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INTERNATIONAL STANDARD

Information technology – Home electronic system (HES) architecture – Part 3-6: Media and media dependent layers – Twisted pair for network based control of HES Class 1

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Schneider Electric Industries SAS has informed IEC and ISO that they have the patent applications or granted patents as listed below:

EP 0370 921 B1, EP 0911 777 A1.

IEC and ISO draw attention to the fact that it is claimed that compliance with this document may involve the use of a patent primarily concerning activities as described in 6.2: Requirements for analogue bus signals and 6.3: Medium attachment unit (MAU).

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EP 0365 696 B1, EP 0487 759 B1, EP 0489 194 B1, EP 0643 893 B1, EP 0770 285 B1, EP 0854 587 A1, EP 0858 142 A1, EP 0858 194 A1, WO 00/42694 A1.

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This International Standard is a product family standard. It shall be used in conjunction with ISO/IEC 14543-2-1, 14543-3-3, 14543-3-4, 14543-3-5 and 14543-3-7.

The list of all currently available parts of ISO/IEC 14543 series, under the general title *Information technology – Home electronic system (HES) architecture,* can be found on the IEC web site.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

INTRODUCTION

The reference model for Open System Interconnection (OSI), specified in ISO/IEC 7498, assigns the functions that are needed for communications between two entities that are connected by medium to seven logical layers. This International Standard specifies interconnection of entities used for home and building control via the medium twisted pair. It specifies the medium and medium dependent functions such as the cable, the connectors and the transmission technology in terms of the Physical Layer and the Data Link Layer according to ISO/IEC 7498.

Currently, ISO/IEC 14543, *Information technology – Home Electronic System (HES) architecture*, consists of the following parts:

Part 2-1: *Introduction and device modularity*
Part 3-1: *Communication layers – Application layer for network based control of HES Class 1*
Part 3-2: *Communication layers – Transport, network and general parts of data link layer for network based control of HES Class 1*
Part 3-3: *User process for network based control of HES Class 1*
Part 3-4: *System management – Management procedures for network based control of HES Class 1*
Part 3-5: *Media and media dependent layers – Powerline for network based control of HES Class 1*
Part 3-6: *Media and media dependent layers – Twisted pair for network based control of HES Class 1*
Part 3-7: *Media and media dependent layers – Radio frequency for network based control of HES Class 1*
Part 4: *Home and building automation in a mixed-use building (technical report)*
Part 5-1: *Intelligent grouping and resource sharing for HES Class 2 and Class 3 – Core protocol (under consideration)*
Part 5-2: *Intelligent grouping and resource sharing for HES Class 2 and Class 3 – Device certification (under consideration)*
Additional parts may be added later.

INFORMATION TECHNOLOGY –
HOME ELECTRONIC SYSTEM (HES) ARCHITECTURE –

Part 3-6: Media and media dependent layers –
Twisted pair for network based control of HES Class 1

1 Scope

This part of ISO/IEC 14543 defines the mandatory and optional requirements for the medium specific physical and data link layer for twisted pair for network based control of HES Class 1 in its two variations called TP0 and TP1.

NOTE Data link layer interface and general definitions, which are media independent, are specified in ISO/IEC 14543-3-2.

2 Normative references

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

ISO/IEC 14543-2-1, *Information technology – Home Electronic System (HES) architecture – Part 2-1: Introduction and device modularity*

ISO/IEC 14543-3-2, *Information technology – Home electronic system (HES) architecture – Part 3-2: Communication layers – Transport, network and general parts of data link layer for network based control of HES Class 1*

ISO/IEC 14543-3-3, *Information technology – Home Electronic System (HES) architecture – Part 3-3: User process for network based control of HES Class 1*

ISO/IEC 14543-3-4, *Information technology – Home Electronic System (HES) architecture – Part 3-4: System management – Management procedures for network based control of HES Class 1*

ISO/IEC 14543-3-5, *Information technology – Home Electronic System (HES) architecture – Part 3-4: Media and media dependent layers – Powerline for network based control of HES Class 1*

ISO/IEC 14543-3-7, *Information technology – Home Electronic System (HES) architecture – Part 3-6: Media and media dependent layers – Radio frequency for network based control of HES Class 1*

IEC 60189-2, *Low-frequency cables and wires with PVC insulation and PVC sheath – Part 2: Cables in pairs, triples, quads and quintuples for inside installations*

IEC 60227-2, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 2: Test methods*

IEC 60245-2, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 2: Test methods*

IEC 60332-1 (all subparts), *Tests on electric and optical fibre cables – Part 1: Test for a vertical flame propagation for a single insulated wire or cable*

IEC 60754-2, *Test on gases evolved during combustion of electric cables – Part 2: Determination of degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH and conductivity*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

EN 50090-2-2, *Home and Building Electronic Systems (HBES) – Part 2-2: System overview – General technical requirements*

3 Terms, definitions and abbreviations

3.1 Definitions

For the purposes of this part the terms and definitions given in ISO/IEC 14543-2-1 and the following apply.

3.1.1
HES Class 1 Twisted Pair Type 0
Twisted Pair medium Twisted Pair Type 0 (TP0) is a physical layer specification for data and power transmission on a single twisted pair, allowing asynchronous character-oriented data transfer in a half duplex bi-directional communication mode, using a specifically unbalanced/unsymmetrical base-band signal coding with collision avoidance under SELV conditions

3.1.2
HES Class 1 Twisted Pair Type 1
Twisted Pair medium Twisted Pair Type 1 (TP1) is a physical layer specification for data and power transmission on a single twisted pair, allowing asynchronous character-oriented data transfer in a half duplex bi-directional communication mode, using a specifically balanced/symmetrical base-band signal coding with collision avoidance under SELV conditions

3.1.3
distributed power supply
the bus is powered in a distributed way by a number of the devices connected to the line (compared to a centralised power supply)

3.1.4
Logical Tag Extended HEE
usage of the L_Data_Extended frame dedicated to extended group addressing

3.1.5
Remote Powered Devices
remote Powered Bus Devices (RPD) do not extract their energy for the application circuit and the bus controller from the bus but from another independent source of energy, for example, mains. Owing to the reduced DC power consumption of RPD, a bus line equipped with such devices requires less power from the installed Power Supply Unit (PSU). The connection of bus-controller and application to the same electrical potential reduces the effort of galvanic separation in RPD

3.1.6
TP0 C Factor
to simplify system engineering, the supply current of a TP0 device (both power supply and bus device) is expressed by a factor "C", defined as

$$C = \frac{\text{Actual current}}{\text{Reference device supply current}}$$

The actual current can either be the one provided by a power supply or used by a device

3.1.7
TP0 Character
11 bit set including 8 data bits, 1 check bit (odd parity bit) and two synchronization bits (start and stop bits)

3.1.8
TP0 Distortion
percentage ratio of the deviation time between the instant a transition occurs and the ideal transition instant, and the bit duration (~208 µs); the distortion is measured for each bit of a character, starting with the start bit

3.1.9
TP0 Inter-Frame Time
time between the end of a frame (end of stop bit for the last character) and the beginning of the next frame (beginning of the start bit of the first character)

3.1.10
TP0 Line Load
percentage ratio representing the proportion of actual character transmission during a specified integration time interval

3.1.11
TP0 Odd parity bit
check bit whose value is such that there is an odd number of logic “0” within the data and parity fields

3.1.12
TP0 Repeater
connects a primary segment to a secondary segment

3.1.13
TP1 Backbone Couplers
15 backbone couplers can be used to couple up to 16 zones to a full sized TP1 network

3.1.14
TP1 Backbone Line
the main line of the inner zone is called backbone line

3.1.15
TP1 Bridge
four TP1-64 physical segments can be combined to a line by using bridges; 256 devices can then be connected to such a line

3.1.16
TP1 Line
a TP1 line consists of a maximum of 256 devices, either directly connected in case of TP1-256 or separated over 4 physical segments in case of TP1-64, each with 64 devices

3.1.17
TP1 Line Couplers
routers that combine lines to a zone are called line couplers

3.1.18
TP1 Logical Unit
converts the serial bit stream to octets and octets to the serial bit stream, which is a serial stream of characters

3.1.19
TP1 Medium Access Unit
converts information signals to analogue signals and vice versa, typically extracts DC power from the medium

3.1.20
TP1 Main line
the inner line of a zone is called main line

3.1.21
TP1 Physical Segment
a physical segment is the smallest entity in the TP1 topology. To a physical segment of TP1-64 up to 64 devices can be connected. To a physical segment of TP1-256 up t 256 devices can be connected

3.1.22
TP1 Polling Master
the device transmitting the Poll_Data frame is called the TP1 Polling master or Poll_Data master

3.1.23
TP1 Polling Slave
the device transmitting a Poll_Data character is called the TP1 polling slave or Poll_Data slave

3.1.24
TP1 Router
a router acknowledges frames on data link layer and transmits the received frame on the other side of the router, provided the device associated with the destination address is located on the other side

3.1.25
TP1 Sub-line
the outer lines of a zone are called sub-lines or lines

3.1.26
TP1 Zone
16 TP1 lines can be connected to a zone by using 15 routers

3.2 Abbreviations

AC	Alternating Current
ACK	Acknowledge
APDU	Application layer Protocol Data Unit
AT	Address Type
CSMA/CA	Carrier Sense, Multiple Access with Collision Avoidance
CKS	Checksum
DA	Destination Address
DC	Direct Current
DL TP	Data Link layer Type Twisted Pair
DPS	Distributed Power Supply
CTRL	Control Field
HEE	HVAC Easy Extension
HES Class 1	refers to simple control and command.
HES Class 2	refers to Class 1 plus simple voice and stable picture transmission
HES Class 3	refers to Class 2 plus complex video transfers
IFT	Inter-Frame-Time
LC	Line Coupler
LG	Length information for APDU
LN	Length
LPDU	Link layer Protocol Data Unit
LSDU	Link layer Service Data Unit
LTE-HEE	Logical Tag Extended HEE
MAU	Medium Attachment Unit
NACK	Negative Acknowledge
NPCI	Network layer Protocol Control Information
NRZ	Non-Return-to-Zero
OCP	Over-Current Protection
PELV	Protective Extra Low Voltage
PDU	Protocol Data Unit
PSU	Power Supply Unit
RPD	Remote Powered Bus Devices
RUP	Reverse Polarity Protection
SA	Source Address
SDU	Service Data Unit
SELV	Safety Extra Low Voltage
TP	Twisted Pair
TPDU	Transport layer Protocol Data Unit
UART	Universal Asynchronous Receiver Transmitter
up	power-up

4 Conformance

A device conforming to this International Standard shall support

- either the TP0 mode specified in clause 5
- or the TP1 mode specified in clause 6.

Entities that support the TP1 mode shall support the minimum performance specified for TP1-64 in clause 6 and optionally the performance specified for TP1-256 specified in clause 6.

5 Requirements for HES Class 1, Twisted Pair Type 0 (TP0)

5.1 Datagram service

5.1.1 Transmission method

5.1.1.1 Description

The following subclauses specify the valid signals on the medium and the encoding and decoding rules and the composition of characters and datagrams.

5.1.1.2 Modulation method

The open/closed circuit switching of the line shall be used as modulation technique.

5.1.1.3 Encoding rules

The line code shall be the Non-Return-to-Zero (NRZ) code using negative logic, as shown in Figure 1.

Logic “0” shall indicate the open-circuit state of the line (or idle state).
Logic “1” shall indicate closed-circuit state of the line for the duration of a bit time.

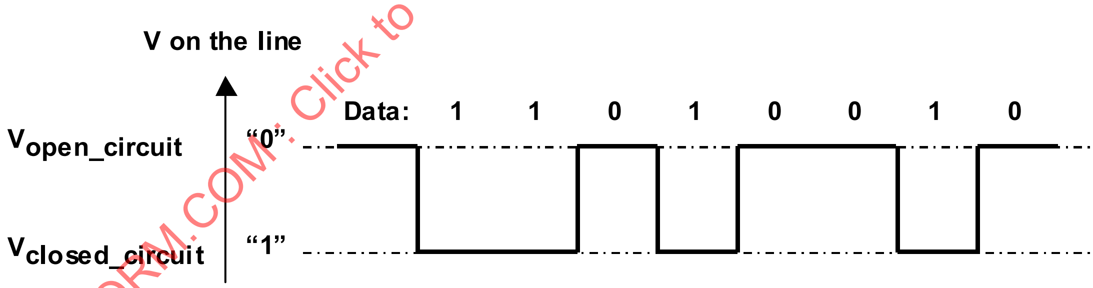


Figure 1 – NRZ line code

5.1.1.4 Bit rate

The line signal shall be transmitted at a rate of 4,8 kbit/s.

5.1.1.5 Electrical data encoding

Line open/closed-circuit modulation shall conform to the following values:

Table 1 – Electrical data encoding

	Start	Stop	Logic “0”	Logic “1”
Receiver	U < 7 V (closed)	U > 9 V (open)	U > 9 V (open)	U < 7 V (closed)
Sender	U < 1,5 V at 330 mA (closed)	I < 100 µA at 18 V (open)	I < 100 µA at 18 V (open)	U < 1,5 V at 330 mA (closed)

Fault orientation: circuits shall be designed in such a way as to avoid that a failure of any component closes the line.

5.1.1.6 Character format

A frame shall be sent as a character string in standard asynchronous format.

The character format is shown in Figure 2.

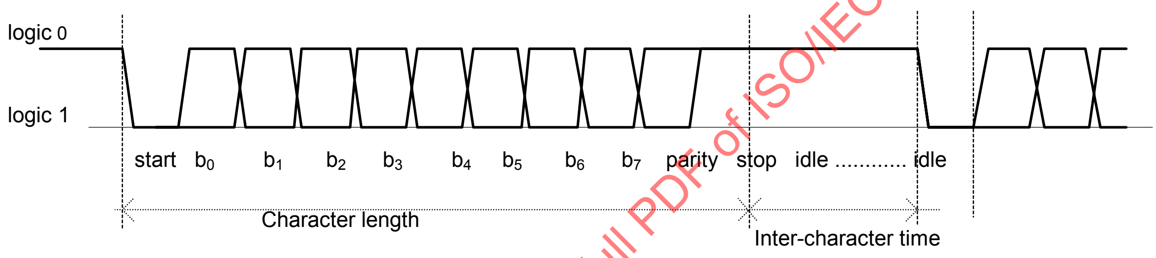


Figure 2 – Character format

Each character shall consist of one Start bit, eight Data bits b_0… b_7, one parity bit and one Stop bit. Each data octet (b_7 (= msb), b_6 to $b_{0)}$ shall be formatted as a character and shall be sent with lsb (= b_0) first.

The start bit shall be a Logic “1”.

The parity bit shall make an odd parity of the count of the Logic “0” values over the data bits and the Parity bit.

The stop bit shall be a Logic “0”.

5.1.1.7 Synchronization

The bits of a character shall be transmitted as one continuous stream. The leading edge of the start bit as defined in 5.1.1.6 shall be interpreted as the start of the character and shall be used for bit and character synchronization. The character shall end with the stop bit.

The characters in a frame (see 5.4.1) shall be sent as one stream with an inter-character time <2,3 ms.

5.1.2 Transceiver characteristics

5.1.2.1 Description

The following subclauses specify the electrical and timing requirements for senders and transmitters.

5.1.2.2 Sending part

The requirements shown in Table 2 and Figure 3 shall be met:

Table 2 – Transceiver characteristics – Sending part

Feature	Requirement
Maximum closed-circuit voltage across terminals	1,5 V at 330 mA
Maximum open-circuit leakage current	100 μA at 18 V
Maximum distortion	10 %
Rising edge	0,8 μs ≤ t_r ≤ 5 μs (see test set-up in Figure 3)
Falling edge	0,8 μs ≤ t_f ≤ 5 μs (see test set-up in Figure 3)

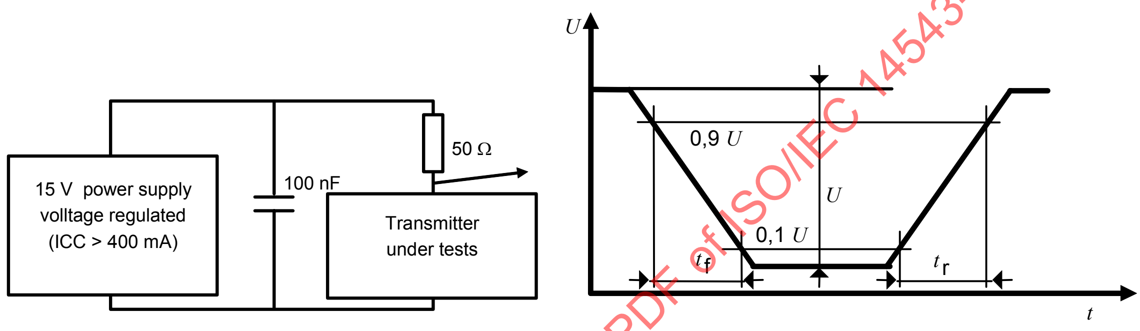


Figure 3 – Transmitter rising and falling edges

5.1.2.3 Receiving part

The requirements shown in Table 3 shall be met:

Table 3 – Transceiver characteristics – Receiving part

Feature	Requirement
Maximum input resistance	500 kΩ
Minimum current drain per device	30 μA
Threshold voltage	8 V ± 1 V
Minimum permissible distortion	30 %

5.1.3 Physical layer services – Physical data service

This Ph-Data-service shall transfer a single octet of data between co-operating peer data link layer entities. It shall consist of three primitives:

Ph-Data.Request — this primitive shall be used to transmit a single octet

Ph-Data.Confirm — this primitive shall indicate to the client layer the success or otherwise of the transmission

Ph-Data.Indication — this primitive shall convey the received octet to the receiving data link layer.

Table 4 – Mandatory and optional requirements for physical layer services

Parameter name	Request	Indication	Confirm
Ph-SDU	Mandatory	Mandatory	Not used
Ph-Result	Not used	Mandatory	Mandatory

Parameter Ph-SDU shall contain the octet to be transmitted (values 00h to FFh) or received. It is mandatory, both in the Ph-Data.Request and Ph-Data.Indicate primitives. The physical layer, on receiving the Ph-Data.Request primitive from the data link layer, shall:

- insert a start bit before the 8 data bits,
- calculate the odd parity value and insert the parity bit after the 8 data bits,
- terminate the bit string with a stop bit and
- send the 11-bit character and monitor the line for possible collision.

Upon completion of the transmission, successful or not, the Ph-Data.Confirm primitive shall carry the Ph-Result parameter to the data link layer.

When the physical layer is not transmitting a character, it shall monitor the line for a close-circuit condition. If this condition happens, the physical layer shall start with the reception of an 11-bit character. If a character is received, the start bit, stop bit and the parity bit, shall be checked and if correct shall be discarded. The character shall be delivered to the data link layer in a Ph-Data. Indication primitive and the Ph-Result parameter shall convey the correct or incorrect reception.

