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Edition 4.2 2024-03
CONSOLIDATED VERSION

INTERNATIONAL STANDARD

colour inside

Industrial communication networks – Installation of communication networks in industrial premises

IEC 61918:2018-09+AMD1:2022-03+AMD2:2024-03 CSV(en-fr)

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INDUSTRIAL COMMUNICATION NETWORKS –

Installation of communication networks in industrial premises

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This consolidated version of the official IEC Standard and its amendments has been prepared for user convenience.

IEC 61918 edition 4.2 contains the fourth edition (2018-09) [documents 65C/928/FDIS and 65C/933/RVD], its amendment 1 (2022-03) [documents 65C/1141/FDIS and 65C/1162/RVD] and its amendment 2 (2024-03) [documents 65C/1282/FDIS and 65C/1290/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendments 1 and 2. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 61918 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This fourth edition constitutes a technical revision.

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

a) the reference to ISO/IEC 24702 has been replaced with reference to the new ISO/IEC 11801-3; this affects Table 2;
b) some terms and abbreviated terms have been modified in Clause 3;
c) Subclauses 4.1.2, 4.4.2.5, 4.4.3.4.1 and 5.7 have been updated;
d) Figure 2 and Figure 3 have been updated; Figure 13, Figure 16, Figure 30 and Figure 49 have been added;
e) Table 7 has been updated;
f) Annex D and Annex M have been extended to cover additional communication profile families; Annex H has been extended to cover the M12-8 X-coding connector use;
g) Annex O has been modified by including references to the new edition of the ISO/IEC 11801 series, ISO/IEC TR 11801-9902 and ISO/IEC 14763-4;
h) Annex P has been added.

This standard is to be used in conjunction with the IEC 61784-5 series with regard to the installation of communication profiles (CPs).

Those standards of the IEC 61784-5 series which are still specified for use in conjunction with IEC 61918:2013 can also be used in conjunction with this edition, provided that the user takes into account the fact that the reference to ISO/IEC 24702 has been replaced with a reference to ISO/IEC 11801-3:2017.

NOTE This solution applies for the installation profiles that are affected only by this modified reference.

This standard is referenced by ISO/IEC 14763-2, which covers installation of generic cabling outside the automation islands in industrial premises.

This standard was developed in cooperation with ISO/IEC JTC1/SC25 which is responsible for the ISO/IEC 11801 series.

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

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

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

Process and factory automation rely increasingly on communication networks and fieldbuses that are inherently designed to cope with the specific environmental conditions of the industrial premises. The networks and fieldbuses provide for an effective integration of applications among the several functional units of the plant/factory. One of the benefits of integrating field-generated data with higher-level management systems is to reduce production costs. At the same time, integrated data helps to maintain or even increase the quantity and quality of production. A correct network installation is an important prerequisite for communications availability, reliability, and performance. This requires proper consideration of safety and security conditions and environmental aspects such as mechanical, liquid, particulate, climatic, chemicals and electromagnetic interference.

The specifications of these communication networks are provided in the following documents.

ISO/IEC 11801-3 specifies design of generic telecommunications infrastructures within industrial premises and provides the foundations for some of the transmission performance specifications of this document. ISO/IEC 11801-3 specifies only the raw bandwidth capability of a channel; it does not specify useful data transfer rate for a specific network using that channel or expected errors after taking account of interference during the communication process, as is needed for industrial automation.

The IEC 61158 fieldbus standard and IEC 62026-3 and their companion standard IEC 61784-1 and IEC 61784-2 jointly specify several Communication Profiles (CPs) suitable for industrial automation. These CPs specify a raw bandwidth capability and in addition, they specify bit modulation and encoding rules for their fieldbus. Some profiles also specify target levels for useful data transfer rate, and maximum values for errors caused by interference during the communication process.

This document provides a common point of reference for the installation of the media of most used industrial communication networks for most industrial sites.

This document provides a consistent set of installation rules for industrial automation islands where control applications reside. In addition, it offers support for the definition and installation of the interfaces between automation island networks and generic cabling.

One of the problems it seeks to solve is the situation created when different parts of a large automation site are provided by suppliers that use non-homogeneous installation guidelines having different structures and contents. This lack of consistency greatly increases the potential for errors and mismatch situations liable to compromise the communication system.

This document was developed by harmonising the approaches of several user groups and industrial consortia.

The document covers the life cycle of an installation in the following clauses (see the map of the document in Figure 1):

- Clause 4: Installation planning;
- Clause 5: Installation implementation;
- Clause 6: Installation verification and acceptance test;
- Clause 7: Installation administration;
- Clause 8: Installation maintenance and installation troubleshooting.

The methods described in these clauses are written in such a way as to provide installation guidance for a wide range of technician skills.

