux composants de limitation du courant et de la tension.

#### 22.2.4.4 Valeurs maximales de sécurité

Le Tableau 150 présente les paramètres de sécurité pertinents, ainsi que leurs valeurs, pour l'ensemble du système de bus de terrain.

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**Tableau 150 – Valeurs maximales de sécurité**

| Paramètre | Description | Valeur | Remarque |
|---|---|---|---|
| **Système de bus** | | | |
| Tension d'entrée maximale | $U_I$ [V] | \|±4,2\| | |
| Courant d'entrée maximal | $I_I$ [A] | 4,8 | Le circuit a une caractéristique linéaire Rs = Uo/Io |
| Rapport maximal inductance / résistance (voir la Note) | L'/R' [µH/Ω] | 15 | Pour l'ensemble de la plage de températures d'exploitation du système de bus |
| Nombre d'appareils | $N_{TN}$ | ≤ 32 | Un appareil de terrain peut être conçu avec un débit limité de transmission de données |
| **Appareil de communication** | | | |
| Tension de sortie maximale | Uo [V] | \|±4,2\| | |
| Courant de sortie maximal | Io [mA] | 149 | Courant total des conducteurs A, B et alimentation de terminaison de bus |
| Tension d'entrée maximale | $U_I$ [V] | \|±4,2\| | |
| Inductance interne maximale | $L_I$ [H] | 0 | Aucune inductance concentrée n'est tolérée le long du bus de terrain |
| Capacité interne maximale | $C_I$ [nF] | N/A | Non significatif pour la sécurité |
| **Terminaison de bus active externe** | | | |
| Tension de sortie maximale | Uo [V] | \|±4,2\| | |
| Courant de sortie maximal | Io [mA] | 16 | |
| Tension d'entrée maximale | $U_I$ [V] | \|±4,2\| | |
| Inductance interne maximale | $L_I$ [H] | 0 | Aucune inductance concentrée n'est tolérée le long du bus de terrain |
| Capacité interne maximale | $C_I$ [nF] | N/A | Non significatif pour la sécurité |
| NOTE Pour une tension inférieure à 10 V, la capacité du câble ne génère pas de danger supplémentaire. Cependant, pour des raisons fonctionnelles, la capacité du câble de bus est limitée à C' < 40 nF/km. | | | |

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Pour des raisons fonctionnelles, il convient de subdiviser de manière symétrique la résistance de limitation du courant.

#### 22.2.4.5 Répéteur d'isolation du bus de terrain

Pour créer ou connecter des segments de bus de terrain de sécurité intrinsèque, des répéteurs d'isolation de bus de terrain (voir la Figure 125 et la Figure 126) sont exigés. Les interfaces du bus de terrain de sécurité intrinsèque de ces appareils doivent également être mises en œuvre conformément à la présente spécification de MAU. Il faut notamment prendre en considération, du point de vue de la sécurité, les données de sécurité maximale (voir 22.2.4.4) et l'isolation galvanique par rapport à tous les autres circuits (voir 22.2.1).

Le répéteur d'isolation de bus de terrain doit être conçu comme matériel associé. Si des répéteurs d'isolation de bus de terrain doivent être installés dans la zone dangereuse, des mesures supplémentaires de protection contre l'explosion sont nécessaires.

# 23 Type 3: Unité de liaison au support: transmission asynchrone, support optique

## 23.1 Caractéristiques techniques de la transmission de données sur fibre optique

Le Tableau 151 présente les caractéristiques techniques d'une transmission de données sur fibre optique.

**Tableau 151 – Caractéristiques techniques**

| Élément | Description |
|---|---|
| Support de transmission | Câble à fibre optique (FOC) en quartz ou en plastique |
| Caractéristiques | - Large plage, indépendante de la vitesse de transmission<br>- Insensibilité aux perturbations électromagnétiques<br>– Isolation galvanique entre les nœuds connectés<br>- Connexion non réactive – même aux applications existantes<br>- Configuration des composantes optiques avec des composantes normalisées et économiques |
| Structure du réseau | Topologies en étoile, en anneau, linéaires et mixtes (arborescentes)<br>Connexion à des segments du réseau électrique |
| Composants de réseau | Coupleur en étoile actif<br>Répéteur<br>Convertisseur opto-électrique } avec ou sans resynchronisation |
| Débits de données | 9,6 kbit/s; 19,2 kbit/s; 45,45 kbit/s; 93,75 kbit/s; 187,5 kbit/s; 500 kbit/s; 1,5 Mbit/s; 3 Mbit/s; 6 Mbit/s; 12 Mbit/s |
| Portée du réseau et nombre de nœuds | En fonction du nombre et du type de composants de réseau utilisés<br>EXEMPLE 1 Segment de réseau avec 1 coupleur en étoile actif et un câble à fibre optique de verre (multimodale):<br>- 3 400 m (indépendant du nombre de nœuds).<br>EXEMPLE 2 Segment de réseau avec 1 coupleur en étoile actif et un câble à fibre optique en plastique:<br>- 88 m (indépendant du nombre de nœuds).<br>NOTE Il est possible d'augmenter les portées et le nombre de nœuds par la liaison de segments de réseau. |