Service parameter Ph-Result shall convey the result of a call of the Ph-Data.Request or Ph-Data.Indication primitive to the data link layer, and shall have one of the following values:

Table 5 – Physical-Result parameter

Value	Meaning
0	Ph-Result_OK: octet was correctly transmitted or received
1	Ph-Result_Coll: octet was corrupted due to collision
2	Ph-Result_Fail: octet was not correctly sent
3	Ph-Result_NOK: received octet was corrupted

5.1.4 Physical layer protocol

5.1.4.1 General

The physical layer (layer 1) shall perform the following tasks:

- generate and check the start bit, parity bit and stop bit for each octet of the frame;
- send each bit of each octet of the frame, while comparing the signal on the line with the intended information;
- immediately stop transmissions when it detects a collision, and switch to reception;
- monitor the medium for signals, receive characters and pass them on to the data link layer.

5.1.4.2 Octet transmission and reception

Each octet passed by the data link layer to the physical layer shall be transmitted on the medium. The Ph-Data.Confirm primitive shall indicate whether the octet was successfully transmitted or whether it was corrupted. If the device is not transmitting, the Ph-Data.Indication primitive shall convey each received octet to the data link layer together with the Ph-Result indicating successful or corrupted reception of the octet.

5.2 Medium definition

5.2.1 Topology

Devices shall be connected in multidrop mode.

Bus, ring or star topologies or any combination thereof are allowed.

5.2.2 Line

The line shall be a single twisted pair cable, shielded if necessary. The line shall carry the data signals to all connected devices and provide power supply to the line-supplied devices.

The following requirements shall be met:

Table 6 – Requirements for the TP0 line

Feature	Requirement
Maximum line resistance between power supply and most remote devices	12 Ω
Maximum line capacitance	250 nF
Maximum sum of device protection capacitance	150 nF

5.2.3 Line connection

The line polarity shall be observed.

Appliances may either be hardwired to the line or may be attached to it by means of a connector.

5.2.4 Repeater

A repeater shall consist of two receivers, two transmitters and optionally one or two power supplies. Between any two TP0 devices, a maximum of two repeaters are allowed. The information flow transfer logic shall be transparent to data. A short-circuit detected on one segment shall not be transmitted on the other segment for longer than 195 ms. A segment shall be regarded as short-circuited when it is in close-circuit state for longer than 165 ms. The turning logic shall not disturb collision detection and arbitration between devices on different segments and shall not increase distortion by more than 5 %.

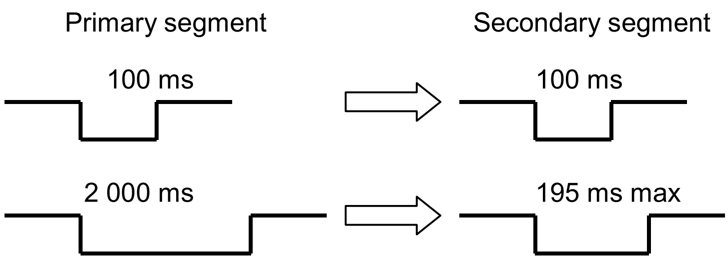


Figure 4 – Repeater maximum transition time

5.2.5 Medium installation requirements

The medium shall be supplied at Safety or Protective Extra Low Voltage (SELV or PELV); with an insulating sheath having a dielectric strength in compliance with IEC 60189-2.

5.2.6 General hardware requirements

The requirements shown in Table 7 shall be met.

Table 7 – General hardware requirements

Feature	Requirement
Maximum coupling capacitance between line and all other I/Os	100 pF
Line/earth and mains/earth isolation	Compliance to the relevant standards
Decoupling capacitors line/ground or mains/ground	Allowed but complying to the relevant standards
Dielectric strength line / 230 V mains	4 kV for 1 min at 50 Hz
Dielectric strength line/metal masses connected to protection conductor	2 kV for 1 min at 50 Hz
Insulation resistance line / 230 V mains	5 MΩ at 500 V
Minimum creepage distance line / 230 V mains	8 mm
Minimum creepage distance line/metal masses connected to protection conductor	3 mm

5.3 Power feeding service

5.3.1 General

The used modulation technique shall allow connection to the line of devices supplied with power from the line, and devices supplied by an external source (e.g., 230 V mains). The maximum line-supply current shall not exceed 150 mA.

Line-supplied devices shall ensure retention of required data during a line-closed-circuit condition of up-to-200 ms.

5.3.2 Power feeding device types

Supplying power to a device may be achieved via:

1) line (bus) power,

2) local mains,

3) local batteries or another independent power source.

All devices connected to the network are permitted to use line power provided that they meet the requirements of 5.3.3.

5.3.3 Factor C (current consumption)

As regards current consumption the following requirements shall be met:

Table 8 – Current consumption requirements

Type of device	Average (quiescent)	Peak (reception)
Devices supplied via line [a]	0,5 mA maximum	0,825 mA maximum
Devices supplied via external source [b]	100 µA maximum	165 µA maximum

[a] For devices supplied via the line, C shall be calculated for the average and peak current drain and the higher of the two values shall be rounded up to the next higher integer value.

[b] For devices not supplied via the line, a fixed C value of 0,2 shall be taken into account.

In an installation, the C factor shall never exceed 300 and the C factor of the power supply unit shall always exceed the total C factor of the installed devices.

5.3.4 Line power supply general requirements

The following requirements shall be met:

- power on/off switching shall be provided. The leakage current shall be lower than 1 mA on short circuit;
- power supply shall withstand a permanent line short-circuit condition and shall recover its characteristics within 5 min after short-circuit suppression;
- the sum of the line-supplied device capacitance values shall be lower than 40 mF, corresponding to a power-on time of 3 s maximum;
- the operation voltage for line-supplied devices shall be at least 9,5 V.

5.3.5 Power supply voltage

The requirements shown in Table 9 and Figure 5 shall be met:

Table 9 – Power supply voltage

Feature	Requirement
No-load voltage	15,5 V ± 10 % (static, I < 100 µA)
Minimum voltage under load	13,5 V at C × 0,825 mA (250 mA if C = 300), (200 ms minimum current pulse duration) 12 V at 250 mA (2 ms minimum current pulse)
Closed-circuit current	300 mA ± 10 % independently of power supply's C (200 ms minimum with 5,1 V and 1 V maximum)

The requirements as stated in Table 9 and Figure 5 shall be complied with for at least the indicated time duration T_{min}.

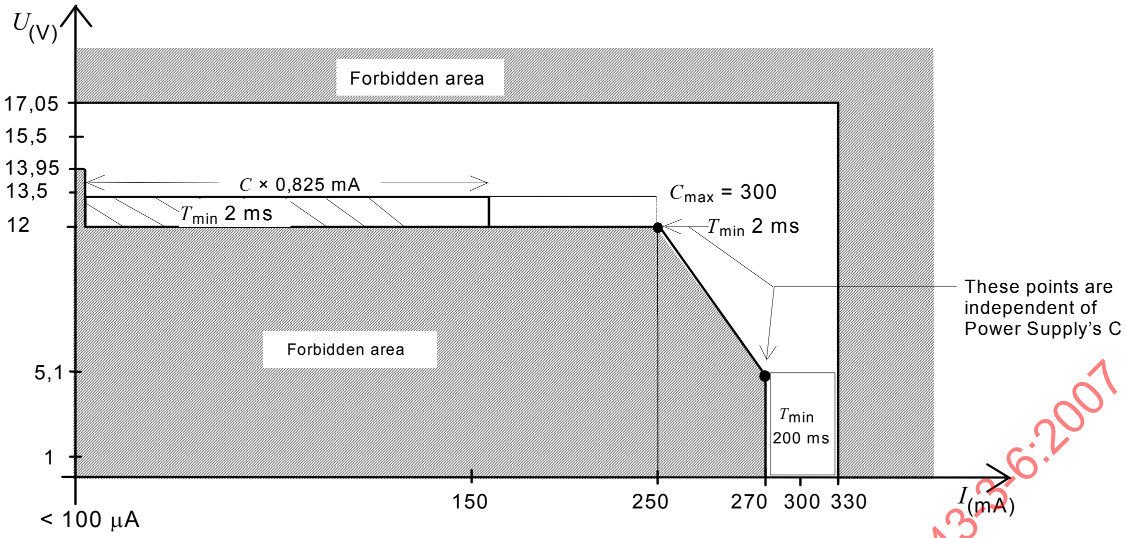


Figure 5 – TP0 power supply gauge

5.3.6 Dynamic characteristics

5.3.6.1 Dynamic internal resistance of current generator

The dynamic internal resistance of the current generator shall be maximum 1 kΩ, measured at 50 Hz, (see test set-up in Figure 6). ΔU shall be ≥10 V in the linear area of the curve.

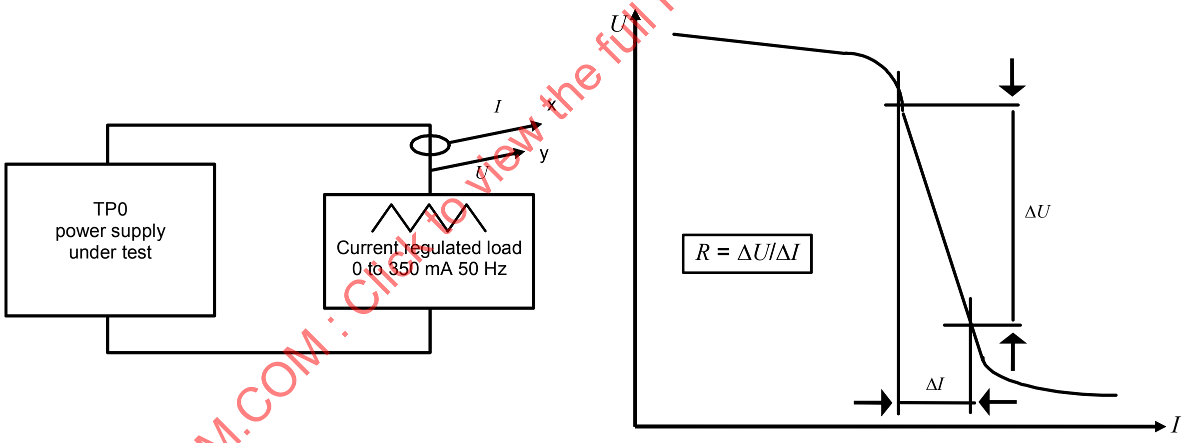


Figure 6 – Power supply dynamic internal resistor measuring test set-up

5.3.6.2 Switching from voltage to current mode

The following requirements shall be met:

- rising edge for voltage shall be minimum 0,6 µs, maximum 5 µs;
- over-current shall be maximum 30 % of current flowing from power supply during maximum 5 µs.

Measuring shall be carried out with a standard transmitter (t_r = 1,1 µs ± 20 %, t_f = 1,5 µs ± 20 % according to 5.1.2). See test set-up in Figure 7.

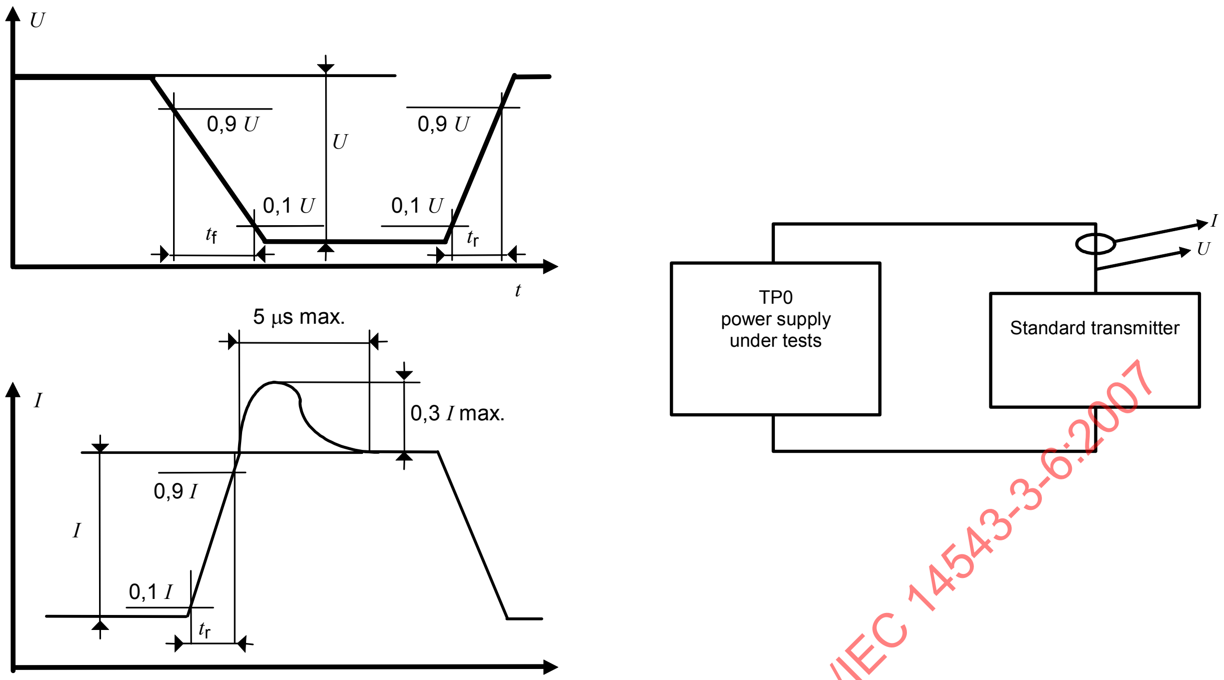


Figure 7 – Falling edge and over-current measurements

5.3.6.3 Additional requirements

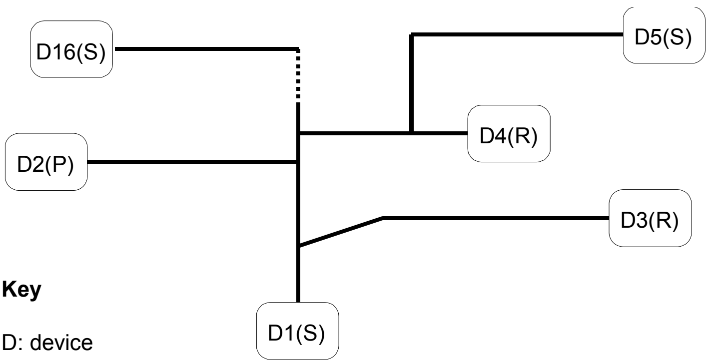
The above mentioned specifications are given for a mains powered system. A system with battery back-up may be designed so that parameters "no-load voltage", "C on one segment", "line resistance" and "line voltage drop" may be different during a power down. Their arrangement shall, however, ensure a minimum noise margin of 0,5 V in open circuit state for all points of the system (opened voltage 9,5 V minimum). The resulting installation constraints shall be clearly explained in the product documentation.

Peak supply current measurements shall be carried out at least 800 ms after the beginning of transmission of frames to the device under test. These frames shall contain the same number of “0” and “1” separated by a 22 ms inter frame time.

Installation rules require that for PELV circuits the negative pole of the power supply shall be grounded. The connection from the line to the ground shall be made at one point (and only one point) of the TP0 power supply. If one line is composed of more than one segment without isolation between segments, only one point shall be grounded.

5.3.7 Distributed power supply (DPS)

5.3.7.1 Overview



Key

D: device

(S): device with DPS

(R): device remotely powered from the bus

(P): passive device (neither DSP nor powered from the bus)

Figure 8 – TP0 Network with distributed power supply

The use of the Distributed Power Supply (DPS) on a TP0 network may be used in the following cases:

- small networks with less than 16 devices connected to the bus (regardless of their type - S, R or P - see Figure 8);
- devices separated by short cable distances (250 m to 1 400 m depending on the number of devices with activated DPS);
- when only a few devices have to be powered from the bus. The available average supply current is limited to 10 to 60 mA depending on the number of devices with DPS.

Automatic Over-Current Protection (OCP) function shall be implemented in devices with DPS feature. The number of devices with activated DPS shall be limited to a maximum of 8. If more devices with DPS capability are connected to the network, the OCP function shall automatically disable DPS in some devices in order to limit the resulting signal current (closed circuit) to a maximum value of 176 mA. Devices with disabled DPS shall behave like passive P devices (see Figure 8).

Devices with DPS feature shall allow manual disabling of the DPS function (for instance by means of a jumper or configuration of a parameter).

5.3.7.2 Requirements for one supplying DPS device

The requirements as shown in Table 10 and Figure 9 shall be met:

Table 10 – Requirements for one supplying DPS device

Feature	Requirement
Bus voltage, no load	Typical 15,5 V - range 14 V to 17 V
Bus voltage at 16,6 mA 'peak' supply current	Typical 14,7 V - range 13,5 V to 17 V
Signal current ('closed circuit')	22 mA ± 15 % (⇒ I_{min} = 18,7, I_{max} = 25,3 mA) at bus voltage < 6 V
Available supply current: (for bus-supplied devices)	10 mA average [a] - maximum 16,6 mA ('peak') [a]
Capacitance load for simulation	Cable 25 nF + input capacitance of two other devices (< 3 nF)
Dynamic characteristics (transient voltage/current)	According to centralised TP0 bus power supply
[a] 10 mA average supply current are normally sufficient to power 1-2 simple sensor devices.	

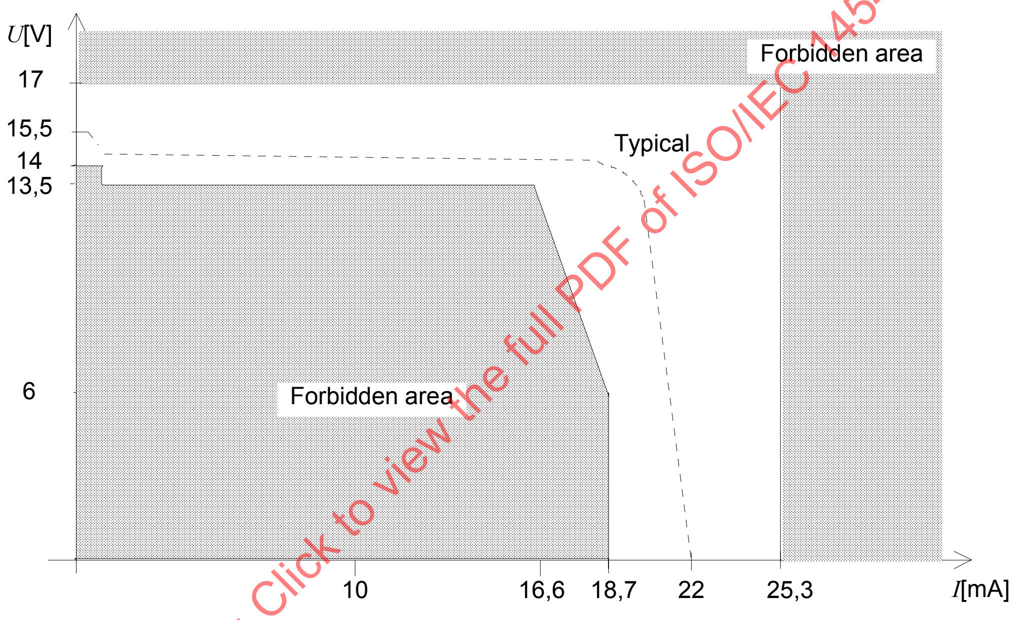


Figure 9 – Voltage/Current gauge of one node

5.3.7.3 Over-current protection (OCP)

In a DPS network, the maximum resulting signal-current shall be limited to a value considerably lower than the current of a centralised TP0 bus power supply (300 mA), in order to avoid damage if a centralised bus power supply is connected to a system using DPS.