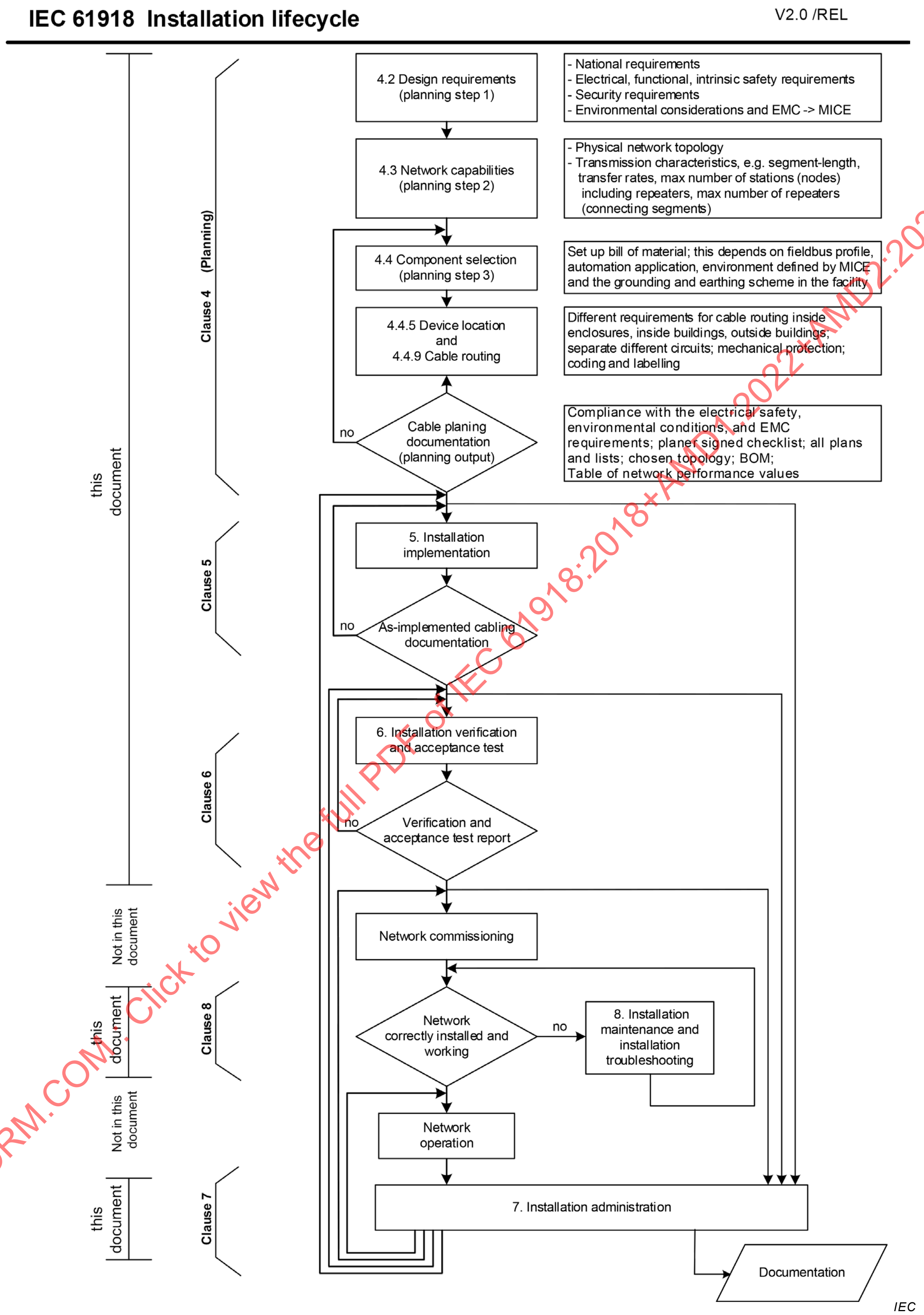


Figure 1 – Industrial network installation life cycle

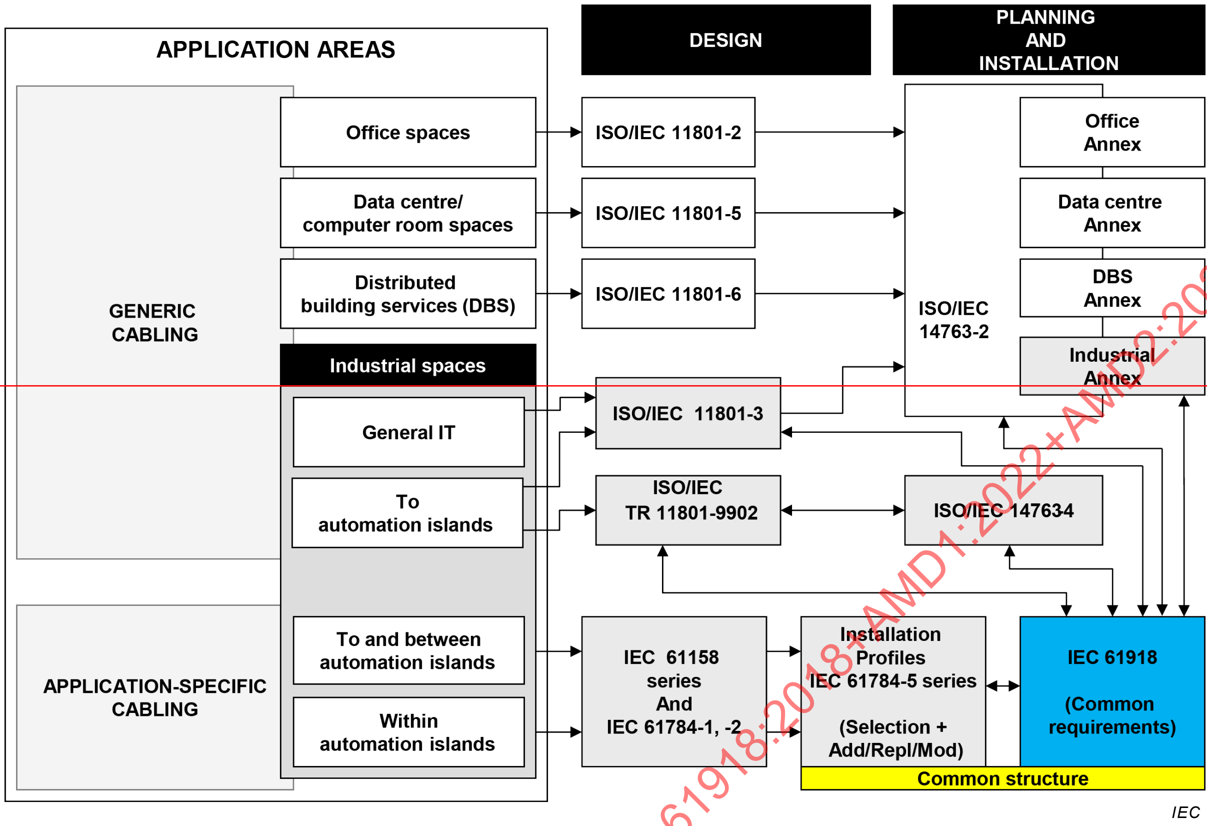
The installation of a communication system is supported by this document used in conjunction with the relevant installation profile. The installation profile establishes the technology-specific requirements in terms of which requirements apply as they are in this document, or which have been extended, modified, or replaced.

For the fieldbuses that are defined in the IEC 61784 (all parts) as communication profiles (CPs) of the communication profile families (CPF), the installation is specified in the installation profiles that are available in the IEC 61784-5-n documents, where n is the CPF number.
IEC 61158-1 describes the relationship between the fieldbus and the CPs and the relevant installation profiles (see Figure 2).

Those documents of IEC 61784-5 (all parts) that are still specified for use in conjunction with IEC 61918:2013 can also be used in conjunction with this edition 2018, provided that the user takes into account the fact that the reference to ISO/IEC 24702 has been replaced with a reference to ISO/IEC 11801-3:2017.

NOTE This solution applies for the Installation profiles that are affected only by this modified reference

For the installation of generic cabling in industrial premises, IEC 61918 is referenced to by ISO/IEC 14763-2 (see Figure 2).



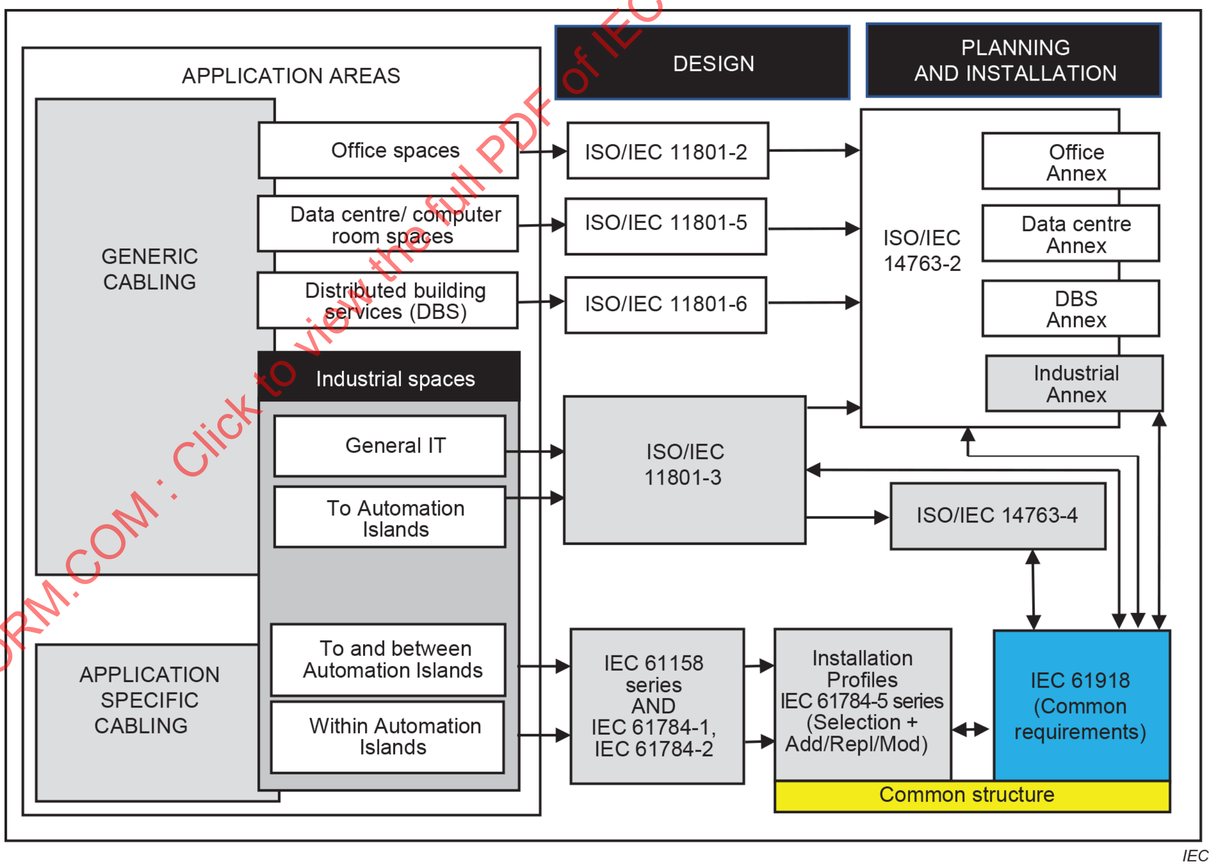


Figure 2 – Standards relationships

One of the advantages of this structure is that the users of a network know which installation requirements are common to most networks and which are specific to a particular network.