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La Figure 135 représente la MAU à fibre optique à côté d'une MAU TIA-485-A:1998. Cela signifie que la MAU à fibre optique doit être connectée à une DLL par l'intermédiaire d'une interface DL-Ph de la même manière qu'une MAU TIA-4785A:1998. L'interface mentionnée est décrite au 5.4.2.

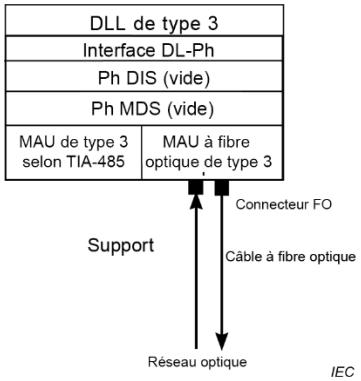


**Figure 135 – Connexion au réseau optique**

### 23.2 Caractéristiques de base d'un support de transmission de données sur fibre optique

Un support de transmission de données sur fibre optique est caractérisé par:

– une insensibilité aux perturbations électromagnétiques, c'est-à-dire:
  a) l'absence de diaphonie entre différentes lignes de signaux sur fibre optique,
  b) l'immunité aux injections de perturbations en provenance et vers des lignes électriques,
  c) l'immunité aux perturbations de champs électromagnétiques qui peuvent apparaître, par exemple, lors de la commutation de charges électriques importantes.
– une isolation galvanique entre les nœuds connectés, c'est-à-dire:
  d) l'absence de courants d'égalisation entre des potentiels de terre différents
  e) aucune mesure particulière de protection contre la foudre n'est exigée pour la liaison de transmission.
– La possibilité d'utiliser des pontages en fibre optique sur de grandes distances et à des vitesses de transmission élevées.
– L'installation simple et économique de réseaux plus courts à base de fibres plastiques.
– Un faible poids.
– L'absence de toute corrosion.
– Un câblage simplifié et normalisé des bâtiments au moyen de fibres de référence identiques pour de nombreuses autres normes de communication.

### 23.3 Réseau optique

Le convertisseur électro-optique qui assure l'interface entre la partie électrique de la MAU et un support de réseau optique est une composante importante de la MAU à fibre optique d'un nœud.

Un émetteur optique convertit des signaux électriques en signaux optiques et les injecte dans le support à fibre optique. A l'inverse, un récepteur optique convertit les signaux optiques reçus du support à fibre optique en signaux électriques.

La Figure 136 représente la structure de principe d'un réseau optique.

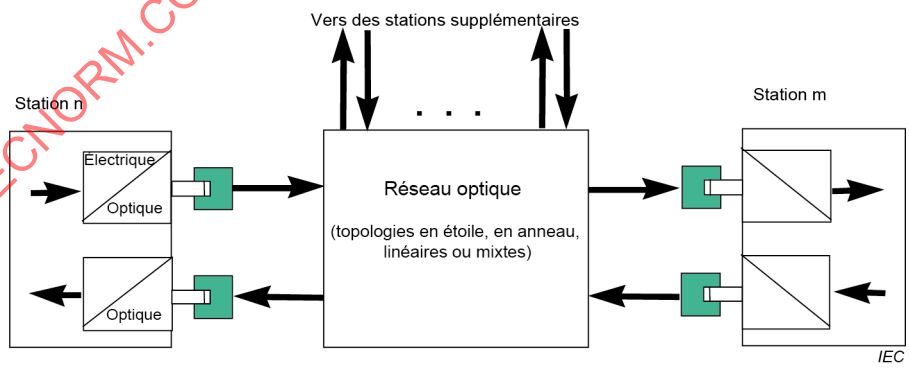


**Figure 136 – Structure de principe d'un réseau optique**

Il est spécifié, pour chaque type de fibre, un convertisseur électro-optique avec un bilan spécifique de niveau de signal qui tient compte des différences physiques entre fibres de verre et fibres plastiques.

L'utilisateur peut "consommer" le bilan de niveau de signal comme un affaiblissement sur la liaison optique.

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