NOTE During transient time the sum of both power supplies apply.

Automatic over-current detection shall switch off DPS nodes if the resulting signal-current is too high.

NOTE Since over-current is only detected during local transmission, the maximum transition time is variable. This time depends on the number of devices producing the over-current and when they initiate their first transmission. Typically, over-current may only appear after power-up (together with centralised supply) or after removal of a bus short-circuit.

Signal current measuring and automatic enabling/disabling of local bus power supply shall be implemented in each device with DPS feature. The following shall be taken into account:

a) if bus power is up, local bus power supply shall be off;

b) if the measured signal current is less than the lower threshold, the local bus power supply shall be switched on;

c) if signal current is higher than upper threshold, the local bus power supply shall be switched off;

d) in a neutral zone of 28 mA (above lower threshold) the state of the bus power supply shall not change;

e) the accuracy of signal current measurement shall be 10 mA;

f) the OCP characteristics (signal current, closed circuit) shall be as follows:

   1) lower threshold: 138 mA ± 10 mA;

   2) upper threshold: 166 mA ± 10 mA.

The signal current measurement shall be carried out during local transmission only. The signal current shall be measured in the middle of a start bit.

NOTE Signal reflections produce transient signal current during the first half of a start bit.

Owing to possibilities of sending collisions, the signal current may be split between several transmitters in the first octets of the frame. Therefore signal current measurement shall only be enabled in the transmission octets 4 … 7 and the average value of these 4 signal current samples shall then be calculated for the OCP function.

In view of the fact that the automatic over-current protection may not be 100 % reliable in every case (for instance after removal of a bus short-circuit after start-up), in larger networks with more than 16 devices a centralised TP0 power supply should be used. Distributed supply on the devices shall then be switched off manually by the installer (for instance by means of a jumper or configuration-parameter).

In a system with more than 6 devices with enabled DPS feature, the selection of the devices with activated DPS may change as a result of accuracy of current measurement and thermal changes of electrical characteristics. Therefore, the supplying devices may ”drift“.

5.3.7.4 Requirements for entire DPS

A system consisting of up to 16 devices may be operated without a central bus power supply.

The following requirements shall be met:

Table 11 – Requirements for entire DPS

Feature	Requirement
Maximum number of supplying devices (OCP limitation of signal current)	Nominal 7 - (actual 6 to 8, owing to accuracy of current measurement)
Minimum available total supply current for bus-supplied devices	60 mA average (6 × 10 mA, see Table 10) – 100 mA 'peak'
Total resulting signal current (consideration of accuracy of current measurement)	128 mA … 176 mA (see OCP: 138 mA – 10 mA / 166 mA + 10 mA)
Cable	See Table 12
Capacitance load for simulation	Total cable maximum 140 nF + input capacitance of maximum 16 devices (< 25 nF)
Sum of bus supplied station for capacitance	Maximum 15 mF at 60 mA available average current for bus-supplied devices
Power-up time	3 s
Polarity	Shall be respected for all devices with DPS [a]

[a] If, in the system, one or several devices have been connected to the bus with their wrong polarity, the resulting bus voltage will be in the range from -17 V to ±17 V .

In that case, the bus voltage is the result of an unstable equilibrium and also dependent on the ambient conditions (e.g., the temperature). Often, however, the bus voltage "tips" in the vicinity of +15,5 V or -15,5 V. It is also possible, however, that the bus power supplies counterbalance one another so that the bus voltage is in the vicinity of 0 V. Owing to external effects, such as self-heating of the devices, the unstable equilibrium and thus the bus voltage may vary considerably. This behaviour makes fault tracing more difficult.

Each time a bus connection with incorrect polarity has been rectified, the newly resulting bus voltage shall be measured. In the case of bus power supply with incorrect polarity, a permanent bus current can be recorded (even in the idle state).

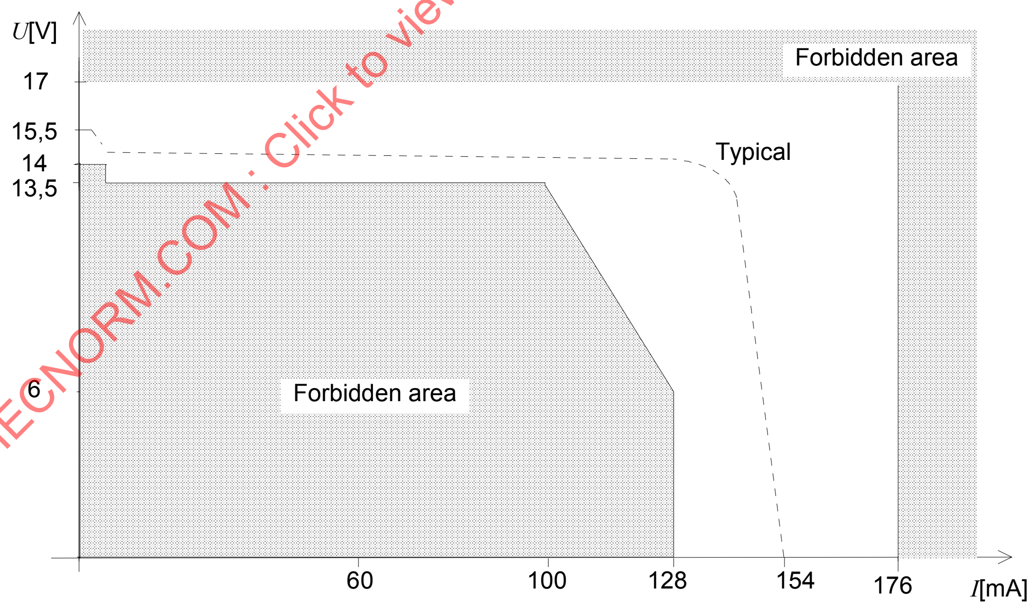


Figure 10 – Voltage/Current gauge of entire distributed power supply with 6 to 8 supply nodes

Table 12 – Possible cable lengths depending on number of DPS devices connected (for a typical cable)

Limitation R (cable resistance)	Specified cross-sectional area of cable	1,5 mm^2
	Maximum cable length between the remotest devices	250 m per device with DPS feature connected to the bus But 1 000 m maximum
Limitation C (cable capacitance)	Maximum total cable capacitance (sum of all branches)	25 nF per device with DPS feature connected to the bus But 140 nF maximum
	Total cable length (sum of all branches) at 100 pF/m cable capacitance [a]	250 m per device with DPS feature connected to the bus But 1 400 m maximum

[a] Greater cable capacitance requires a proportional reduction of the permissible total cable length, L' in meters

$$L' = \frac{L \times 100\ \text{pF/m}}{\text{effective capacitance per unit}}$$

EXAMPLE 1

- TP0 system with three connected devices with enabled DPS feature;
- cable capacitance 100 pF/m;
- maximum cable length between the remotest devices: 3 × 250 m (limitation R) - Total cable length: 3 × 250 m (limitation C).

EXAMPLE 2

- TP0 system with six connected devices with enabled DPS feature;
- cable capacitance 125 pF/m;
- maximum cable length between the remotest devices: 1 000 m (limitation R);
- total cable length: 1 120 m instead of 1 400 m owing to higher cable capacitance (limitation C).

5.3.7.5 Start-up conditions

When, after a power failure, the mains voltage is restored, it will take a certain period of time until communication on the bus can be resumed in view of the fact that the DPS has to be established first.

During start-up (power-up) of the network, the bus is not powered (no or low bus voltage). Depending on an implemented address-related „random“-delay time, one device shall take initiative to turn on the first supply. Other devices will add their supply (also depending on their implemented address-related delay) until the bus voltage is sufficient and provided the upper signal-current threshold is not reached (OCP):

After power-up each DPS capable device shall spontaneously send frames, according to the following requirement:

Address-related delay time for first frame: t = 5 s + DeviceAddress × 100 ms (Device address: 0 to 255).

As the power-up time for a centralised bus power supply is fixed to maximum 3 s, it may be assumed that if 5 s after system power-up the bus is still not powered, no centralised power supply is connected to the bus and DPS may therefore be established.

After switching on the network, it will therefore take 5 s to 30 s until the distributed bus power supply is built up.

5.4 Data link layer type Twisted Pair Type 0

5.4.1 Frame formats

5.4.1.1 General

The frame shall consist of a sequence of characters.

A receiving device shall consider a frame as ended when the expected number of characters has been received.

An inter-character time interval of less than 2,3 ms shall not be considered as an "end-of-frame" condition.

An inter-character time interval exceeding 2,3 ms may be considered as an "end-of-frame" condition.

An inter-character time interval exceeding 6 ms shall be considered as an "end-of-frame" condition.

Two frame formats may be implemented:

- a variable length frame format conveying L_Data (L_Data frame) and
- an Acknowledgement frame format (ACK frame). ACK frames are identified by their reduced length (1 octet).

Two L_Data Frame formats may be implemented:

- a standard frame format (L_Data_Standard frame), and
- an extended frame format (L_Data_Extended frame).

The usage of the different L_Data formats depends on the value of the frame format parameter to the link layer. The standard frame format shall be used if the frame format parameter is 0, otherwise the extended frame format shall be used.

L_Data_Standard and L_Data_Extended frame formats shall both start with two control fields CTRL & CTRLE. The two L_Data formats are differentiated in CTRLE field.

Octet 0	Octet 1	Octets 2 to n + 2	Octets n + 7 & n + 8
CTRL	CTRLE	L_Data_Standard or L_Data_Extended subsequent frame fields	CKS

Figure 11 – Common part of frame structure

Other frame formats than L_Data or ACK frames shall be ignored.

NOTE This way future extensions are possible.

The character corresponding to octet 0 shall be sent first, the octet with the highest number shall be the last sent character. The individual bits of an octet shall be sent in ascending order, i.e., the lowest significant bit (bit 0) shall be sent first.

5.4.1.2 Control field (CTRL)

The control field shall contain information about the layer 2 service, that is, its priority, identification of group or individual addresses (Address Type AT) and a flag indicating if an acknowledge is requested, see Figure 12. It shall also transport layer 3 control information (NPCI: hop count).

Control field

b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	
hop count	hop count	hop count	priority	priority	g/i	ack		
x	x	x	pr_1	pr_0	x	x	1	L_Data-frame

pr_1	pr_0	
0	0	system priority
1	0	urgent priority
0	1	normal priority
1	1	low priority

g/i: group/individual flag = Address Type (AT)
g/i = 0 : individual address
g/i = 1 : group address

ack: ack_request flag
ack = 0 : no ack requested
ack = 1 : ack requested

Figure 12 – Control field

The control field shall indicate the type of the request frame: L_Data or Acknowledgement frame. The two priority-bits of the control field shall control the priority of the frame, if two or more devices start transmission simultaneously. It shall also enable routers to reuse the same priority when retransmitting the frame.

5.4.1.3 Extended control field (CTRLE)

The extended control field is an octet which shall contain the following bits.

- b_7 = 1. This bit shall always be set to 1. It allows the separation of the present protocol from certain other protocols, for which the value 0 is already specified.
- b_6, b_5 = 0, 0. These bits identify the L_Data_Standard and L_Data_Extended frames. Other combinations are reserved for future use.
- b_4: FT (Frame Type) standard/extended;
  1 = L_Data_Standard frame; 0= L_Data_Extended frame.
- b_3, b_2, b_1, b_0: These bits shall be used for two different fields.
  – In case of an L_Data_Standard frame, these bits compose the LG field, which shall be the APDU length information.
  – In case of an EFF L_Data_Extended, these bits compose the EFF field and shall contain the Extended Frame Format parameter as defined in ISO/IEC 14543-3-2.

b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
1	0	0	FT				
1	0	0	1	LG			
1	0	0	0	EFF			

Figure 13 – CTRLE field

5.4.1.4 L_Data_Standard frame

5.4.1.4.1 General

The structure of the variable length frame shall comply with Figure 14.

Octet 0	Octet 1	Octets 2&3	Octets 4&5	Octets 6 to n + 6	Octets n + 7 & n + 8
CTRL	CTRLE (LG)	DA	SA	L_Data = TPDU	CKS

Figure 14 – Format1s, L_Data_Standard frame format with standard field-name abbreviations

NPCI information shall be distributed in the Control Field (CTRL) and LG fields for transportation on TP0.

5.4.1.4.2 Length (LG)

Length information LG for L_Data_Standard frame shall be encoded in the composite CTRLE field. (Please refer to 5.4.1.3.)

LG field shall indicate the APDU-length coded as defined in ISO/IEC 14543-3-2. L_Data_Standard frames shall transport APDU from 0 to 15 octets (short frames only). This leads to a maximum L_Data_Standard frame length of 24 characters.

NOTE APDU-length is the number of characters (n = 0 to 15) of the APDU transported by the L_Data request frame starting with the octet 7 to octet (n-1)+7.

5.4.1.4.3 Destination address (DA) and address type (AT)

The destination address shall define the device(s) that shall receive the frame. For L_Data_Standard request frames, the destination address may be either an individual address (CTRL.g/i=0) or a group address (CTRL.g/i=1), depending on the Address Type AT in the group Address flag (g/i) of octet 0.

5.4.1.4.4 Source address (SA)

The source address shall be the individual address of the device that requested the transmission of the frame.

5.4.1.4.5 L-DATA transport layer protocol data unit (TPDU)

This field shall contain the transported data octets and correspond to TPDU.

5.4.1.4.6 Checksum (CKS)

The last two octets of a request frame shall consist of a frame check sequence based on a checksum calculation. (See 5.4.3.3).

5.4.1.5 L_Data_Extended frame

5.4.1.5.1 General

The extended frame format shall be used for:

- messages with APDU > 15 octets (long messages) which do not fit into L_Data_Standard frame because of its limited length, or
- messages with extended addressing capabilities.

L_Data_Extended frame shall not be used instead of L_Data_Standard frame if encoding capabilities of L_Data_Standard frame are sufficient (e.g., for short frames).

The structure of the variable length extended frame shall comply with.

Octet 0	Octet 1	Octets 2&3	Octets 4&5	Octet 6	Octets 7 to $n + 7$	Octets $n + 8$ & $n + 9$
CTRL	CTRLE	DA	SA	LG	L_Data = TPDU	CKS

Figure 15 – Format 1e, L_Data_Extended frame format with standard fieldname abbreviations

5.4.1.5.2 Extended frame format

The field EFF in the extended control field CTRLE of the L_Data_Extended frame shall be encoded as specified in Figure 16.

EFF				
b_3	b_2	b_1	b_0	Usage
0	0	0	0	Standard messages enabling long APDU > 15 octets Standard usage of DA for peer to peer or group messages
0 0 0	0 0 0	0 1 1	1 0 1	Reserved
0	1	X	X	LTE-HEE extended frame format b_1, b_0 containing extension of DA Group Address
1 1 1 1 1 1 1	0 0 0 0 1 1 1	0 0 1 1 0 0 1	0 1 0 1 0 1 0	Reserved
1	1	1	1	Escape

Figure 16 – EFF field

EFF(b_3, b_2, b_1, b_0) in Extended Frame Format is defined in ISO/IEC 14543-3-2.

5.4.1.5.3 Length (LG)

The L_Data_Extended frame format has a variable length; the maximum length shall be 74 characters. This shall enable to transport an APDU of up to 64 octets.

The field LG shall indicate the APDU-length coded as defined in ISO/IEC 14543-3-2.

NOTE APDU-length is the number of characters (1 to 64) of the APDU transported by the L_Data_Extended frame starting with octet 8 to octet (n-1)+8.

The encodable range of the LG field (0 … 255) is larger than the allowed usable range of 0 … 64. The limitation of the APDU to 64 octets is a consequence of limitations of the physical layer (power feeding, line overload prevention, acceptable response time for all devices).

5.4.1.5.4 Destination address (DA) and address type (AT)

For L_Data_Extended frames, the destination address may be either an individual address (CTRL.g/i=0) or a Group Address (CTRL.g/i=1), depending on the address type AT in the group address flag (g/i) of octet 0.

In the L_Data_Extended frame the type of the destination address depends next to the address type also on the extended frame format parameter EFF of the extended control field CTRLE. With EFF = 0000 the same address type shall be used as in L_Data_Standard format. With EFF ≠ 0000 dedicated address formats and tables shall be used.

In case of group addressing in LTE-HEE messages the destination address field is extended by two bits (b_1, b_0) of EFF in the CTRLE field as defined in ISO/IEC 14543-3-2.

5.4.1.5.5 Source address (SA)

This is the same as in the L_Data_Standard frame (see 5.4.1.4.4).

5.4.1.5.6 L-DATA (TPDU)

This is the same as in the L_Data_Standard frame (see 5.4.1.4.5).

5.4.1.5.7 Checksum (CKS)

This is the same as in the L_Data_Standard frame (see 5.4.1.4.6).

5.4.1.6 Acknowledgement frame

The short acknowledgement frame format shall consist of one single character, which shall be used to acknowledge an L_Data.request frame.

Two types of acknowledgement may be implemented, as specified in Figure 17.

ACK: this acknowledgement frame shall be used for positive acknowledgement on reception of individual frame requesting an ACK and shall have the value 00h;

FULL: this acknowledgement frame may be used for negative acknowledgement on reception of individual frame requesting an ACK if reception buffer is full and shall have the value 02h.

Octet 0								
Short ACK								
b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	
0	0	0	0	0	0	0	0	**ACK**
0	0	0	0	0	0	1	0	**FULL**

Figure 17 – Format 2, Short acknowledgement frame format

5.4.2 Medium access control

5.4.2.1 General

This subclause lays down requirements for TP0 medium monitoring and collision detection.

The method used for medium access shall be Carrier Sense, Multiple Access with Collision Avoidance (CSMA/CA). This shall operate as follows.

If no activity is detected on the medium during a preceding period Inter-Frame-Time (IFT), transmission may start immediately.

The IFT may have different values, depending on the priority level used (see 5.4.2.4).

If any activity is detected on the medium, the transmitter shall wait until transmission of the current frame is finished before starting its own transmission. The transmitter shall measure a time IFT from the end of the last stop bit of the Checksum field of the current message and then start transmission of the first octet of its frame.