Every single plant/factory has its own installation needs in accordance with the specific critical conditions that apply to the specific application. This document and its companion standards described above provide a set of mandatory installation requirements ("shalls") and a number of recommendations ("shoulds"). It is up to the owner of the specific industrial enterprise to explicitly request that the cabling installation be implemented in accordance with these standards and to list all recommendations that shall be considered as mandatory requirements for the specific case.

INTRODUCTION to Amendment 1

This Amendment 1 describes the installation in the critical environment of industrial premises of balanced 1-pair networks that use cabling in connection with Ethernet specified in 1000BASE-T1 type A, which allows bidirectional signal transmission at 1 000 Mbit/s up to 15 m, 1000BASE-T1 type B for 1 000 Mbit/s up to 40 m, 100BASE-T1 for 100 Mbit/s up to 15 m, 10BASE-T1S for 10 Mbit/s up to 15 m, 10BASE-T1L for 10 Mbit/s up to 1 000 m.

These balanced 1-pair networks use the industrial versions of 1 000 Mbit/s and 100 Mbit/s ISO/IEC/IEEE 8802-3:2021, and 10 Mbit/s IEEE Std 802.3cg networks.

INTRODUCTION to Amendment 2

This Amendment 2 describes the result of the maintenance activity of IEC 61918:2018 that takes into account the evolution of the technology, which is being considered during the Installation Profiles revision cycle.

The following technical changes were made in IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024:

a) Subclauses 4.1.2, 4.1.3, 4.2.1.2, 4.2.2, 4.2.3.2, 4.3.2.1, 4.3.2.3, 4.4.1.2.1, 4.4.2.2, 4.4.2.5. 4.4.3.1, 4.4.3.2.1, 4.4.3.4.1, 4.4.7.1.4, 4.4.7.3.1, 5.1.1, 5.7, 6.1, 6.2.8.3, 6.3.2.1.2 and 8.3.3 have been updated;

b) Annex O has been modified by replacing the references to ISO/IEC TR 11801-9902 with references to ISO/IEC 11801-3:2017/AMD1:2021;

c) Table B.3 has been updated;

d) Clause B.6 has been added;

e) Annexes D, I, J, K and M have been updated;

f) Annex Q has been added.

INDUSTRIAL COMMUNICATION NETWORKS –

Installation of communication networks in industrial premises

1 Scope

This document specifies basic requirements for the installation of media for communication networks within and between the automation islands, of industrial sites. This document covers balanced and optical fibre cabling. It also covers the cabling infrastructure for wireless media, but not the wireless media itself. Additional media are covered in IEC 61784-5 (all parts).

This document is a companion standard to the communication networks of the industrial automation islands and especially to the communication networks specified in IEC 61158 (all parts) and IEC 61784 (all parts).

In addition, this document covers the connection between the generic telecommunications cabling specified in ISO/IEC 11801-3 and the specific communication cabling of an automation island, where an automation outlet (AO) replaces the telecommunication outlet (TO) of ISO/IEC 11801-3.

NOTE If the interface used at the AO does not conform to that specified for the TO of ISO/IEC 11801-3, the cabling no longer conforms to ISO/IEC 11801-3 although certain features, including performance, of generic cabling may be retained.

This document provides guidelines that cope with the critical aspects of the industrial automation area (safety, security and environmental aspects such as mechanical, liquid, particulate, climatic, chemicals and electromagnetic interference).

~~This document does not recognise implementations of power distribution with or through Ethernet balanced cabling systems.~~

This document deals with the roles of planner, installer, verifier, and acceptance test personnel, administration and maintenance personnel and specifies the relevant responsibilities and/or gives guidance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

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

IEC 60364-4-44, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

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

IEC 60512-29-100, *Connectors for electronic equipment – Tests and measurements – Part 29-100: Signal integrity tests up to 500 MHz on M12 style connectors – Tests 29a to 29g*

~~IEC 60603 (all parts), *Connectors for electronic equipment*~~

IEC 60603-7 (all parts), *Connectors for electronic equipment – Part 7: Detail specification for 8-way, unshielded, free and fixed connectors*

IEC 60757, *Code for designation of colours*

IEC 60793 (all parts), *Optical fibres*

IEC 60793-2-10, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*

IEC 60794 (all parts), *Optical fibre cables*

IEC 60807-2, *Rectangular connectors for frequencies below 3 MHz – Part 2: Detail specification for a range of connectors, with assessed quality, with trapezoidal shaped metal shells and round contacts – Fixed solder contact types*

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

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*

IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

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

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

IEC 61010-2-201, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-201: Particular requirements for control equipment*

IEC 61010-2-203:—[1], *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-203: Particular requirements for industrial communication circuits and communication port interconnection*

IEC 61076-2-101, *Connectors for electronic equipment – Product requirements – Part 2-101: Circular connectors – Detail specification for M12 connectors with screw-locking*

IEC 61076-2-104, *Connectors for electronic equipment – Product requirements – Part 2-104: Circular connectors – Detail specification for circular connectors with M8 screw-locking or snap-locking*

[1] Under preparation. Stage at the time of publication: IEC/ACDV 61010-2-203:2021.

IEC 61076-2-109, *Connectors for electronic equipment – Product requirements – Part 2-109: Circular connectors – Detail specification for connectors with M 12 x 1 screw-locking, for data transmission frequencies up to 500 MHz*

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

IEC 61076-3-122, *Connectors for electrical and electronic equipment – Product requirements – Part 3-122: Detail specification for 8-way, shielded, free and fixed connectors for I/O and data transmission with frequencies up to 500 MHz and current-carrying capacity in industrial environments*

IEC 61076-3-124, *Connectors for electrical and electronic equipment – Product requirements – Part 3-124: Rectangular connectors – Detail specification for 10-way, shielded, free and fixed connectors for I/O and data transmission with frequencies up to 500 MHz*

IEC 61076-3-106, *Connectors for electronic equipment – Product requirements – Part 3-106: Rectangular connectors – Detail specification for protective housings for use with 8-way shielded and unshielded connectors for industrial environments incorporating the IEC 60603-7 series interface*

IEC 61076-3-117, *Connectors for electronic equipment – Product requirements – Part 3-117: Rectangular connectors – Detail specification for protective housings for use with 8-way shielded and unshielded connectors for industrial environments incorporating the IEC 60603-7 series interface – Variant 14 related to IEC 61076-3-106 – Push-pull coupling*

IEC 61156 (all parts), *Multicore and symmetrical pair/quad cables for digital communications*

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

IEC 61156-11, *Multicore and symmetrical pair/quad cables for digital communications – Part 11: Symmetrical single pair cables with transmission characteristics up to 600 MHz – Horizontal floor wiring – Sectional specification*

IEC 61156-12, *Multicore and symmetrical pair/quad cables for digital communications – Part 12: Symmetrical single pair cables with transmission characteristics up to 600 MHz – Work area wiring – Sectional specification*

IEC 61156-13:2023, *Multicore and symmetrical pair/quad cables for digital communications – Part 13: Symmetrical single pair cables with transmission characteristics up to 20 MHz – Horizontal floor wiring – Sectional specification*

IEC 61158 (all parts), *Industrial communication networks – Fieldbus specifications*

IEC 61158-2:~~2014~~2023, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

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

IEC 61753 (all parts), *Fibre optic interconnecting devices and passive components performance standard*

IEC 61753-1, *Fibre optic interconnecting devices and passive components performance standard – Part 1: General and guidance for performance standards*

IEC 61753-1-3, *Fibre optic interconnecting devices and passive components – Performance standard – Part 1-3: General and guidance for single-mode fibre optic connector and cable assembly for industrial environment, Category I*

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

IEC 61754-4, *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces – Part 4: Type SC connector family*

IEC 61754-20, *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces – Part 20: Type LC connector family*

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

IEC 61754-24, *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces – Part 24: Type SC-RJ connector family*

IEC 61784 (all parts), *Industrial communication networks – Profiles*

~~IEC 61784-1:—, *Industrial communication networks – Profiles – Part 1: Fieldbus profiles*[2]~~