In both cases, the transmitter shall verify that the line is effectively free before transmitting (see 5.4.2.2).

5.4.2.2 Free line detection

The line shall be considered free if no line close-circuit condition is detected during at least 2,3 consecutive milliseconds. The time required for this test shall be added to the IFT.

5.4.2.3 Collision detection and arbitration

A collision may occur when two or more devices start transmission simultaneously after detecting a free line condition.

If a collision occurs, the logic “1” state (closed circuit) shall take precedence over a logic “0” (open circuit).

During the transmission of a logic “0”, the device shall observe the line in an attempt to detect whether any other device is transmitting a logic “1”.

This process shall be performed over the complete frame transaction.

A device shall consider that a collision has occurred and terminate the transmission if the line switches to close-circuit condition between the moment it detects a free line and the moment it actually starts transmission.

When a transmitting device observes a difference between the transmitted “0” and the received bit, a collision, the device shall stop transmitting immediately and change over to the receiving state. The device shall then retain the frame and wait for the line to become free before accessing the medium again.

In order to avoid telegram losses, any device (including the device that halts transmission after collision) shall receive frames without corruption. In order to achieve this, devices shall store any data received while transmitting.

When a collision is detected, the transmitter shall terminate the transmission of its frame after the first bit in collision. It shall free the line after a collision in less than 180 µs.

After a collision, the device may try again to transmit. This new attempt shall start at least 1 inter-frame time after the end of the preceding frame. The number of attempts is unlimited.

During transitions, the system time constants may cause an apparent fault condition that shall not be considered as a collision. The collision detection window shall start minimum 20 µs after open/close transition.

5.4.2.4 Priority handling – Priority of frames

Different priority levels may be supported with different access time:

Table 13 – Priority of frames – IFT

Coding	Name	Recommended use	IFT
11	low	Burst traffic	>25 ms
01	normal	Default	>22 ms
10	urgent	Urgent frames	∈]20 ms … 22 ms[
00	system	Reserved for high priority, system configuration and management procedures	[a]

[a] System priority is not supported by TP0. If system priority is set by upper layers, the frame shall be sent on the bus using one of the defined inter-frame time. Selection of this time may be manufacturer specific. The system priority encoding transported in the frame (pr) shall be kept if there are routers to other media.

5.4.3 L_Data service and protocol

5.4.3.1 General

See ISO/IEC 14543-3-2 for the description of the service interface.

TP0 data link layer shall also support line overload prevention. The following subclauses specify these processes.

5.4.3.2 Protection against transmission errors

Transmission integrity shall be ensured by an odd parity bit per character together with a 12-bit checksum calculated for the entire frame and transmitted as two characters.

TP0 devices may implement acknowledgement mechanisms to indicate success or failure of the transmission to the sender. Retransmission mechanisms may be implemented to remedy transmission errors.

5.4.3.3 Checksum calculation

The checksum shall be calculated in the following way.

a) Complement all data octets.

b) Calculate the 16 bit sum of these complements.

c) Complement this sum.

d) Set the 4 most significant bits to 0.

5.4.3.4 Frame acceptance criteria

A frame shall be considered valid when the number of characters received without any parity error is consistent with the content of the "frame length" field, and the checksum calculated for the received frame is equal to the contents of the "checksum" field.

Any invalid frame shall be ignored.

In addition, any reserved fields shall have the awaited value.

Frames too long for the reception capabilities of the device shall be ignored.

5.4.3.5 Address check

The frame shall be intended for the receiving device if the destination address (individual or group address according to the value set in the CTRL is recognised.

5.4.3.6 Acknowledgement sending, frame re-transmission

The receiver of a data frame shall only transmit an acknowledgement if

a) the received frame is considered valid according to the data link layer specifications (refer to 5.4.3.4),

b) the value of the acknowledge request flag is “1”.

Acknowledgement may be requested both for individual and group addressed frames.

However, only 1 device shall be entitled to send an acknowledge for a given address.

This shall be ensured at least at configuration time (see ISO/IEC 14543-3-4).

By default, devices shall not request acknowledge on group addressed frames.

By default, devices shall not acknowledge group addressed frames.

The acknowledgement transmission shall start in a time gap, elapsing from 18 ms to 19,8 ms after the end of the last stop bit of the received frame.

ACK transmission shall respect medium access rules (with reduced IFT value). However, in case of unexpected line occupation or collision, the ACK transmission shall be aborted. ACK transmission shall not be delayed due to line overload prevention mechanism (see 5.4.3.9).

5.4.3.7 Acknowledgement wait time, frame re-transmission

The sender of a frame requesting an acknowledgement shall not initiate any new transmission until the acknowledgement is received or transmission is aborted.

Pending completion of the transmission, outgoing data frames shall be queued in the order they are received from the application; received data frames shall be processed and any necessary acknowledgements shall be transmitted.

If, after a predetermined time delay, the sender has not received the expected acknowledgement, it shall retransmit the data frame. This condition shall be respected for each re-transmission, regardless of its rank.

After a predetermined number of retries, the destination shall be declared inoperative: transmission will be declared failed and data link layer shall indicate failure to the layer above.

Therefore the following requirements shall be met:

Table 14 – Requirements for acknowledgement wait time, frame re-transmission

Feature	Requirement
Ack wait time before deciding retry:	20 ms
Retry time delay after previous transmission:	Immediate, using same priority as for initial transmission.
Number of retries:	2 [a]
[a] i.e. 3 attempts in all.	

The Data Link protocol does not have to foresee mechanisms to prevent data frame duplication as a result of certain error conditions (e.g., loss of acknowledgement). The application software shall be capable of handling possible duplications.

Delayed retries may also be sent after the reception of a FULL acknowledge.

If implemented, the following requirements shall be met:

Table 15 – Requirements for full wait time, frame re-transmission

Feature	Requirement
Retry on "FULL" time delay:	>300 ms
Number of retries on "FULL":	2^5

5.4.3.8 Assemble/Disassemble frame

Before transmitting a frame on the line, the data link layer shall assemble service parameters into a Link layer Protocol Data Unit (LPDU).

It shall ensure the following mapping.

- The Frame Type shall be calculated from the Frame Format parameter as defined in ISO/IEC 14543-3-2 and put into FT flag in CTRLE field.
- For extended frame format the EFF field shall be taken from the Frame Format parameter as defined in ISO/IEC 14543-3-2 and put into EFF field in CTRLE.
- The length information shall be calculated from Octet_Count parameter and put into LG field (either in octet 1 or in octet 6 depending on FT).
- The Address Type AT shall be put into CTRL field (Group Address flag g/i).
- The network layer information shall be put into CTRL field.

When receiving a Protocol Data Unit (PDU), the data link layer shall carry out the reverse operation.

- It shall disassemble the frame into parameters to be transmitted in a L_Data.ind.
- It shall regenerate the NPCI field of the Link layer Data Unit (LSDU) from the value of the LN and CTRL fields.
- It shall generate the Octet_Count parameter from the value of the LN and CTRL fields.

5.4.3.9 Line overload prevention

In order to ensure proper power supply of line-supplied devices, the line shall not be in close circuit condition more than 25 % of the time during any transmission.

Duration of a transmission includes the time from the last bit of the last frame to the last bit of the frame sent (last bit of checksum) or if requested the last bit of the ACK.

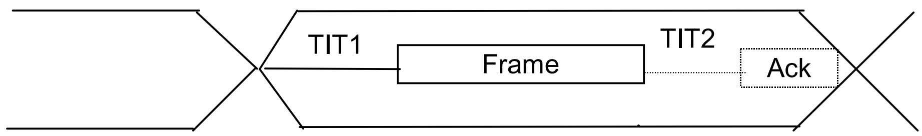


Figure 18 – Transmission definition

5.4.4 L_Busmon service

See ISO/IEC 14543-3-2.

5.4.5 L_Service_Information service

Please refer to the corresponding clause in ISO/IEC 14543-3-2.

5.5 Full Twisted Pair Type 0 frame structure

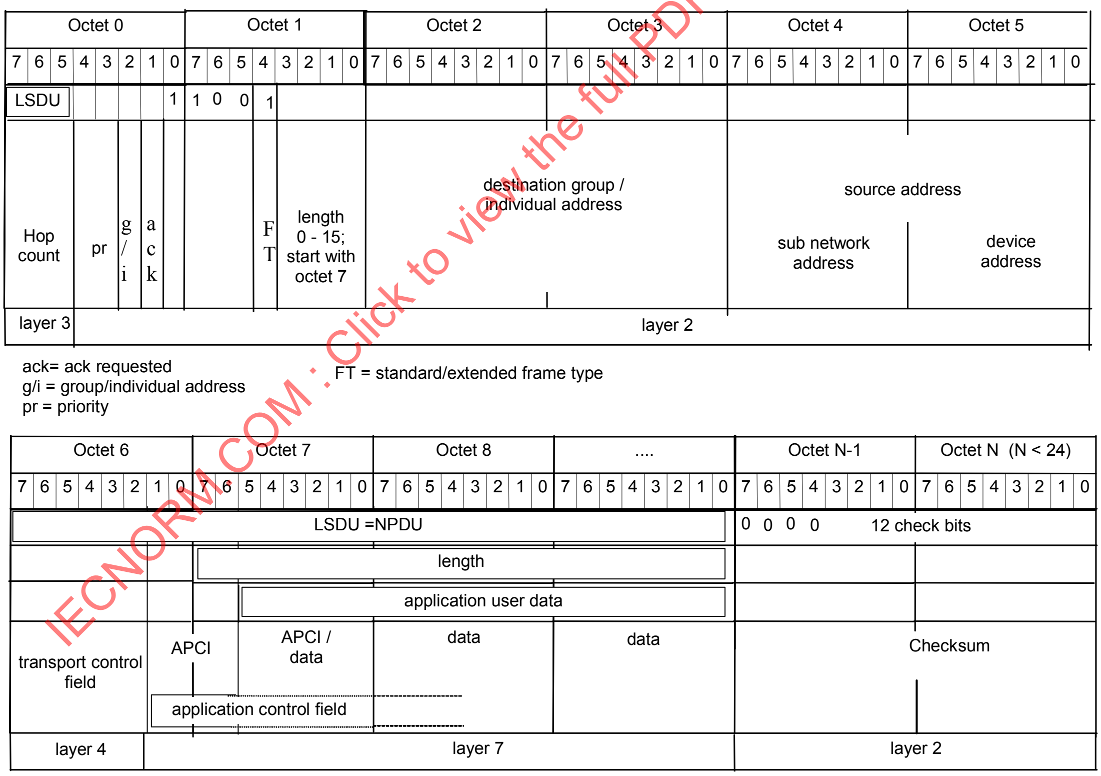


Figure 19 – Format 1s, Full L_Data_Standard request frame format

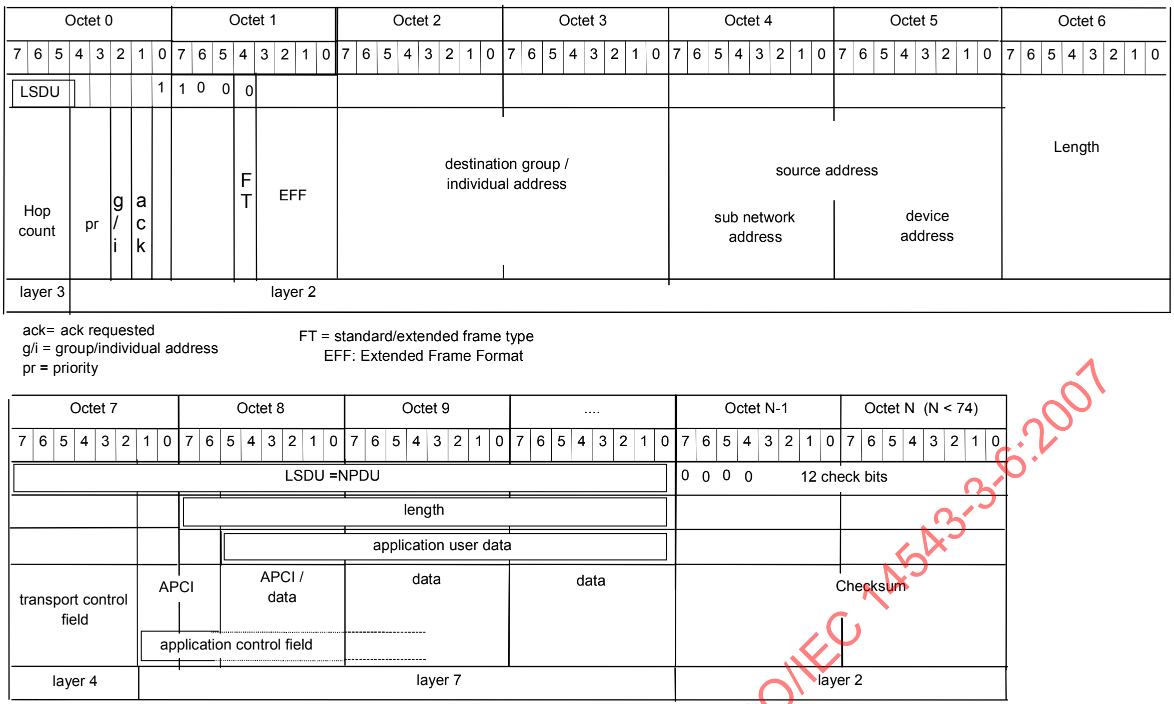


Figure 20 – Format 1e, Full L_Data_Extended request frame format

6 Requirements for HES Class 1, Twisted Pair Type 1 (TP1-64 & TP1-256)

6.1 Physical layer requirements – Overview

The Physical Layers described in this clause are called Physical Layer type twisted pair TP1-64 and twisted pair TP1-256. The main differences are shown in Table 16. TP1-256 is backwards compatible towards TP1-64. If common features of TP1-64 and TP1-256 are described, only the expression TP1 is used.

The Twisted Pair medium TP1 characteristics are:

data and power transmission with one pair of wires;

asynchronous character-oriented data transfer;

half duplex bi-directional communication;

a specifically balanced/symmetric base-band signal coding under SELV conditions.

All characteristics given in the following subclauses, for instance maximum number of devices or possible cable length per physical segment are only valid for cables complying with the requirements as shown in 6.4 and for TP1 devices whose bus power consumption does not exceed 12 mA).

NOTE A fan-in model that allows devices with higher bus power consumption is under consideration.

Table 16 – System parameters of physical layer Type TP1-64 and TP1-256

Characteristics	Description TP1-64	Description TP1-256
Medium	Shielded twisted pair [a]	
Topology	Linear, star, tree or mixed	
Baud rate	9 600 bps	
Device supplying	Normal: bus powered devices - optional: remote powered devices	
Device power consumption	3 mA to 12 mA	
Power Supply Unit (PSU)	DC 30 V	
Number of PSUs per physical segment	Maximum 2	
Number of connectable devices per physical segment	Maximum 64	Maximum 256
Number of addressable devices per physical segment	Maximum 255 [b]	Maximum 255
Total cable length per physical segment	Maximum 1 000 m	
Distance between two devices	Maximum 700 m	
Total number of devices in a network	More than 65 000 (with bridges)	More than 65 000
Protection against shock	SELV (Safety Extra Low Voltage)	
Physical signal	Balanced/symmetric baseband signal encoding	

[a] The shield is not mandatory, shielded cables with earth connection can improve noise immunity.

[b] In TP1-64 a physical segment can be extended with up to 3 extra physical segments, each connected to it via a bridge. Every physical segment can contain 63 devices.

Figure 21 shows the logical structure of the physical layer type TP1 entity. Every device includes one; every router and bridge is equipped with two such physical layer type TP1 entities.

The physical layer type TP1 entity consists of four blocks:

- cable (medium);
- connector, connecting a device or a bridge to the transmission medium;
- a Medium Attachment Unit (MAU);
- logical unit.

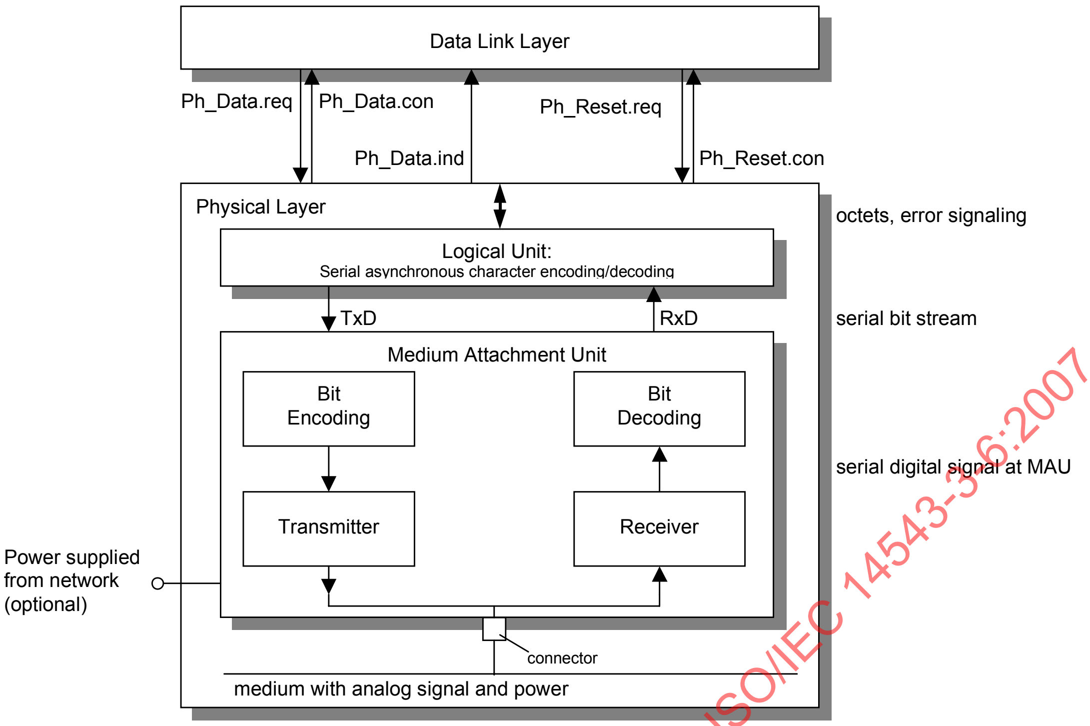


Figure 21 – Logical structure of physical layer type TP1

Figure 22 shows the relationship between the bits of an octet and the Universal Asynchronous Receiver Transmitter (UART) character data bits.