IEC 61784-1-x, *Industrial networks – Profiles – Part 1-x: Fieldbus profiles*

~~IEC 61784-2:—, *Industrial communication networks – Profiles – Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3*[3]~~

IEC 61784-2-x, *Industrial networks – Profiles – Part 2-x: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3*

IEC 61784-3 (all parts), *Industrial communication networks – Profiles – Part 3: Functional safety fieldbuses – General rules and profile definitions*

IEC 61784-5 (all parts), *Industrial communication networks – Profiles – Part 5: Installation of fieldbuses*

IEC 61935-1:~~2015~~2019, *Specification for the testing of balanced and coaxial information technology cabling – Part 1: Installed balanced cabling as specified in ISO/IEC 11801-1 and related standards*

IEC 61935-1-1:2019, *Specification for the testing of balanced and coaxial information technology cabling – Part 1-1: Additional requirements for the measurement of transverse conversion loss and equal level transverse conversion transfer loss*

IEC 61935-2, *Specification for the testing of balanced and coaxial information technology cabling – Part 2: Cords as specified in ISO/IEC 11801 and related standards*

IEC 62439 (all parts), *Industrial communication networks – High availability automation networks*

~~[2] Under preparation. Stage at the time of publication: IEC/FDIS 61784-1:2018~~

~~[3] Under preparation. Stage at the time of publication: IEC/FDIS 61784-2:2018.~~

IEC 62443 (all parts), *Security for industrial automation and control systems*[4]

IEC 62708, *Documents kinds for electrical and instrumentation projects in the process industry*

IEC 63171-2:2021, *Connectors for electrical and electronic equipment – Part 2: Detail specification for 2-way, shielded or unshielded, free and fixed connectors: mechanical mating information, pin assignment and additional requirements for type 2*

IEC 63171-5:2022, *Connectors for electrical and electronic equipment – Part 5: Detail specification for 2-way M8 and M12 circular connectors, shielded or unshielded, free and fixed – Mechanical mating information, pin assignment and additional requirements for Type 5*

IEC 63171-6, *Connectors for electrical and electronic equipment – Part 6: Detail specification for 2-way and 4-way (data/power), shielded, free and fixed connectors for power and data transmission with frequencies up to 600 MHz*

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

ISO/IEC 11801 (all parts), *Information technology – Generic cabling for customer premises*

ISO/IEC 11801-1:2017, *Information technology – Generic cabling for customer premises – Part 1: General requirements*

ISO/IEC 11801-3:2017, *Information technology – Generic cabling for customer premises – Part 3: Industrial premises*
ISO/IEC 11801-3:2017/AMD1:2021

~~ISO/IEC TR 11801-9902:2017, *Information technology – Generic cabling for customer premises – Part 9902: Specifications for End-to-end link configurations*~~

ISO/IEC 14763-2:~~2012~~2019, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*
~~ISO/IEC 14763-2:2012/AMD1:2015~~[5]

ISO/IEC 14763-3:2014, *Information technology – Implementation and operation of customer premises cabling – Part 3: Testing of optical fibre cabling*
ISO/IEC 14763-3:2014/AMD1:2018

ISO/IEC 14763-4:~~2018~~2021, *Information technology – Implementation and operation of customer premises cabling – Part 4: Measurement of end-to-end (E2E) links, modular plug terminated links (MPTL) and direct attach cabling*

ISO/IEC TS 29125:2017, *Information Technology – Telecommunications cabling requirements for remote powering of terminal equipment*
ISO/IEC TS 29125:2017/AMD1:2020

EN 50174-2, *Information technology – Cabling installation – Part 2: Installation planning and practices inside buildings*

4 Check http://webstore.iec.ch for the published parts. Other parts are under consideration.

~~5 A consolidated version of this publication exists, comprising ISO/IEC 14763-2:2012 and ISO/IEC 614763-2:2012/AMD 1:2015.~~

EN 50310, *Application of Equipotential Bonding and Earthing in Buildings with Information Technology Equipment*

IEEE Std 802.3-~~2015~~2022, ~~*IEEE*~~ *Standard for Ethernet,* available at http://www.ieee.org

NOTE 1 The contents of IEEE Std 802.3cg have been integrated in IEEE Std 802.3-2022, Clause 146.

NOTE 2 Physical Layer specifications for 100BASE-T1 and 1000BASE-T1 are provided in IEEE Std 802.3-2022, Clause 96 and Clause 97 respectively.

ANSI/(NFPA) T3.5.29 R1-2007, *Fluid power systems and components – Electrically-controlled industrial valves – Interface dimensions for electrical connectors*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61158 (all parts), IEC 61784 (all parts), ISO/IEC/IEEE 8802-3:2021, ISO/IEC 11801-1, and ISO/IEC 11801-3, some of which have been repeated here for convenience of the user, and the following apply.

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

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

3.1.1
acceptance test
contractual test to prove to the customer that the installed cabling meets certain conditions of its specification

Note 1 to entry The network owner or a third party usually performs this action.

[SOURCE: IEC 60050-151:2001, 151-16-23, modified – "Item" has been changed to "installed cabling" and Note 1 to entry has been added]

3.1.2
active network element
network element containing electrically and/or optically active components that allows extension of the network

Note 1 to entry: Examples of active network elements are repeaters and switches.

3.1.3
active network
network in which data transmission between non-immediately-connected devices is dependent on active elements within those intervening devices that form the connection path

Note 1 to entry: A failure of an active network element can disrupt the network communications.

3.1.4
administration
methodology defining the documentation requirements of a cabling system and its containment, the labelling of functional elements and the process by which moves, additions and changes are recorded

3.1.5
apparatus
one or more pieces of equipment having specific and defined overall functions within industrial premises served by one or more network interfaces

Note 1 to entry: This definition applies only to IT equipment. It does not apply to devices that implement automation functions.

[SOURCE: ISO/IEC 11801-3:2017, 3.1.1, modified – Note 1 to entry has been added]

3.1.6
automation island
AI
premises where combination of all systems that control, monitor, and protect the process of a plant is installed

Note 1 to entry: A plant may contain one or more AIs. Examples of a plant that has more than one AI are: a plant that is divided in various distinct physical (geographical) areas, or a plant that is composed of several distinct processes, or a plant where a large process is divided in various distinct sub-processes.

3.1.7
automation island attachment cabling
AI attachment cabling
cabling used to connect the automation outlet (AO) to the network interface (NI) for the automation island

3.1.8
automation island network
network used for the communication within and among systems of an AI

3.1.9
automation outlet
AO
fixed connecting hardware which provides an interface to the network(s) of an automation island

Note 1 to entry: For generic cabling in accordance with ISO/IEC 11801-3, the AO replaces the TO and is the demarcation point between the generic communications cabling and the automation communication cabling.

Note 2 to entry: Where the interface used at the AO does not conform to that specified for the TO of ISO/IEC 11801-3, the generic cabling no longer conforms to ISO/IEC 11801-3.

3.1.10
balanced cable
cable consisting of one or more metallic symmetrical cable elements (twisted pairs or quads)

Note 1 to entry: There is a great variety of shielded cable and unshielded cable construction and a number of systems to identify these constructions in a shortened form. See ISO/IEC 11801-1:2017, Annex D for acronyms to use.

[SOURCE: ISO/IEC 11801-1:2017, 3.1.12, modified – Note 1 to entry has been added]

3.1.11
bonding
act of connecting together exposed conductive parts and extraneous conductive parts of apparatus, systems, or installations that are at essentially the same potential

Note 1 to entry: For safety purposes, bonding generally involves (but not necessarily) a connection to the immediately adjacent earthing system.

[SOURCE: IEC TR 61000-5-2:1997, 3.1]

3.1.12
bridge
device, operating at the data link layer of the OSI model, used to connect two networks

3.1.13
bulkhead
wall or barrier which maintains the ingress and climatic environmental classifications applicable on either side

[SOURCE: ISO/IEC 11801-3:2017, 3.1.5]

3.1.14
bulkhead connector
connector assembly mounted to a bulkhead which provides electrical or optical signal pass-through while maintaining environmental integrity

3.1.15
bulkhead connection
one (or two) optical or electrical connection(s) within a bulkhead connector assembly

3.1.16
bulkhead cable gland
hardware at an enclosure bulkhead that provides cable passage for power or signals while maintaining environmental integrity

Note 1 to entry: This hardware has no electrical connections.

3.1.17
bus
passive network having a long trunk and a number of spurs where each spur is used to connect a device to the trunk

Note 1 to entry: In a bus, all the communicating devices share a common medium to transfer data.

3.1.18
bus bar
low-impedance conductor to which several electric circuits can be connected at separate points

Note 1 to entry: In many cases, the bus bar consists of a bar.

[SOURCE: IEC 60050-151:2001, 151-12-30]

3.1.19
cable
assembly of one or more conductors and/or optical fibres, with a protective covering and possibly filling, insulating and protective material

[SOURCE: IEC 60050-151:2001, 151-12-38]

3.1.20
cable gland
installation hardware designed to permit the entry of a cable into an enclosure and which provides sealing and retention

[SOURCE: IEC 60670-1:2015, 3.10, modified – Definition has been adapted for all kinds of cables]

3.1.21
cabling
system of communication cables, cords and connecting hardware that can support the connection of automation equipment

[SOURCE: ISO/IEC 11801-1:2017, 3.1.21, modified – A reference to automation equipment has been added]

3.1.22
channel
end-to-end transmission path connecting any two pieces of application specific equipment

Note 1 to entry: Equipment cords are included in the channel, but not the connecting hardware into the application specific equipment.

Note 2 to entry: Channels specified in this document may only comprise passive components.

[SOURCE: ISO/IEC 11801-1:2017, 3.1.26, modified – Note 1 to entry and Note 2 to entry have been added]

3.1.23
condition-based (conditional) maintenance
preventive activity performed on the basis of the documentation of the performance degradation of an item (as results of, for example, auto diagnostic or wear measurement)

Note 1 to entry: It is based on a proper visibility of performance degradation or intermittent failures.

3.1.24
connection (of conductors)
intentional electric contact between conductors

[SOURCE: IEC 60050-151:2001, 151-12-07, modified – Text referring to conductors has been selected]

3.1.25
connection (of optical fibres)
intentional alignment between optical fibres to allow light to pass through

[SOURCE: IEC 60050-151:2001, 151-12-07, modified – Text has been adapted to cover optical fibres.]

3.1.26
connector
<conductors> component providing conductor connection and disconnection

Note 1 to entry: The connector is the mated pair.

Note 2 to entry: A connector has one or more contact members.

[SOURCE: IEC 60050-151:2001, 151-12-19, modified – The definition has been adapted and Note 1 to entry has been added]

3.1.27
connector
<optical fibres> component normally attached to an optical cable or piece of apparatus, for the purpose of providing optical interconnection/disconnection of optical fibres or cables

Note 1 to entry: The connector is the mated pair.

Note 2 to entry: The connector usually consists of two plugs mated together in an adaptor.

3.1.28
cord
cable, cable unit, or cable element, with a minimum of one termination

[SOURCE: ISO/IEC 11801-1:2017, 3.1.36]

3.1.29
corrective maintenance
maintenance carried out after a fault recognition and intended to put an item into a state in which it can perform a required function

[SOURCE: IEC 60050-191:1990[6], 191-07-08]

3.1.30
daisy chain
bus where each passive network interface connects two trunk sections and provides a DC coupling between those sections

Note 1 to entry: One of the sections may be a bus terminator.

Note 2 to entry: With regard to the use of "daisy chain" term for active networks, see the definition given for linear topology.

3.1.31
device
physical entity connected to the fieldbus composed of communication element and possibly other functional elements

[SOURCE: IEC 61158-2:2014, 3.1.13, modified – Some details have been deleted.]

3.1.32
distributor
functional element enabling the termination and connection of cabling subsystems to other cabling subsystems or transmission equipment

[SOURCE: ISO/IEC 11801-1: 2017, 3.1.41]

3.1.33
earth (noun), en GB
ground (noun), en US
conductive mass of the Earth, whose electric potential at any point is conventionally taken as zero

[SOURCE: IEC 61131-2: 2017, 3.1.10]

3.1.34
earth (verb), en GB
ground (verb), en US
make an electric connection between a given point in a system or in an installation or in equipment and a local earth

Note 1 to entry: The connection to local earth may be intentional, or unintentional or accidental.

Note 2 to entry: The connection may be permanent or temporary.

[6] Withdrawn.

[SOURCE: IEC 60050-195:1998, 195-01-08]

3.1.35
enclosure
housing affording the type and degree of protection suitable for the intended application

[SOURCE: IEC 61131-2: 2017, 3.1.13]

3.1.36
end-to-end link
E2E link
end to end transmission path formed by structured cabling based on passive components including the portion of the end connection that is attached to the link and the portion of the end connection that is attached to the end equipment

[SOURCE: ISO/IEC TR 11801-9902:2017, 3.1.1]

3.1.37
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality

[SOURCE: IEC 60050-195:1998, 195-01-10]

3.1.38
equipotential bonding system
interconnection of conductive parts providing equal potential between those parts

Note 1 to entry: If an equipotential bonding system is earthed, it forms part of an earthing arrangement.

[SOURCE: IEC 60050-195:1998, 195-02-22]

3.1.39
failure
termination of the ability of an item to perform a required function

Note 1 to entry: After failure, the item has a fault.

Note 2 to entry: Failure is an event, as distinguished from fault, which is a state.

[SOURCE: IEC 60050-191:1990, 191-04-01]

3.1.40
fault
state characterized by the inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

Note 1 to entry: IEC 61508-4 defines fault as an abnormal condition that may cause a reduction in, or loss of, the capability of a functional unit to perform a required function.

[SOURCE: IEC 60050-191:1990, 191-05-01, modified – Note 1 to entry has been changed and Note 2 to entry has been deleted]

3.1.41
functional earth, en GB
functional ground, en US
earthing point or points in a system or in an installation or in equipment, used for purposes other than electrical safety

[SOURCE: IEC 60050-195:1998, 195-01-13]

3.1.42
high flex cable
cable that can withstand high number of repeated flexes (usually millions of cycles) while maintaining the specified performance

3.1.43
inactive metal part
any non-current carrying metal that may be contacted by a person

3.1.44
inspection
taking measures for the observation and evaluation of the actual condition

3.1.45
intermediate cable
cable connecting the intermediate distributor to the telecommunication outlet

[SOURCE: ISO/IEC 11801-3:2017, 3.1.9]

3.1.46
intermediate distributor
distributor used to make connections between the intermediate cable, other cabling subsystems and active equipment

[SOURCE: ISO/IEC 11801-3:2017, 3.1.10]

3.1.47
intermediate industrial distributor
intermediate distributor used to make connections to and between automation islands and transmit critical process control, monitoring and automation data (PCMA) between them

[SOURCE:ISO/IEC 11801-3:2017, 3.1.11]

3.1.48
jack
part of the connector which mates with a plug

Note 1 to entry: This document uses the term jack to refer to a fixed connector.

[SOURCE: IEC 60050-581:2008, 581-26-24, modified – Text has been adapted for automation applications and Note 1 to entry has been added]

3.1.49
jack-to-jack adaptor
J-J adaptor
back-to-back jacks that have one type of jack on one side and another type of jack on the other side and do not are on an enclosure/environmental barrier

3.1.50
jack-to-jack coupler
J-J coupler
back-to-back jacks that have the same type of jack on both sides and do not are on an enclosure/environmental barrier

3.1.51
linear topology
topology where the nodes are connected in series, with two nodes connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

Note 1 to entry: This topology corresponds to that of an open ring.

3.1.52
maintenance
combination of all technical and corresponding administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function

Note 1 to entry: See "preventive maintenance", and "corrective maintenance", for a more detailed definition of maintenance.

Note 2 to entry: The required function may be defined as a stated condition.

[SOURCE: IEC 60050-191:1990, 191-07-01, modified – "Administrative actions" has been replaced by"corresponding administrative actions" and the two notes to entry have been added]

3.1.53
maintenance intervention
taking measures for retaining the specified condition

3.1.54
mean time between failures
MTBF
expectation of the time between failures

[SOURCE: IEC 60050-191:1990, 191-12-08]

3.1.55
mean time to recovery
MTTR
expectation of the time to restoration

Note 1 to entry: In IEC 60050-191:1990, 191-13-08, the use of "mean time to repair" (MTTR) is deprecated.