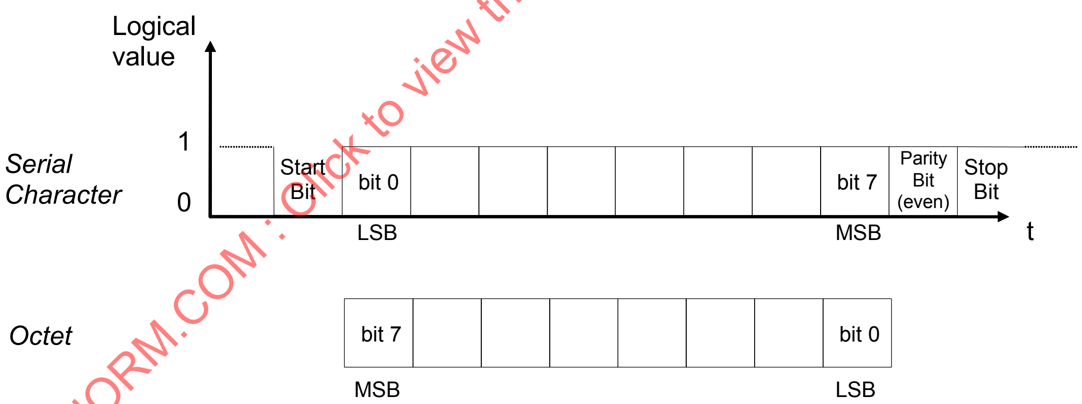


Figure 22 – Octet mapped to a serial character

6.2 Requirements for analogue bus signals

6.2.1 General

In the underneath description, UREF is an internal reference voltage for the DC part of the bus voltage, used by the transmitter/receiver for evaluating the sent/received signal levels. This reference voltage is sampled before the start bit of a byte. This UREF may vary with the values given in 6.2.5.

The underneath specifications classify a 0 and 1 signal on the bus: the requirements for signal generation and extraction for the transmitter and receiver respectively are defined in 6.3.2.6 and 6.3.2.7.

6.2.2 Specification of logical "1"

A logical "1" shall be regarded as the idle state of the bus, that means that the transmitter of a MAU shall be disabled during sending a "1". The analogue signal at the bus consists normally only of the DC-Part. There is no difference between sending a "1" and sending nothing. A decline of voltage during a "1" may occur, if a '0 bit' was preceding. The graph shall be within the shaded areas of Figure 23.

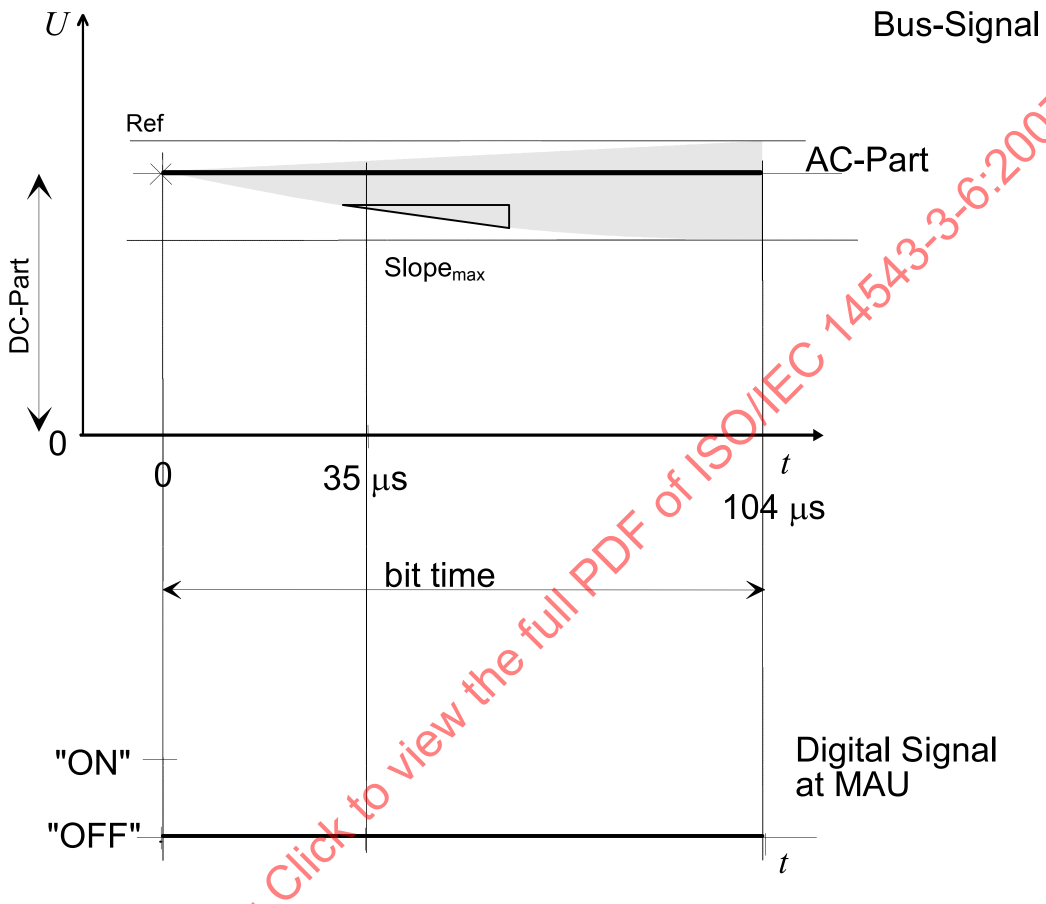


Figure 23 – "1"-Bit frame

The characteristics of a logical 1 signal shall follow the values given in Table 17.

Table 17 – Analogue and digital signal of a logical "1"

Parameter	Value
bit-time	104 µs
voltage (DC-Part)	21 V DC to 32 V DC
slopes (AC-Part)	maximum 400 mV/ms

6.2.3 Specification of logical "0" (Single)

A logical "0" shall be a defined voltage drop (U_a) of the analogue bus signal with a duration of t_{active} (see Figure 24). During the following equalization time the voltage may be higher than the DC-Part to enable recharging of energy consumed during the active part. The graph shall be within the shaded areas of Figure 24.

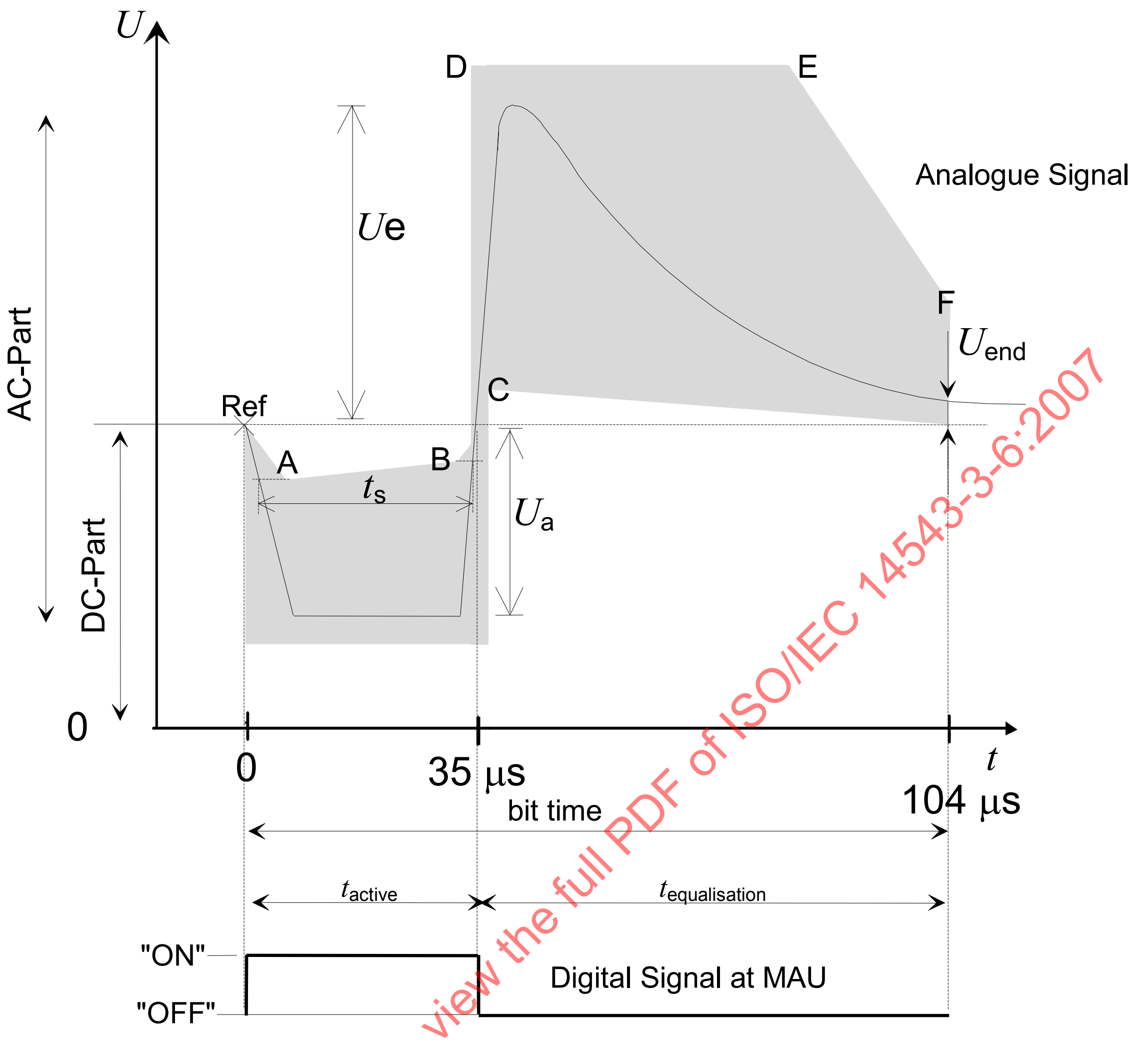


Figure 24 – "0"-Bit frame

The characteristics of a logical "0" signal shall follow the values given in Table 18.

Table 18 – Analogue and digital signal of logical "0"

Parameter / Point	Minimum	Maximum
bit-time	104 µs (typical)	
t_{active}	35 µs (typical)	
t_s (time between U_a > A and U_a > B)	25 µs	70 µs (see also 6.2.4)
time (Point D - E)	50 µs	
voltage (DC-Part)	21 V	32 V
voltage U_a (Point A) compared to Ref	- 0,7 V	- 10,5 V
voltage U_a (Point B) compared to Ref	- 0,1 V	- 10,5 V
Voltage U_a (Point C - D) compared to Ref	0 V	+ 13 V
voltage U_{end} (Point F) compared to Ref	- 0,35 V	+ 1,8 V

6.2.4 Specification of logical "0" (overlapping)

Overlapping means, that a logical "0" is transmitted at the same time by several devices (e.g. common ACK). Owing to the propagation delay of the bus cable (PhL-Medium) a time shift of logical zeros can occur, if sending devices are located at a distance from the receiving devices. The MAU and the Logical Unit shall be able to detect and interpret these signals. Figure 25 shows an example of two mixed logical "0" that have a delay (td) of about 10 µs. Assuming that the point of measuring is at device A, the signal of device B appears after 10 µs with a lower signal amplitude than device A, as it has been damped along the bus cable.

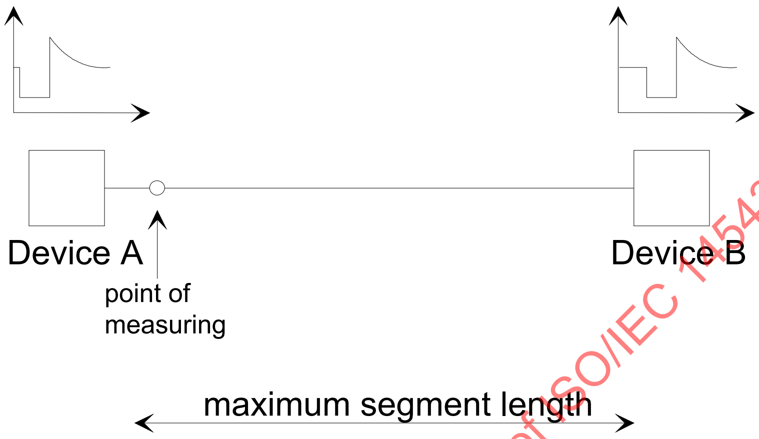


Figure 25 – Delayed logical "0"

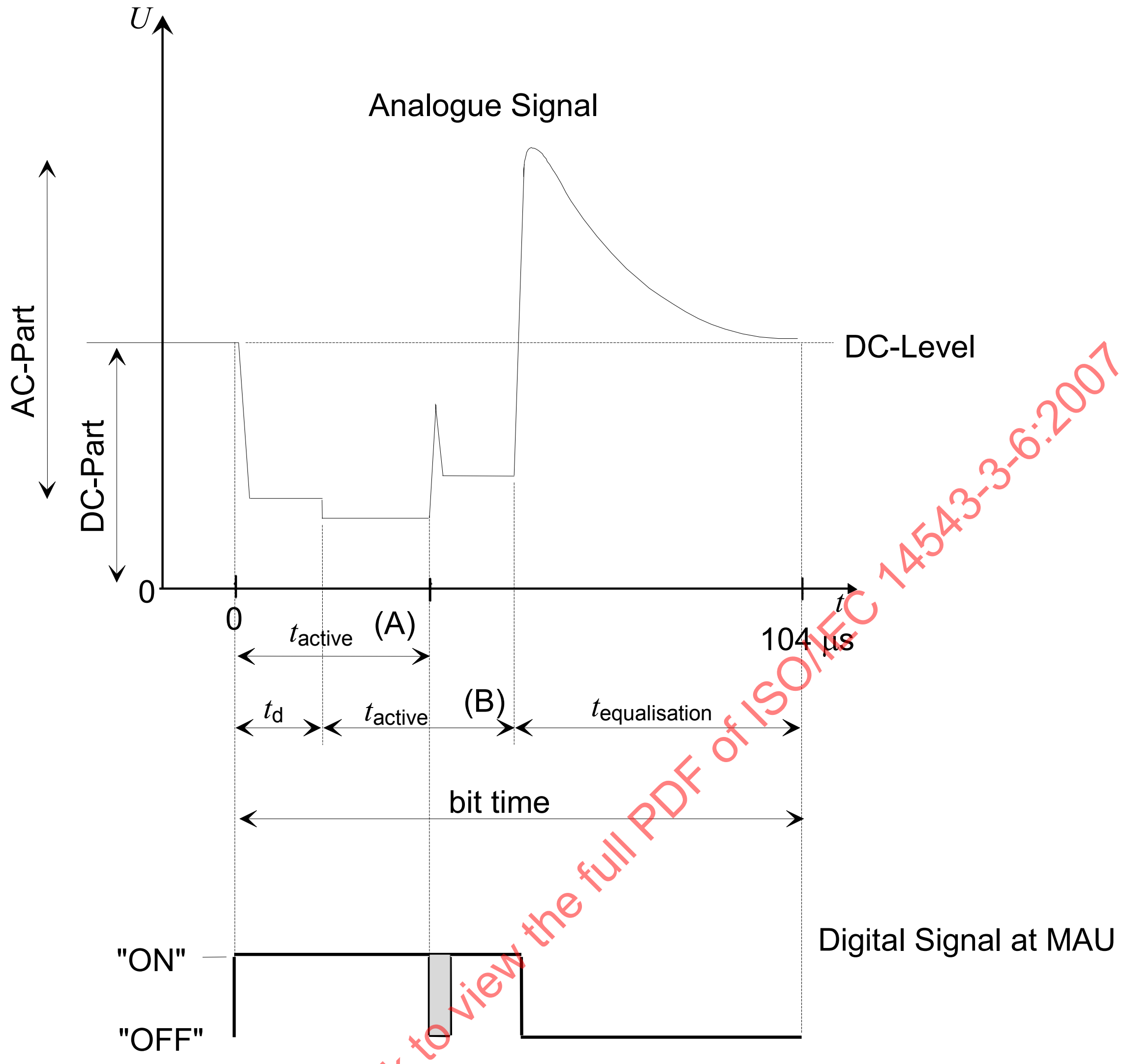


Figure 26 – Overlapping of two logical "0" (example)

The receiver of the MAU converts this mixed analogue signal to a digital signal. This digital signal differs from that of a normal "0", because the width of the receiver's output pulse is the sum of t_{active} + t_d. However, it is possible, that the receiver's output delivers a gap at the end of t_{active}. (See shaded area in Figure 26.) This behaviour requires dedicated decoding software that is able to decode such effects.

6.2.5 Analogue requirements within a transmitted character

6.2.2 and 6.2.3 describe the voltage shape and timing when transmitting a single logical bit. When transmitting an entire character (consists of a series of bits), the additional requirements of Table 19 shall be met. The values U_a* and U_e* are referred to U_{ref} at the beginning of the active part of the first bit of the transmitted character.

Table 19 – Limits within a character

Parameter	Value
U_a*	maximum - 10,5 V
U_e*	maximum 11,5 V
U_{ref} (any bit)	maximum - 1 V / + 3 V

6.2.6 Simultaneous sending / collision behaviour

Although devices shall investigate the bus line before they begin sending, it is possible that two or more devices send simultaneously. Simultaneous sending of a character occurs when two or more devices simultaneously transmit ACK, Negative Acknowledgement (NACK) or BUSY messages.

Simultaneous transmission of a logical “0” and a logical “1” will result in a logical “0”.

Simultaneous sending of logical “0” by several devices will result in a signal that is nearly identical to that of a single transmitting device, as signals are coded in the baseband.

This common signal shall therefore also comply with the values given in Table 17.

If a sending device detects that its own logical “1” was overwritten by another logical “0”, transmission shall be disabled after this bit. The receiver of both devices shall, however, remain active.

This behaviour of the physical layer allows a CSMA/CA medium access in data link layer (see 6.8).

6.3 Medium attachment unit (MAU)

6.3.1 General

The medium attachment unit (MAU) shall split the analogue signal of the medium into the DC part and the serial bit stream. Vice versa, the serial bit stream shall be converted to the analogue bus signal.

The DC-Part may be used internally to supply the device with power by using a DC/DC converter or voltage regulator. A wrongly connected MAU shall neither damage the device nor influence the bus communication.

6.3.2 Requirements within a physical segment

6.3.2.1 General

Within a physical segment the following principal requirements shall be met:

- in an installed system the DC voltage at every device shall be at least 21 V. Devices shall continue to operate with a DC voltage down to 20 V. The difference between 20 V and 21 V has been laid down as a reserve;
- the propagation delay of the serial bit stream at the MAU shall be short enough to allow bit-wise CSMA/CA arbitration during a bit time. The total delay (MAU - Cable - MAU) shall not exceed 12 µs. Refer also to 6.8.3;
- the Power Supply Unit [PSU(s)] connected to a physical segment shall provide the necessary effective current required by the devices connected to the physical segment;
- SELV requirements shall be met according to EN 50090-2-2.

6.3.2.2 Power-up behaviour

Power-up means, that either a single bus device is installed in a ‘running’ bus segment or a PSU is switched on in a fully equipped bus segment. The rising of the bus voltage is different. Power-up behaviour can be divided into two steps as follows.