[SOURCE: IEC 60050-191:1990, 191-13-08]

3.1.56
network
all of the media, connectors, repeaters, routers, gateways and associated node communication elements by which a given set of communicating devices are interconnected

[SOURCE: IEC 61158-2:2014, 3.1.30]

3.1.57
node
end-point of a branch in a network

3.1.58
passive network
network in which data transmission is independent of active elements within the device attached to the network

Note 1 to entry: Failure of a device does not affect the propagation of information.

3.1.59
pathway
cable route used to accommodate cables between termination points

Note 1 to entry: The cable route (e.g., conduit, ductwork, tray, or tube) is defined by a physical structure.

[SOURCE: ISO/IEC 14763-2:2012, 3.1.43, modified – The definition has been adapted and Note 1 to entry has been added.]

3.1.60
permanent link
transmission path between distributors or between the telecommunications/automation outlet and the intermediate distributor

Note 1 to entry: It excludes apparatus attachment cords, equipment cords, patch cords and jumpers but includes the connection at each end.

Note 2 to entry: This is a modification to the definition of ISO/IEC 11801 in order to allow it be used for the CPs in accordance with IEC 61784-5 (all parts).

[SOURCE: ISO/IEC 11801-1:2017, 3.1.69, modified – The definition and Note 1 to entry have been adapted and Note 2 to entry has been added]

3.1.61
plug
connector used to make connections to a jack

Note 1 to entry: This document uses the term plug to refer to a free connector.

3.1.62
preventive maintenance
maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item

[SOURCE: IEC 60050-191:1990, 191-07-07]

3.1.63
protective earthing conductor
protective conductor provided for protective earthing

[SOURCE: IEC 60050-195:1998, 195-02-11]

3.1.64
quad
cable element that comprises four insulated conductors twisted together

Note 1 to entry: Two diametrically facing conductors form a transmission pair also referred to as a side circuit.

[SOURCE: ISO/IEC 11801-1:2017, 3.1.75]

3.1.65
RC earthing
earthing via a parallel RC circuit

3.1.66
recovery (of a high resilience item)
event when an item regains its specified degree of communication performance and fault resilience after correction of a fault

Note 1 to entry: High availability networks provide resilience to enable acceptable communication to continue after one fault and possibly after multiple faults.

3.1.67
repair
take measures for the re-establishment of the specified condition

3.1.68
repeater
two-port active physical layer device that receives and retransmits all signals to increase the distance and number of devices for which signals can be correctly transferred for a given medium

[SOURCE: IEC 61158-2:2014, 3.1.38]

3.1.69
resistance to earth
real part of an impedance to earth

[SOURCE: IEC 60050-195:1998, 195-01-18]

3.1.70
restoration
state when a communication network regains its designed level of resilience redundancy

3.1.71
ring
active network where each node is connected in series to two other nodes

3.1.72
scheduled maintenance
preventive activity (time or number-of-actions directed) performed either on predefined schedule or on units of use (e.g. number of start-ups)

[SOURCE: IEC 60050-191:1990, 191-07-10, modified – The definition has been adapted and a reference to units of use has been added]

3.1.73
segment
trunk-cable section of a network that is terminated at both ends by its characteristic impedance

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

[SOURCE: IEC 61158-2:2014, 3.1.39 modified – The definition and the note to entry have been adapted]

3.1.74
shield (of a cable), en US
screen (of a cable), en GB
surrounding metallic layer to confine the electromagnetic field within the cable and to protect the cable from external electrical influence

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

Note 2 to entry: For generic cabling in industrial premises, ISO/IEC 11801-3 uses the term screen instead of shield.

Note 3 to entry: See also Note 1 to entry of the balanced cable definition.

[SOURCE: IEC 61158-2:2014, 3.1.41 modified – The definition has been adapted and the term screen has been added; Notes 2 and 3 to entry have been added]

3.1.75
(optical fibre or electrical conductor) splice
a permanent, or semi-permanent, joint whose purpose is to couple optical power between two optical fibres or to joint two electrical conductors

Note 1 to entry: Joining without connectors.

3.1.76
spur
branch-line (i.e. a link connected to a larger one at a point in its route) that is a final circuit

Note 1 to entry: The alternative term "drop cable" is used in IEC 61158.

[SOURCE: IEC 61158-2:2014, 3.1.42]

3.1.77
star
network of three or more devices where all devices are connected to a central point (which may be active or passive)

3.1.78
tap
point of attachment from a node or spur to the trunk cable

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

[SOURCE: IEC 61158-2:2014, 3.3.34]

3.1.79
telecommunication outlet
TO
fixed connecting device which provides an interface to the terminal equipment

[SOURCE: ISO/IEC 11801-1:2017, 3.1.80]

3.1.80
terminator
entity used to terminate a transmission line in its characteristic impedance to prevent reflections

Note 1 to entry: In some instances, the terminator may be embedded in an end device or in a connector.

[SOURCE: IEC 61158-2:2014, 3.1.43, modified – The definition and Note 1 to entry have been modified]

3.1.81
(network) topology
pattern of the relative positions and interconnections of the individual elements (of the network)

Note 1 to entry: The term topology is sometimes overloaded to include considerations of the delay, attenuation and physical media classes of the paths interconnecting network nodes.

[SOURCE: IEC 60050-131:2002, 131-13-02, modified – Text has been adapted for communication networks and a Note 1 to entry has been added]

3.1.82
troubleshooting
locating the fault(s)

3.1.83
trunk
main communication highway acting as a source of main supply to a number of other lines (spurs)

[SOURCE: IEC 61158-2:2014, 3.1.46]

3.1.84
validation
part of the acceptance test that is solved with measurements

3.1.85
verification
action to assess that an installation is in accordance with its specification

Note 1 to entry: The installer usually performs this action.

Note 2 to entry: This action usually covers verification of component correct selection, physical layout, communication earthing, isolation and continuity of network components.

3.1.86
wire map
mapping of connector pin-to-pin terminations of a cable

3.1.87
balanced 1-pair cable
cable consisting of a single pair of conductors, optional screen, and overall jacket, primarily intended for use in differential-mode signal transmission and power delivery applications

[SOURCE: ISO/IEC TR 11801-9906:2020, 3.1.2]

3.1.88
balanced 1-pair cabling
cabling composed of balanced 1-pair cables and balanced 1-pair connectors

3.1.89
balanced 1-pair cabling channel
transmission path between equipment constructed from balanced 1-pair cables, balanced 1-pair connectors and balanced 1-pair cable assemblies to facilitate signal and power delivery

[SOURCE: ISO/IEC 11801-3:2017/AMD1:2021, 3.1.14]

3.1.90
balanced 1-pair connector
connector intended for use with balanced 1-pair cable in differential-mode signal transmission and power delivery applications

[SOURCE: ISO/IEC TR 11801-9906:2020, 3.1.3]

3.1.91
balanced 1-pair cord
cable assembly constructed from a 1-pair cable and 1-pair connectors

[SOURCE: ISO/IEC TR 11801-9906:2020, 3.1.4]

3.1.92
edge distributor
optional additional distributor to accommodate active equipment to allow transition from balanced 4-pair cabling to balanced 1-pair cabling

[SOURCE: ISO/IEC 11801-3:2017/AMD1:2021, 3.1.15]

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

AC	Alternating current
A.I.	Action item
AI	Automation island
AO	Automation outlet
AWG	American Wire Gauge
BD	Building distributor (ISO/IEC 11801-1)
BER	Bit error rate
BFOC	Bayonet fibre optic connector
BNC	Bayonet Neill Concelman (connector for coaxial cable having a bayonet-type shell)
CBN	Common bonding network
CP	Communication profile (IEC 61784-1)
CPF	Communication profile family (IEC 61784-1)
DC	Direct current
DCR	Direct current resistance
ED	edge distributor
EFT	Electrical fast transient
EFT/B	Electrical fast transient / burst (IEC 61000-4-4)
ELFEXT	Equal level far-end crosstalk
ELTCTL	Equal level transverse conversion transfer loss
EMC	Electromagnetic compatibility (IEC 60050-161, 161-01-07)
EMI	Electromagnetic interference (IEC 60050-161, 161-01-06)
ESD	Electrical static discharge
E2E	End-to-end
FD	Floor distributor (ISO/IEC 11801-1)
FE	Functional earth
ffs	For further study
FI	Fieldbus interface
FOC	Fibre optical connector
F-SMA	Fibre sub miniature version A (IEC 61754-22)
HP	Horse power
ID	Intermediate distributor
IDC	Insulation displacement contact
IID	Industrial intermediate distributor
IP	International protection (IEC 60529)

J-J	Jack-to-jack
kbit/s	One thousand bits per second
LC	Optical fibre connector in accordance with IEC 61754-20
LV	Low voltage
Max.	Maximum
Mbit/s	Million bits per second
MD	Machine distributor (ISO/IEC 11801-1)
MDI	Medium dependent interface (IEEE 802.3)
MDIX	Medium dependent crossover interface (IEEE 802.3)
MHV	Medium high voltage
MICE	Mechanical, Ingress, Climatic and Chemical, Electromagnetic (ISO/IEC 11801-1)
Min.	Minimum
MTBF	Mean time between failures
MTTR	Mean time to repair (use deprecated in IEC 60050-191:1990, 191-13-08) replaced with mean time to recovery
N	Neutral
NA	Numerical aperture (IEC 60793 (all parts))
na	Not available
NEXT	Near end crosstalk loss
NI	Network interface (ISO/IEC 11801-3)
No.	Number
OF	Optical fibre
OMx	Cabled multimode optical fibre category x; where x=1, 2, 3, 4
OSx	Cabled single mode optical fibre category x; where x=1, 1a, 2
PE	Protective earthing conductor (IEC 60050-195:1998, 195-02-11)
PHY	Physical layer
P&ID	Pipe and instrumentation diagram
PMA	Physical medium attachment (IEEE 802.3)
PoE	Power over Ethernet
POF	Plastic optical fibre
PSELFEXT	Power sum equal-level far-end crosstalk loss
RC	Resistor-capacitor (circuit)
Rep	Repeater
SC	Optical fibre connector in accordance with IEC 61754-4
SC-RJ	Optical fibre connector in accordance with IEC 61754-24
TCL	Transverse conversion loss
TNC	Threaded Neill Concelman (threaded version of the BNC connector)
TO	Telecommunication outlet
UV	Ultraviolet
Var.	Variant

3.3 Conventions for installation profiles

Conventions for installation profiles are described in IEC 61784-5 (all parts).

4 Installation planning

4.1 General

4.1.1 Objective

Clause 4 addresses the planning of cabling and associated infrastructures to support communication networks used between and within automation islands in industrial premises.

4.1.2 Cabling in industrial premises

The cabling may comprise:

- automation communication cabling for use within or between AIs as specified in the communication profiles of IEC 61784-1 or IEC 61784-2 and in the relevant installation profiles of IEC 61784-5 (all parts); this includes the balanced 1-pair cablings that are specified in Annex Q;
- generic telecommunications cabling for industrial premises as specified in ISO/IEC 11801-3 (see Annex A);
- elements of generic cabling modified to meet the needs of automation communication cabling within an AI in accordance with the installation profiles of IEC 61784-5 (all parts);
- the apparatus attachment cabling between the TO and the AI in accordance with ISO/IEC 11801-3 with regard to the connection and with this document with regard to the cables;
- the AI attachment cabling between the AO and the AI in accordance with this document and the relevant installation profile(s) of IEC 61784-5 (all parts).

ISO/IEC 11801-3 specifies the structure of generic cabling connected to an AI where the TO interface allows connection of wide range of networking equipment.

Where a designated connection from generic cabling to automation communication cabling within an AI is desired, an AO specified within this document may replace the TO, as shown in Figure 3. The industrial cabling may include an edge distributor to accommodate active equipment to allow transition from balanced 4-pair cabling to balanced 1-pair cabling.

An AI may contain (see Figure 4)

- one or more industrial automation apparatus conforming to generic cabling requirements,
- one or more industrial automation applications implemented with an AI network that uses Ethernet (ISO/IEC/IEEE 8802-3)-based and non-Ethernet-based cabling that conform to IEC 61784-1 or IEC 61784-2.