During Start-up, the internal capacitors are being charged with a current limitation.

During Operation, the capacitors are charged and voltages are constant.

Power-up behaviour requires, that

bus devices run up properly regardless of the installed (allowed) topology, when the associated segment is energised by the PSU (slow ramp),

a single bus device runs up properly if installed in an operating bus segment. Other bus devices already installed in this segment shall not suffer a ‘reset’ owing to the installation of this additional bus device (steep ramp),

a possible signal disturbance, caused by the installation of a single bus device in an operating segment shall not exceed 20 ms, in order to avoid telegram losses.

6.3.2.3 Power down behaviour

The Power down behaviour occurs when the input to the power converter of the device breaks down. This input can either be the DC Part of the bus voltage or a remote power source (see 6.3.3).

The Power Down behaviour can be divided into three steps:

during Operation, the capacitors are charged, voltages are constant,

during hold-up, the Capacitors are discharged,

during Idle, the power converter draws only a leakage current.

When passing from operation to hold-up, the physical layer may generate a U_{save} signal:

to allow devices to backup data before power breaks down,

to disable further transmission of telegrams by the bus device.

For bus powered devices, this U_{save} signal shall be generated when the bus voltage drops below maximal 20 V, thereby taking into account a hysteresis of at least 1 V.

The physical layer shall generate a Reset Signal U_{reset} when the correct functioning of the power converter can no longer be ensured, typically before the end of the hold-up time. Determination of the correct functioning may be manufacturer specific. For a bus powered device the U_{reset} signal shall not be generated for input voltages higher than U_{save}.

6.3.2.4 DC behaviour

Bus devices shall not draw more than the DC bus current as laid down in Table 20, in order to ensure that the maximum number of connectable devices per segment defined in the system parameters (Table 16) can be installed. This current shall not be exceeded in worst case (20 V bus voltage and maximum application power consumption). The manufacturer shall specify this DC current in the product datasheet.

Load changes within a device shall not disturb the signal voltage from the bus in any way. Fast current changes inside a device shall be transformed (smoothened) to slow slopes on the bus side.

Table 20 – Unit currents for standard devices

Parameter	TP1-64/TP1-256
Bus current (at 20 V – 32 V)	Maximum 12 mA
Slope of input current	Maximum 0,5 mA/ms
Slope of input current for manually operated devices (e.g. push buttons)	Maximum 2,5 mA/ms

6.3.2.5 Impedance behaviour

The impedance of a device is not only a property of the receiver but of the complete device. The current drawn from the bus by a device when the bus voltage has the shape of a square pulse (35/104 µs) determines the impedance behaviour. The impedance value within a pulse (T = 104 µs) is however not constant. The value during the active part (t < 35 µs) is different from the one during the equalization part. Impedance matching is important to ensure that signal damping is not too high and the following bits are not disturbed by the equalization event of preceding bits.

6.3.2.6 Transmission behaviour

If no frame is transmitted, the voltage between Bus (+) and Bus (−) lies between 21 V and 32 V DC. This value is determined by the PSU, the voltage drop along the bus cable and the consumption of the devices. This state of the medium over a bit time of 104 µs corresponds to a logical "1". The logical "1" also indicates the idle state when no frame is transmitted. The related output signal to the PhL Logical Unit by the MAU is „OFF" during the entire bit time.

In order to transmit a logical "0", the MAU shall draw an adapted current (I_{send}) to cause a defined voltage drop U_a of the analogue signal with a duration of t_{active} (see also Table 18).

During the following equalization time the energy consumed during the active time may be partly charged back to the bus cable and the connected devices. In this way, bus-powered devices shall not suffer a significant power drop during transmission of a logical "0". The AC part of the analogue signal shall be mainly generated by the transmitter of the MAU and the choke(s).

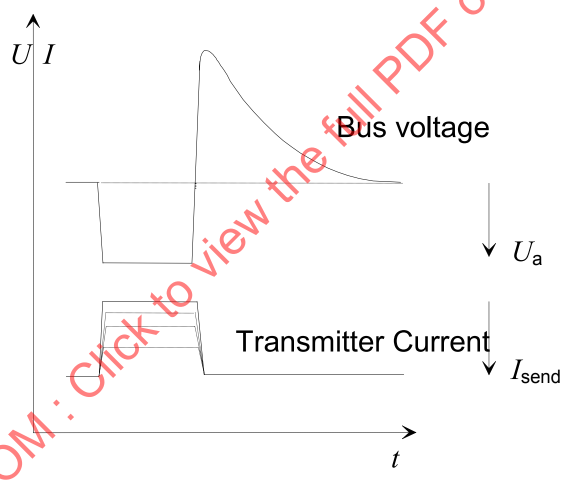


Figure 27 – Method of transmitting

The value of I_{send} of a device depends on

number of connected bus-devices,

number of bus-devices that are sending simultaneously (e.g. in case of ACK),

bus voltage,

segment cable length.

Table 21 – Dynamic requirements of a TP1-64 transmitter

Parameter	Minimum value	Maximum value
I_{send}	~ 0 mA [a]	400 mA [b]
U_a [c]	3 V	9 V

[a] Valid for one device if maximum number of devices are sending simultaneously.

[b] Valid if only one device is sending and the segment is equipped with maximum number of devices.

[c] Measured at the device.

Table 22 – Dynamic requirements of a TP1-256 transmitter

Parameter	Minimum value	Maximum value
I_{send}	~ 0 mA	400 mA
U_a	3 V	10 V

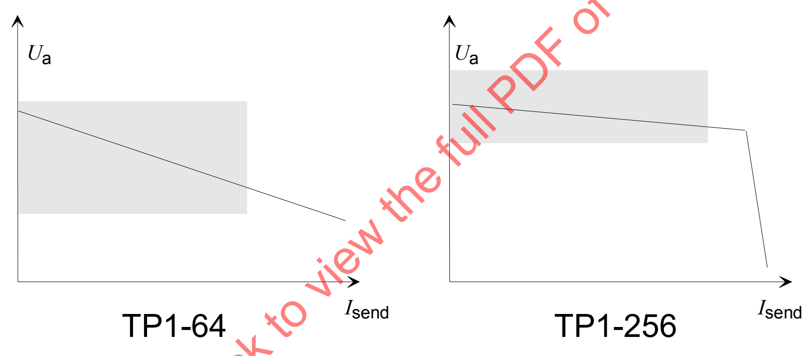
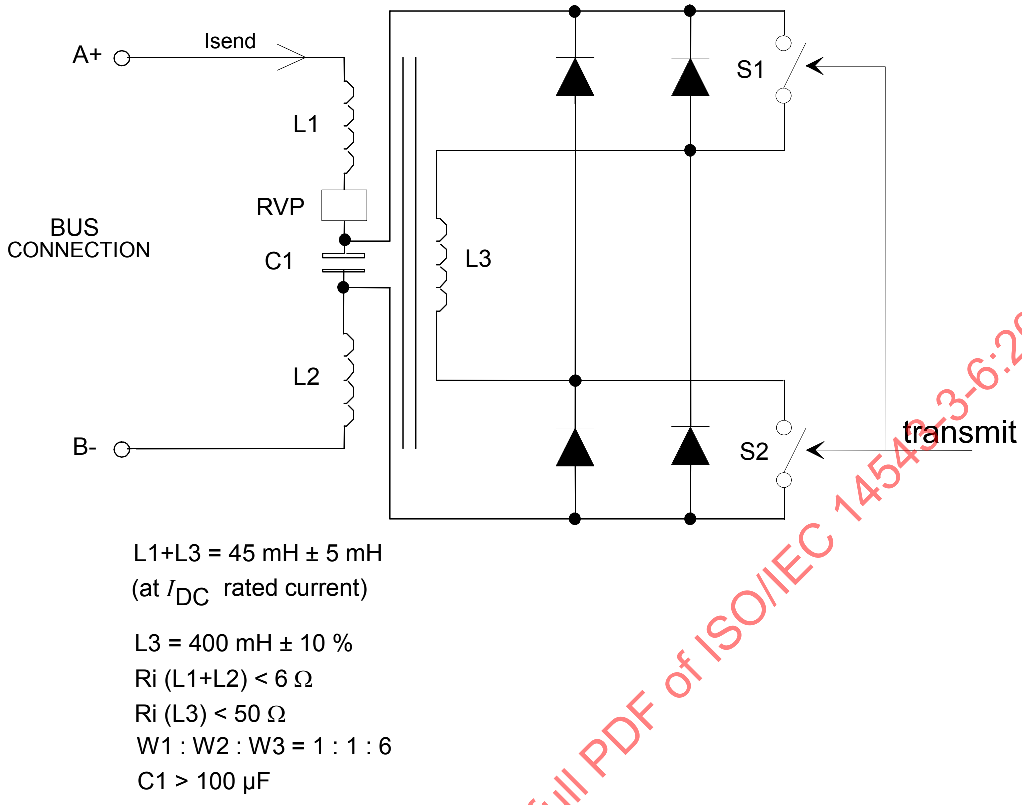


Figure 28 – Example of transmitter characteristics

Figure 29 shows an example of a principle diagram of a TP1-64 transmitter:



NOTE 1 Only during the active part (35 µs) of "Logical 0" S1 and S2 are closed. At any other time, they are both open.

NOTE 2 RVP = Reverse Polarity Protection Switch (Voltage drop < 0,5 V).

Figure 29 – Example of a diagram of a TP1-64 transmitter

Figure 30 shows an example of a principal diagram of a TP1-256 transmitter.

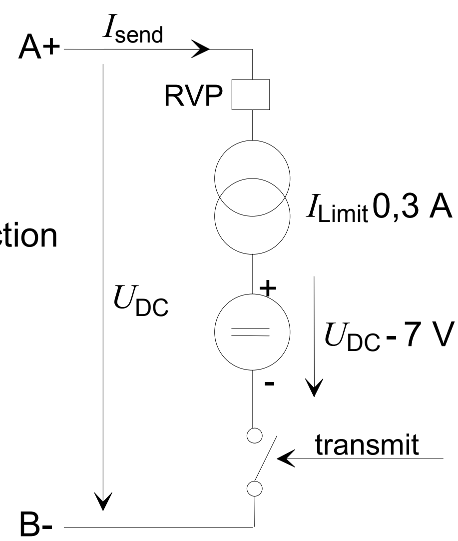


Figure 30 – Example of a diagram of a TP1-256 transmitter (I_{limit} 0,4 A)

6.3.2.7 Receiving behaviour

The MAU shall convert an analogue signal to a digital signal by using a receiver function (see Figure 21). The required threshold voltages for the receiver are shown in Table 23. The relation of ON/OFF and the bus voltage are explained in Table 18.

Table 23 – Requirements for the receiver

State at MAU	Threshold Voltage TP1-64 (relative to DC part)	Threshold Voltage TP1-256 (relative to DC part)
ON	0,5 V (typical)	0,6 V (typical)
OFF	0,2 V (typical)	0,3 V (typical)

6.3.2.8 Signal coding

The Logical Unit shall convert framed data bits into an asynchronous timed serial signal. This signal shall be used to drive the transmitter of the MAU. Figure 31 shows an example of a digital signal and the resulting serial bit stream.

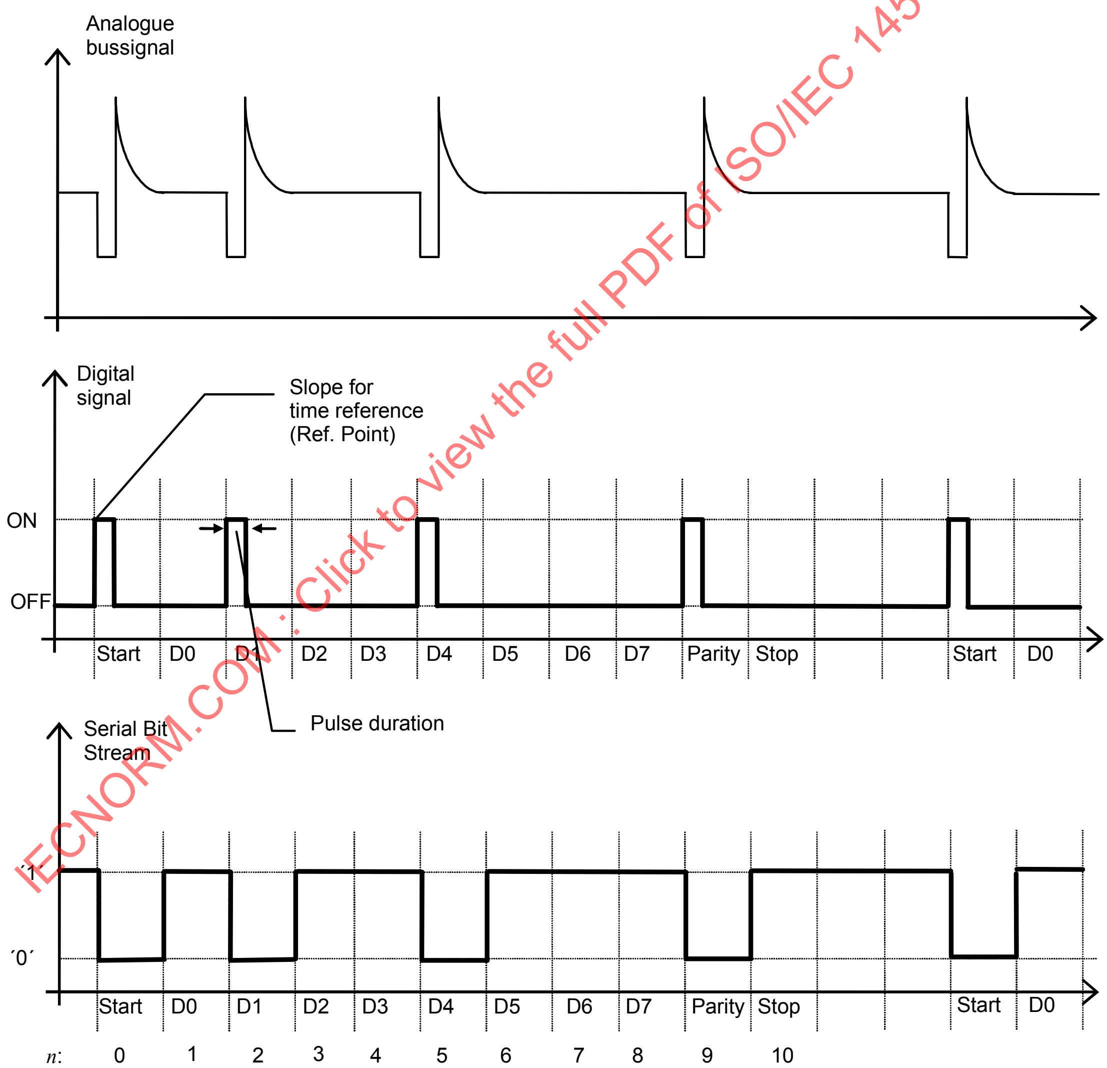


Figure 31 – Relation between framed data and asynchronous signal

Table 24 – Requirements for bit coding

Parameter	Minimum	Typical	Maximum
Bit time		104 µs	
Pulse duration	34 µs	35 µs	36 µs
Time from start bit to following bits (within a byte)	(n × 104) – 2 µs	n × 104 µs	(n × 104) + 2 µs
Time from start bit to start bit of consecutive bytes	(13 × 104) –2 µs	13 × 104 µs	(13 × 104) + 30 µs

Additional timing information and structure of telegrams are given in 6.6 and 6.8.

6.3.2.9 Signal decoding

The output signal of the receiver, regarded as a digital signal, shall be decoded to the serial bit stream by the bit decoding unit of the MAU (see also Figure 21). The following Figure 32 shows an example of a digital signal and the resulting serial bit stream.

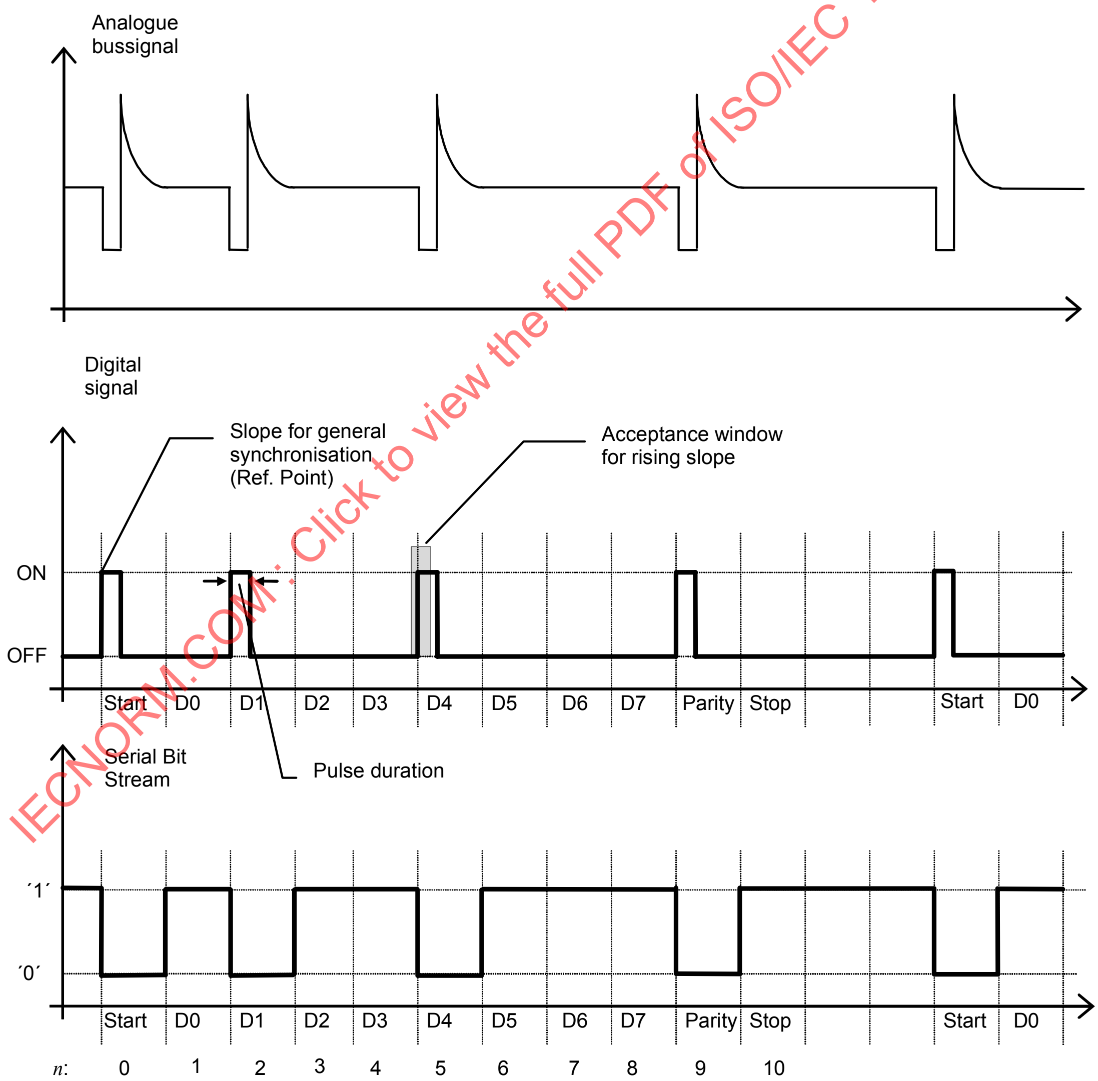


Figure 32 – Relation between digital signal and serial bit stream

The bit-decoding unit of the MAU shall use an acceptance time window. The beginning of the acceptance time window is defined in relation to the start bit. In addition, minimum and maximum pulse duration are laid down. The corresponding values are listed in Table 25.

Table 25 – Requirements for the bit decoding unit

Parameter	Minimum	Typical	Maximum
Bit time		104 µs	
Pulse duration	25 µs	35 µs	70 µs [a]
Acceptance window for the rising slope of a bit n, referred to rising edge of start bit (=Ref. point)	($n \times 104$) - 7 µs	$n \times 104$ µs	($n \times 104$) + 33 µs
Time distance from start bit to start bit within a frame	(13 × 104) - 30 µs	13 × 104 µs	(13 × 104) + 30 µs
[a] See also Table 19.			

The physical layer shall guarantee that the transmission of a logical “0” is dominant versus the simultaneous transmission of a logical “1”. It shall also guarantee that during the simultaneous transmission of bits of equal value by several devices, the resulting physical signal corresponds to the same logical value of the bit sent. This behaviour of the physical layer allows a CSMA/CA medium access in data link layer (see 6.8.3).

6.3.3 Remote powered devices (RPD)

6.3.3.1 General

RPD shall only draw a minimal DC current from the bus line (segment). The AC load shall be similar to a standard device. Only the transceiver shall be supplied by the bus line.

Figure 33 shows an example of a remote powered device.

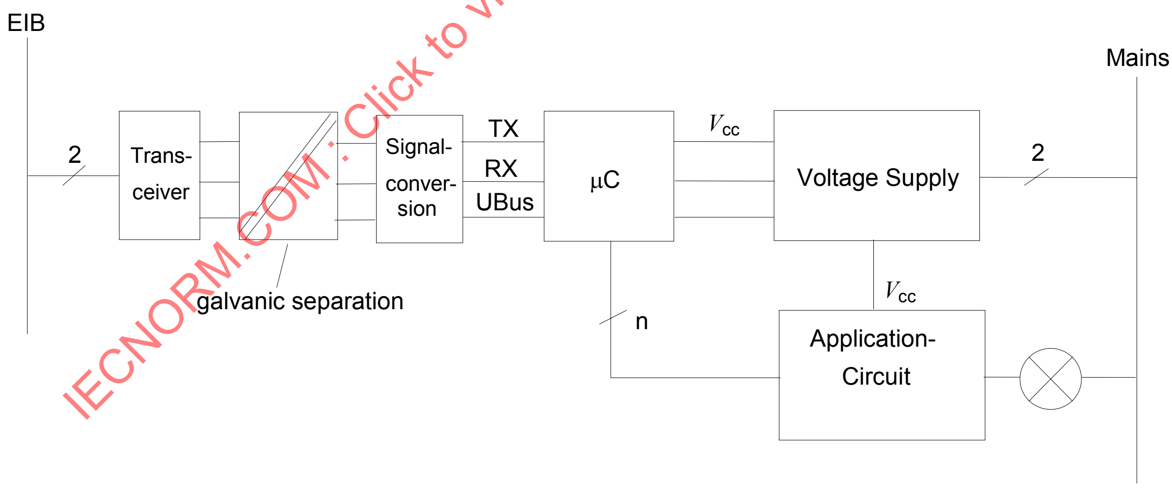


Figure 33 – Example of light dimmer

6.3.3.2 Reset and save behaviour of remote power bus device

The device supply voltage shall be implemented as master voltage. Power-up or power down of this source may cause reset, save and init. Save and init are the routines that may be defined in the user program. They may be executed when the device detects either power-up or power down of the supply voltage. The missing of master voltage shall not disturb the operating bus segment in any way.

Bus voltage shall be implemented as slave voltage. When the bus power breaks down, the RPD shall refrain from further transmission attempts. When the bus power is restored, the RPD shall continue normal operation.

NOTE This is a general requirement, also valid for purely bus-powered devices. This is part of the power-up behaviour of devices as specified in 6.3.2.2.

The behaviour of the device if either master or slave voltage is missing, shall be described in the manufacturer's data sheet.

The manufacturer shall define how to reset a RPD. The device may be forced to a reset from the bus side, through the transmission of a special reset service message.

6.4 Twisted Pair Type 1 bus cable

6.4.1 Requirements

The requirements for TP1 cable as stated in Table 26 ensure that distances as specified in 6.5 can be met.

Table 26 – Requirements for TP1 cable

No.	Features		Requirements	Test
1	Electrical properties	Loop resistance	Maximum 75 Ω/km	Measurement
2.1	Electrical Safety	Outer sheath	Required	-
2.2		Insulation resistance core to outer sheath	100 MΩ/km (20°) respectively 0,011 MΩ/km (70°)	Measurement
2.3		Withstand voltage core/core	800 V	Measurement
2.4		High voltage withstand	2 kV AC 50 Hz 4 kV AC 50 Hz [a]	5 min 1 min All cores and screen connected with each other against outer sheath surface, immersed in water according to IEC 60227-2 and IEC 60245-2
3.1	EMC	Twist	Minimum 5/m	Measurement
3.2		Continuous magnetic and electrical interference fields	$U \leq \pm$ 200 mV peak (50 Hz – 1 GHz)	See 6.4.2
3.3		Transient induced differential voltages	$U \leq \pm$ 45 V peak for level 1: cable length as specified in 6.5 and transient voltages according industrial level (according IEC 61000-6-2) or home level (according IEC 61000-6-1)	See 6.4.2
3.4		Screen	- shall cover entire diameter - drain wire: diameter minimum 0,4 mm	-

[a] In some countries this 4 kV test is required.

[b] For halogen free cable, IEC 60189-2 shall be used as far as applicable. In addition IEC 60332-1 and IEC 60754-2 shall be complied with.

Table 26 – *(continued)*

No.	Features		Requirements		Test
4	Temperature and climate		According to IEC 60189-2 [b]		According to IEC 60189-2
5	Mechanical stress		According to IEC 60189-2 [b]		According to IEC 60189-2
6.1	Communication	Capacity wire/wire	Minimum 10 nF/km Maximum 100 nF/km (10 kHz)		Measurement
6.2	Communication	Inductance	Minimum 450 μH/km Maximum 850 μH/km (10 kHz)		Measurement
6.3	Communication	Maximum signal attenuation	≤50 kHz	15 dB/km	Measurement
			50 kHz to 500 kHz	15 dB/km to 35 dB/km [c]	
			0,5 MHz to 5 MHz	35 dB/km to 95 dB/km [c]	
			5 MHz to 25 MHz	95 dB/km to 200 dB/km [c]	
[c] Increasing linearly with the logarithm of the frequency.					

6.4.2 Measurement of continuous magnetic and electrical interference, respectively transient induced differential voltages

6.4.2.1 Test set-up

Test shall be carried out with a cable length of 50 m.

The cable shall be laid in such a way that the induction is low (straight or with meanders of approximately 20 cm, not rolled up).

The cable causing interference (primary loop: single wire or cable with go and return wire) shall be laid parallel to the bus cable to be tested over its entire length.

The distance between the interfering cable and the bus cable shall be chosen in such a way that the highest possible coupling (that can arise in the field) is reached.

The source of the transient voltages shall be connected to the primary loop with an internal resistance Ri of 2 Ω and 12 Ω, respectively, and the corresponding coupling capacitor. A combination wave generator according to IEC 61000-4-5 with 1,2/50 μs impulse shall generate the transient voltages. The generator shall be coupled to the primary loop as for mains connections according to IEC 61000-4-5.

On one side the bus cable wires shall be connected to the ground with 100 Ω each. On the other side the bus cable shall be short-circuited (this side shall never be connected to ground).

The following values for transient voltages (industry level according to IEC 61000-6-2 or for home level according to IEC 61000-6-1) shall be met; peak voltage 1 kV with Ri = 2 Ω and peak voltage 2 kV with Ri = 12 Ω.

The induced voltage on the bus cable shall be measured as differential voltage.

6.4.2.2 Requirements

The relevant requirements of Table 26 shall be met.

NOTE The relevant requirement of 5.4 will be replaced by a reference to the specification for TP1 cables, currently under consideration in CLC/TC 46XC in the forthcoming EN 50288-13 when available.

6.5 Topology

6.5.1 Physical segment

NOTE The figures shown in 6.5 depict an example of a bus system, in which only two physical segments (connected via one bridge) are used per line, although a line may consist of up to 4 physical segments. Consequently, a maximum of 128 devices is shown in these figures.

The topology of a physical segment may be a linear, star or tree or mixed topology (see Figure 34). Up to 64 (TP1-64) or 256 (TP1-256) devices may be connected to a physical segment, provided the bus cable used complies to the requirements of Table 26. 256 devices correspond to the logical address space of a bus line (see 6.8.2.4.3). The maximum distance between two devices in a physical segment shall not exceed 700 m. The maximum cable length in a tree or star topology may be longer than the maximum distance between two devices. Therefore the maximum cable length of a physical segment shall not exceed 1 000 m for the cables complying with the requirements of Table 26.

Loops within a physical segment are allowed but not recommended.

Terminating resistors are not required.

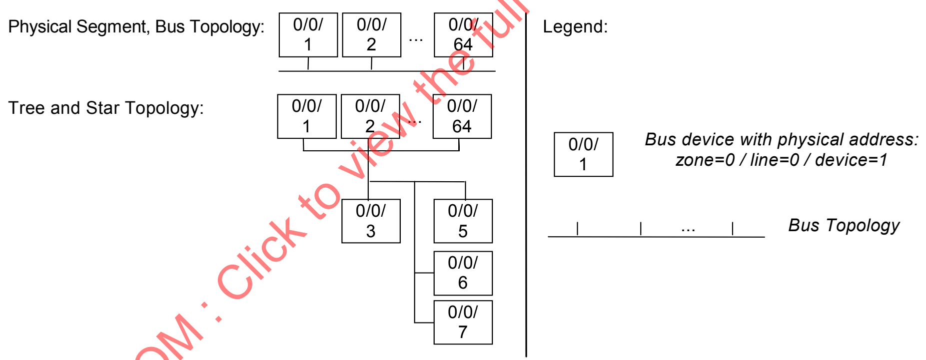


Figure 34 – Physical segments

6.5.2 Bridge

The bridge shall guarantee a galvanic separation of the connected physical segments to improve noise immunity. By using bridges, the maximum cable length can be extended to 3 000 m. The maximum distance between two devices in a line can therefore also be extended to 700 m × 3 = 2 100 m for cables complying with the requirements of Table 26. It is allowed that bridges do not have an Individual Address. They shall, however, acknowledge the frames they receive on Data Link Layer and transmit the received frame on the other side of the bridge.

It is recommended not to equip basic installations with a bridge. Bridges should be used for later extensions only.

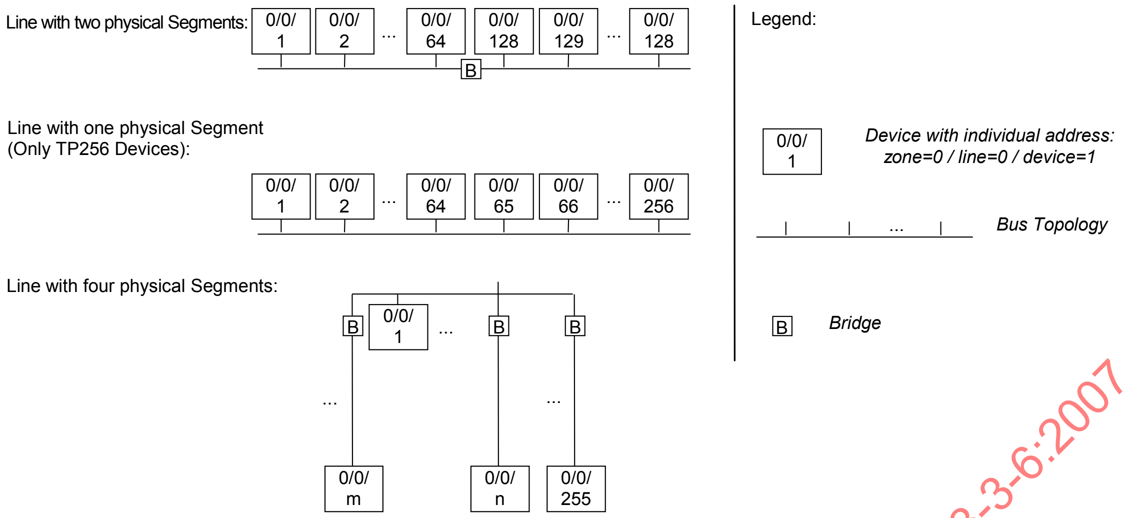


Figure 35 – Physical segments combined to a line

6.5.3 Router, sub-line, main line and zone

A router shall have an Individual Address, acknowledge frames on data link layer and transmit the received frame on the other side of the router, provided the device associated with the destination address of the frame is located on the other side. For larger networks, up to 16 lines may be combined to a zone using 15 routers (Figure 37). Not more than two routers shall be installed in the path between any of two devices of a zone. The router shall guarantee the galvanic separation of the lines connected.

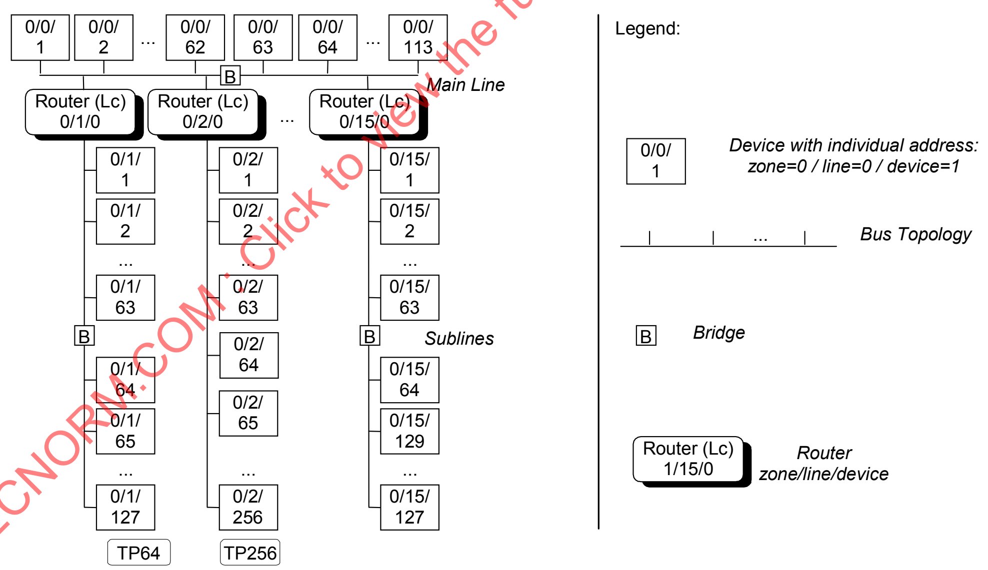


Figure 36 – Lines combined to a zone

Using cable that complies with the requirements of Table 26 and bridges that comply with 6.5.2, a zone may have
256 × 16 = 4 096 devices and a maximum total length of 4 000 m × 16 = 64 km.

The maximum distance between two devices in a zone is then 700 m × 6 = 4,2 km.

NOTE This holds true under the assumption that a maximum of one single bridge is installed between any two devices.

Routers (Backbone couplers) may also be used to connect multiple zones to a maximum size network (Figure 37). Not more than two backbone couplers shall be installed in the path between any of two zones.

A maximum size Network may therefore have up to 4 096 × 16 = 65 536 devices and a total cable length of 64 km × 16 = 1 024 km.

A maximum of 6 coupling devices (i.e. bridges or routers) shall be installed between any of two devices. The maximum distance between two devices in a maximum size Network using cable which complies with the requirements of Table 26 is then 700 m × 7 = 4,9 km.

6.5.4 Gateways to other networks

Gateways may be installed to connect TP1 physical layer to non-TP1 physical layers. Gateways may be included in any line. Gateway connections shall additionally be in conformance with the relevant national regulations. TP1 networks shall never be directly coupled to non-SELV networks.

NOTE Zones may be linked together not only by using the backbone line but also by dedicated gateways to higher-level bus systems.

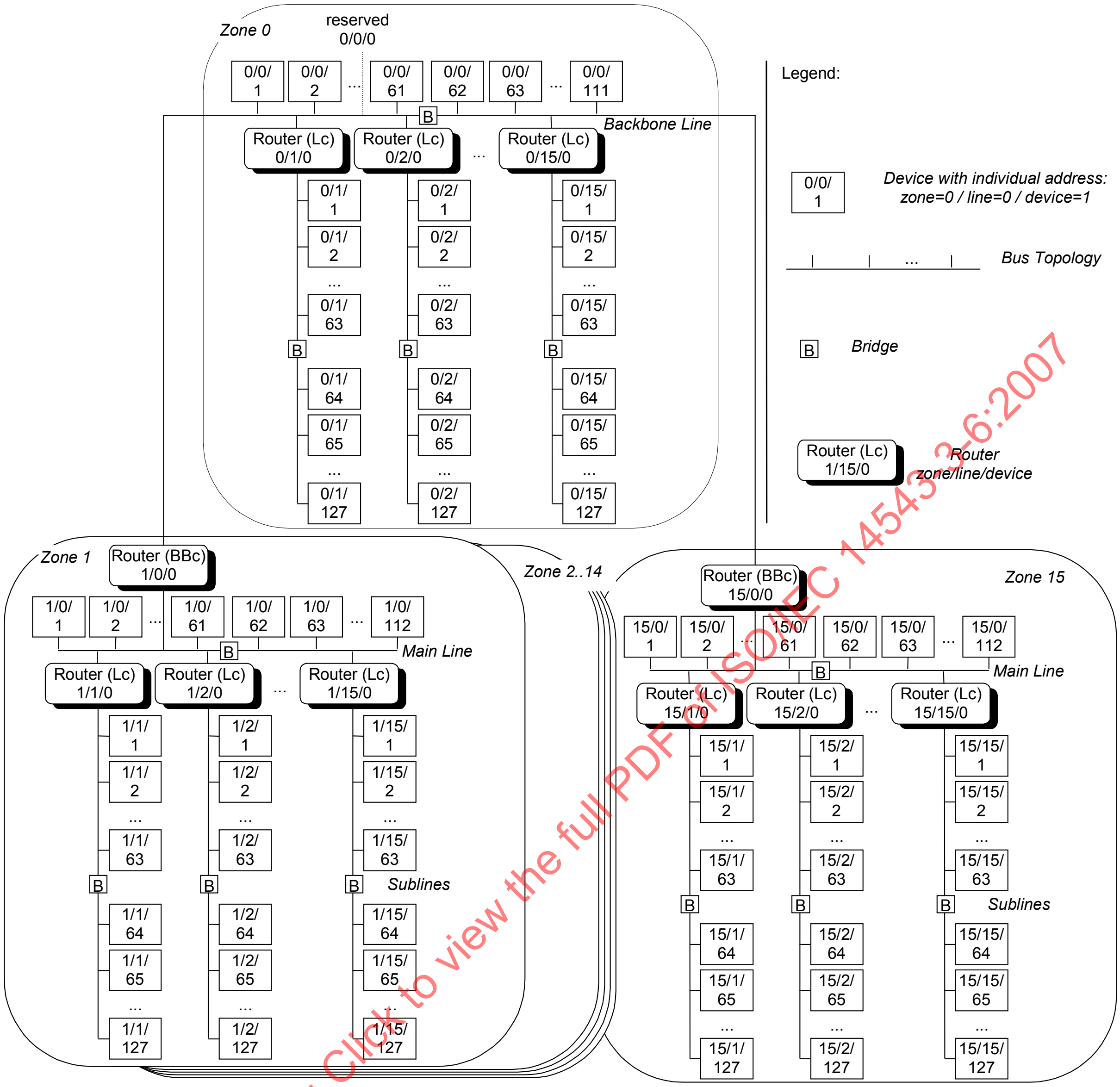


Figure 37 – Network topology

6.6 Services of the physical layer type Twisted Pair Type 1

6.6.1 General

At the interface to the physical layer user the physical layer type TP1 shall offer the Ph_Data service and the Ph_Reset service.

6.6.2 Physical_Data service

The Ph_Data service shall consist of three primitives Ph_Data.req, Ph_Data.ind and Ph_Data.con.

Ph_Data.req(p_class, p_data)

p_class:	start_of_frame:	This parameter value shall be used to start transmission of the first character of a frame **with** line_busy detection at the start bit. For bus free time and delay, see 6.8.3. NOTE The encoding of the start_of_frame parameter values is not part of this standard.
	inner_frame_char:	This parameter value shall be used to start transmission of a character after two bit times **with** line_busy detection at the start bit.
	ack_char:	This parameter value shall be used to start transmission of a character as soon as the time equivalent to 15 bit has elapsed after the preceding character received **without** line_busy detection at the start bit.
	poll_data_char:	This parameter value shall be used to start transmission of a character as soon as the time equivalent to 5 bit has elapsed after the preceding character received **without** line_busy detection at the start bit.
	fill_char:	This parameter value shall be used to start transmission of a character as soon as the time equivalent to 6 bit has elapsed after previous character received **with** line_busy detection at the start bit.
p_data	p_data: octet:	This parameter value shall be used to convert a UART character to an octet and start transmission

The Ph_Data.req primitive shall be applied by the physical layer user to pass user data consisting of an octet via the p_data parameter to the physical layer type TP1. The p_class parameter determines the transmission task to be executed by the physical layer type TP1 entity.

See 6.7 for a more detailed description of line_busy detection at the start bit.

Ph_Data.con(p_status)

p_status:	OK:	This parameter value shall be used to indicate that a character transmission succeeded.
	line_busy:	This parameter value shall be used to indicate that no transmission occurred and that another device is transmitting.
	collision_detected:	This parameter value shall be used to indicate that a collision was detected (logical “1” transmitted, but logical “0” received).
	transceiver_fault:	This parameter value shall be used to indicate that a transceiver fault was detected.

The Ph_Data.con primitive shall pass status information via the parameter p_status back to the physical layer user. The value of p_status shall indicate whether the transmission of the contents of the p_data parameter previously passed to the physical layer type TP1 entity via the Ph_Data.req primitive succeeded.

P_status shall be ‘collision_detected’ if a logical “1” was transmitted as one of the UART character bits, but at the same time a logical “0” was read at the line by the physical layer type TP1 entity. P_status shall be ‘transceiver_fault’ if a logical “0” was transmitted as one of the UART character bits, but at the same time a logical “1” was read at the line.

See 6.7 for a more detailed description of the conditions for p_status values ‘line_busy’, ‘collision_detected’ and ‘transceiver_fault’.

Ph_Data.ind(p_class, p_data)

p_class:	start_of_frame:	This parameter value shall be used to indicate that a first character of a request frame was received. For timing, see 6.8.3.
	inner_frame_char:	This parameter value shall be used to indicate that a character was received at 2 bit times after the preceding one.
	ack_char:	This parameter value shall be used to indicate that a character was received 15 bit times after the preceding one.
	poll_data_char:	This parameter value shall be used to indicate that a character was received at five or six bit times after the preceding one.
	parity_error:	This parameter value shall be used to indicate that a wrong parity bit was detected in the character received.
	framing_error:	This parameter value shall be used to indicate that a wrong stop bit was detected in the character received.
	bit_error:	This parameter value shall be used to indicate that a wrong data bit was detected in the character. Data bit did not meet the bit decoding rules.
p_data:	octet:	This parameter value shall be used to deliver the data octet extracted from the received character.

The Ph_Data.ind primitive shall pass timing information via the parameter p_class and user data via the parameter p_data from the physical layer type TP1 entity to the physical layer user. See 6.7 for more details.

6.6.3 Physical_Reset service

The Ph_Reset service shall be applied by the user of physical layer during start up, in order to synchronise to possibly existing network traffic.

Ph_Reset.req(); This primitive value shall be used to start synchronization activity.

Ph_Reset.con(p_status);

p_status:	OK:	This parameter value shall be used to indicate that a bus free time of 50 bit times was detected.
	transceiver_fault:	This parameter value shall be used to indicate that an undefined physical signal was detected.

The Ph_Reset.con primitive shall indicate either with value 'OK' of parameter p_status an idle time of 50 bit times or with 'transceiver_fault' a malfunctioning transceiver.

6.7 Behaviour of the physical layer type Twisted Pair Type 1 entity

In addition to the rules listed in the description of each physical service (see 6.6) the following rules also apply to the Physical Layer type TP1 entity.

By means of the Line_busy detection mechanism the physical layer type TP1 entity shall check if another physical layer type TP1 entity is already transmitting at the same physical segment, before it starts transmission of the start bit of a character.

According to 6.6.2 line_busy detection shall be on for the p_class values 'start_of_frame', 'inner_frame_char' and 'fill_char' of the Ph_Data.req primitive. In these cases the Ph_Data.req primitive shall result in no transmission and in a Ph_Data.con primitive with p_status = line_busy.

On the other hand the p_class values 'ack_char' and 'poll_data_char' may result in the transmission of the start bit and subsequent data bit transmission without collision detection on. In that case a Ph_Data.con primitive with p_status = line_busy cannot occur.

During transmission (i.e. during Ph_Data.req primitive execution) collision detection shall never be disabled. If a collision is detected, the transmitter shall immediately stop its transmission. Collision detection shall be indicated by a Ph_Data.con primitive with p_status = 'collision_detected'. The following Ph_Data.ind primitive (p_class either of value 'start_of_frame' or 'inner_frame_char') shall pass the p_data value with the complete octet received to the physical layer user.

6.8 Data link layer type Twisted Pair Type 1

6.8.1 General

The data link layer described in this clause is called Data Link layer type Twisted Pair (TP1). Its medium access corresponds to a CSMA/CA mechanism.

6.8.2 Frame formats

6.8.2.1 General

The Data Link layer type Twisted Pair 1 shall support the 2 following frame formats:

1) L_Data Frame Format;

2) Acknowledge Frame Format.

The Data Link layer type Twisted Pair 1 may optionally support the L_Poll_Data Frame Format.

Unsupported or other frame formats shall not be received. The data link layer shall be able to distinguish one frame format from another by means of the control field. Each frame shall be sent as a sequence of characters.

NOTE The subsequent figures show octets instead of UART characters, i.e. the LPDU, to improve reading.

The UART character that corresponds to octet 0 shall be sent first, the octet with the highest number shall be the last character to be sent. The individual bits of an octet shall be sent in ascending order, i.e. the lowest significant bit (bit 1) first.

6.8.2.2 Control field (CTRL)

The first character of each frame shall be the control field. The control field shall contain information about the data link layer service, its priority, a frame type flag and a flag containing the information whether the LPDU is a repeated one (see Figure 38).

Control Field

b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	
Frame type		repeat flag		priority	priority			
FT	0	r	1	p1	p0	0	0	L_Data-frame
1	1	1	1	0	0	0	0	L_Poll_Data-frame
x	x	0	0	x	x	0	0	Acknowledge frame

FT = 0 : extended frame
FT = 1 : standard frame

r = 0 : repeated L_Data-Frame
r = 1 : not repeated L_Data-Frame

p1	p0	
0	0	system priority
1	0	urgent priority
0	1	normal priority
1	1	low priority

Figure 38 – Control field

The control field shall indicate the type of the request frame, L_Data_Standard, L_Data_Extended, L_Poll_Data request frame or acknowledgement frame. The two priority-bits of the CTRL field shall control the priority of the frame, when two devices start transmission simultaneously.

Repeated L_Data frames shall have the repeat_flag set to zero, non-repeated ones to one.

The control field encoding '01r0p1p000' shall not be used for future extensions of the data link layer Twisted Pair 1 protocol.

6.8.2.3 L_Data frame

Two L_Data frame formats are available on the TP1 Medium. The usage of the different formats depends on the value of the frame format parameter to the link layer (see ISO/IEC 14543-3-2). The standard frame format shall be used if the frame format parameter is 0, otherwise the extended frame format is used.

6.8.2.4 L_Data_Standard frame

6.8.2.4.1 General

The structure of the variable length L_Data_Standard frame shall comply with Figure 39.

CTRL	SA	DA	AT, NPCI, LG	TPDU (L_Data_Standard)	FCS
8	16	16	8		8

Figure 39 – Frame fields with standard fieldname abbreviations

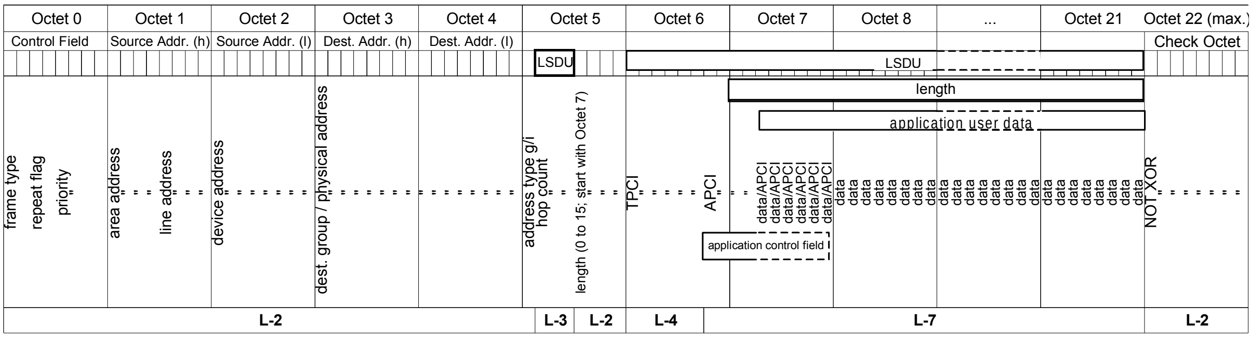


Figure 40 – Format 1s, L_Data_Standard frame format

6.8.2.4.2 Control field (CTRL)

The encoding of the control field is specified in 6.8.2.2 above.

6.8.2.4.3 Source address (SA)

The octets one and two of a request frame shall be the high and lower octet of the source address. This shall be the Individual Address of the device that caused the transmission of the frame.

6.8.2.4.4 Destination address and address type (AT)

The destination address (octets three and four) shall define the devices that shall receive the frame. For L_Data_Standard request frames, the destination address may either be an individual address (AT=0) or a group address (AT=1), depending on the destination address type (AT) of octet five.

6.8.2.4.5 Length

The L_Data_Standard request frame format shall have a variable length. The length information shall indicate the number of characters (0 … 14) transported by the L_Data_Standard frame starting with octet 7. This means that a L_Data_Standard request frame with length 0 shall end after the sixth octet.

6.8.2.4.6 Check octet

The last octet of a request frame shall be the check octet (Figure 41). This octet shall be created by making an odd parity over the set of corresponding bits belonging to the preceding octets of the frame. This represents a logical NOT XOR function (F in Figure 41) over the individual bits of the preceding octets of the frame.

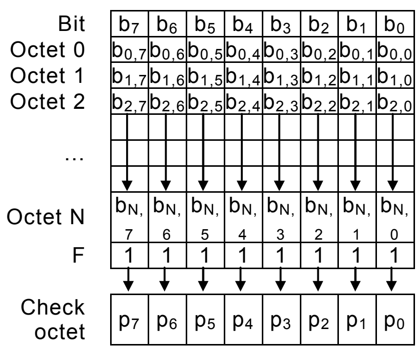


Figure 41 – Check octet

6.8.2.5 L_Data_Extended frame

6.8.2.5.1 General

The extended frame format shall be used for

- messages with APDU > 15 octets (long messages) which do not fit into L_Data_Standard frame because of its limited length, and
- messages with extended addressing capabilities used in LTE-HEE mode.

L_Data_Extended frame shall not be used instead of L_Data_Standard frame if encoding capabilities of L_Data_Standard frame are sufficient (e.g. for short frames).

The structure of the variable length L_Data_Extended frame shall comply with Figure 42.

CTRL	CTRLE	SA	DA	LG	TPDU (L_Data)	FCS
8	8	16	16	8		8

Figure 42 – Frame fields with standard fieldname abbreviations

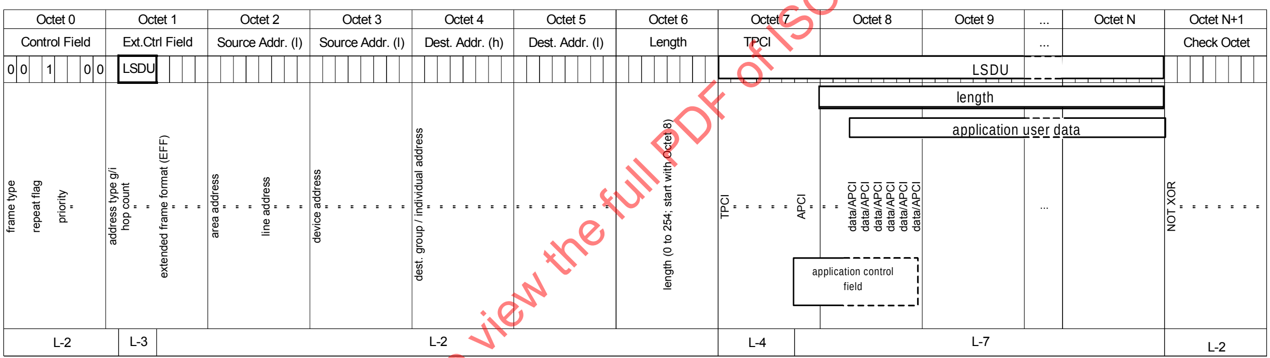


Figure 43 – Format 1e, L_Data_Extended frame format

The encoding of the fields in the frame is specified in 5.8.2.5.2 to 5.8.2.7

6.8.2.5.2 Control field (CTRL)

The common encoding of the Control Field is specified in 6.8.2.2.

6.8.2.5.3 Extended control field (CTRLE)

If the Frame Type flag FT = 1 in the CTRL field, an extended control field CTRLE shall follow in octet 1.

The CTRLE field shall contain the extended frame format parameter EFF and the Hop Count parameter. Bit7 shall contain the destination Address Type (AT) flag g/i.

Extended Control Field

b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	
Dest. Addr Type	Hop Count			Extended Frame Format (EFF)				
AT	r	r	r	t	t	t	t	
0	r	r	r	0	0	0	0	Individual Addressed L-Data extended Frame
1	r	r	r	0	0	0	0	Standard Group addressed L-Data extended Frame
1	r	r	r	0	1	x	x	LTE-HEE extended address type
								All other codes are reserved for future use

Figure 44 – Extended control field

6.8.2.5.4 Source address (SA)

The octets one and two of a request frame shall be the high and low octet of the source address. This shall be the individual address of the device that caused the transmission of the frame.

6.8.2.5.5 Destination address (DA)

In the L_Data_Extended frame the type of the destination address depends, besides the address type (g/i flag), also on the extended frame format parameter EFF of the extended control field CTRLE. With EFF = 0000 the same address type shall be used as in L_Data_Standard format. With EFF ≠ 0000 special address formats and tables shall be used.

6.8.2.5.6 Length

The L_Data_Extended request frame format has a variable length. The length information shall indicate the number of characters (0 to 254, 255=escape code) transported by the L_Data_Extended frame starting with after the TPCI octet. This means that a L_Data_Extended request frame with length 0 shall end after the TPCI octet. The length information shall be encoded by the combination of the frame type-bit in the Control Field and the length field, as specified in ISO/IEC 14543-3-2.

6.8.2.6 L_Poll_Data frame

6.8.2.6.1 General

The Poll_Data request frame shall have the format, as shown in Figure 45.

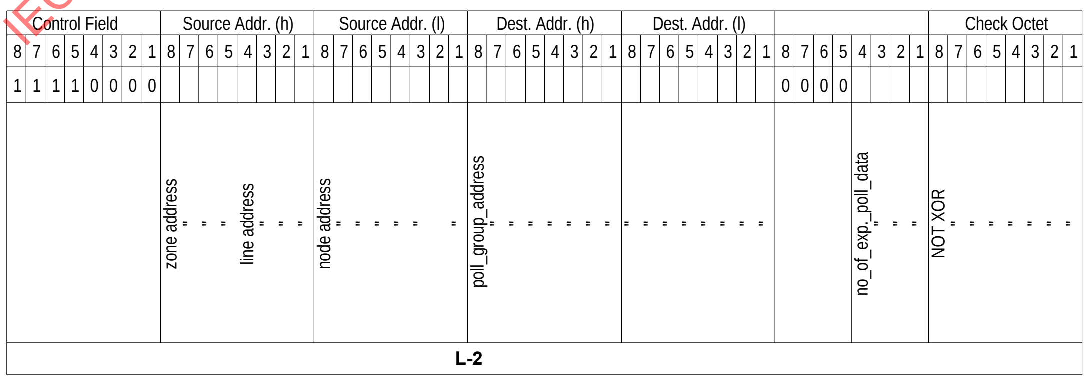


Figure 45 – Format 3 - L_Poll_Data request frame format