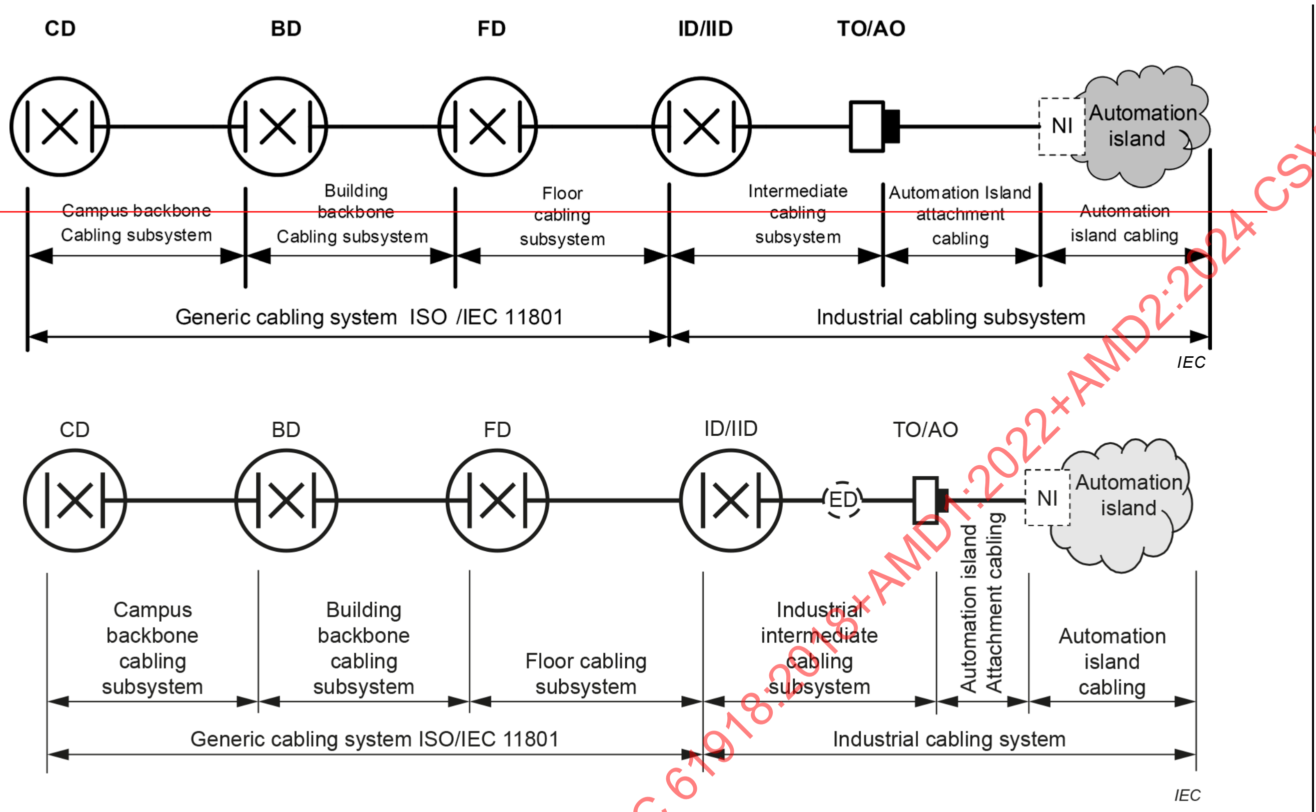


Figure 3 – Automation island cabling attached to elements of generic cabling

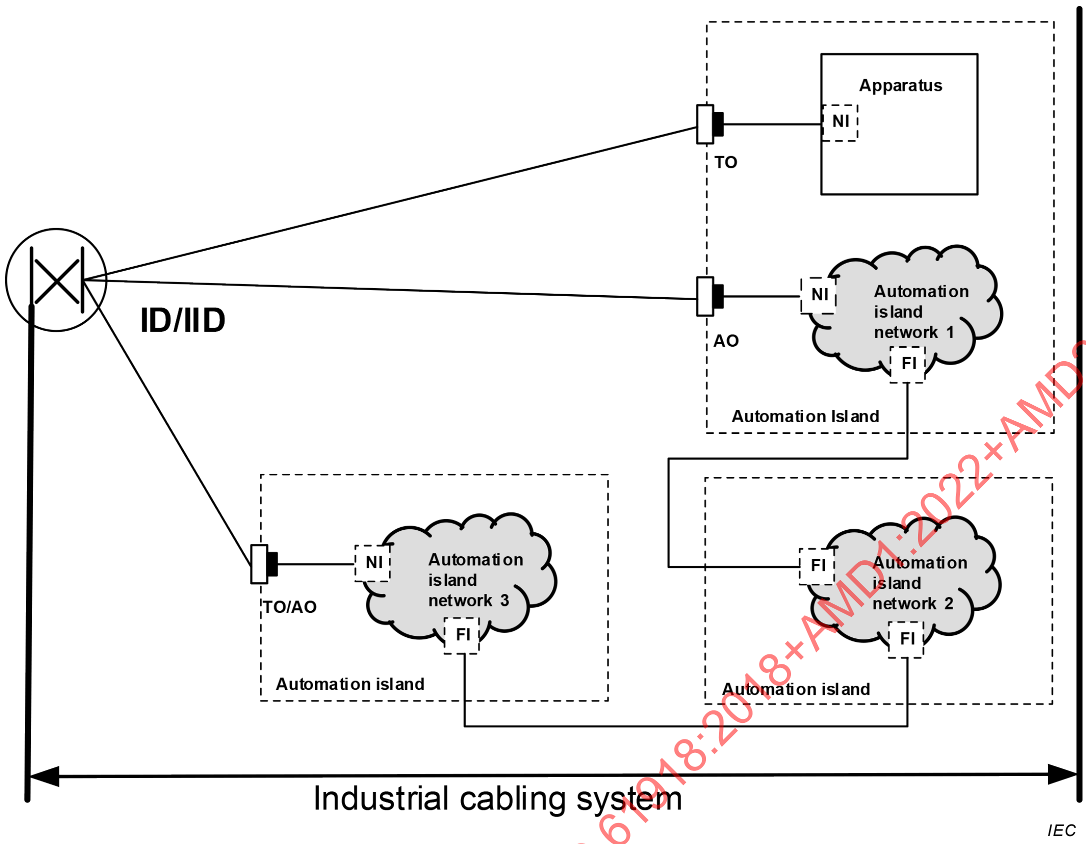


Figure 4 – Automation islands

The interconnections between the AI network and the generic cabling may be achieved through an appropriate converter/adapter (see Figure 5), while the connections among AIs may be achieved through one or more fieldbus to fieldbus connections (defined in the installation profiles in IEC 61784-5 (all parts)) and appropriate converter/adapters or through the generic cabling (see Figure 4).

In general, converter/adapters, such as routers, bridges, and gateways, shall be used to provide physical conversion and protocol transformation between different fieldbuses as specified in the relevant CP installation profiles. If the two interconnected interfaces (NI and FI) have matching specifications, then the converter/adapter function may not be necessary.

If the interconnection between the AIs is through the intermediate distributor/intermediate industrial distributor (ID/IID in Figure 4), it is the responsibility of the planner to check the suitability of the generic cabling to support the requirements for the installation of the communication networks as defined by this document. In this case, the channel performance shall be met from the ID/IID up to the NI (excluding the connector interface at the NI).

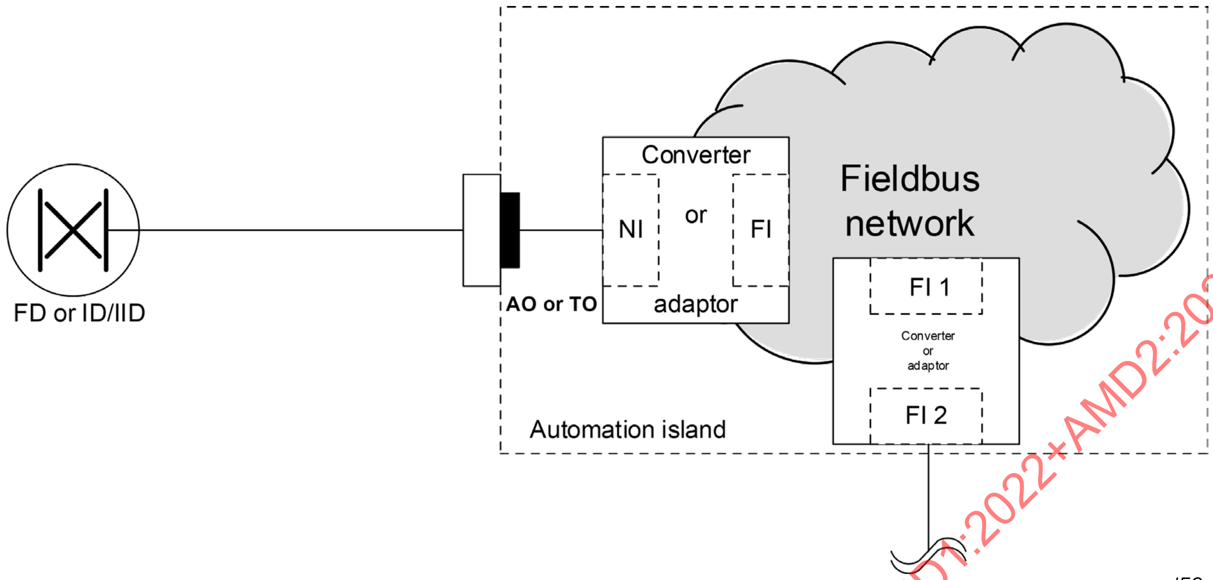


Figure 5 – Automation island network external connections

4.1.3 The planning process

The planning of the communication of an automation system is the responsibility (see Annex L) of one or more of the following: building network designer, automation designer and or machine designer.

The input for the installation planning depends on the kind of industrial automation application. This input is made up of general design requirements, operating manuals for machines or piping and instrumentation diagrams (P&ID) for process installations.

This input is made up of general design requirements, operating manuals for machines or piping and instrumentation diagrams (P&ID) for process installations according to IEC 62708.

Installation planning of industrial communication networks is accomplished through three basic steps.

Step 1 addresses the following installation-specific factors (see 4.2):

- safety
  - the solutions shall comply with existing local and national regulations. Under this condition, safety requirements specified in ~~IEC 60950-1~~ IEC 61010-2-201 may be taken into consideration;
  - if a communication network is installed with easily accessible terminals and wires, IEC 60364-4-41 concerning protection against electrical shock and EMC requirements should be applied;
  - intrinsic safe network is out of scope for this document but may be addressed in the CP installation profiles (IEC 61784-5 (all parts)).
- security;
- environmental
  - the use of the MICE (Mechanical, Ingress, Climatic and Chemical, and Electromagnetic) methodology for description of environmental performance, as described in 4.2.3, is recommended;
  - distinctive of industrial sites is the presence of low voltage (LV) and medium-high-voltage (MHV) power networks in close neighbourhood of the communication network.

The RF influence of neighbouring high-power transmitters (e.g. television transmitters) shall be taken into account;

- electromagnetic compatibility.

Step 2 addresses the capabilities of the different communication networks (see 4.3):

- topologies;
- network characteristics.

Step 3 addresses the selection and use of cabling components in response to steps 1 and 2 (see 4.4).

The result of the planning process in 4.2, 4.3 and 4.4 is the production of the cabling planning documentation described in 4.5, which shall comprise:

a) a statement, signed by the responsible planner, explaining how the planned installation complies with the safety and security requirements and environmental conditions such as mechanical, liquid, particulate, climatic, chemicals and electromagnetic interference and including all necessary documents (e.g. plans and lists) for the installation that result from step 1;
b) documentation of the planned network topology, characteristics, physical extension and transmission performances that results from step 2;
c) the component specifications, where the conformity of the component data with the planned network requirements (functional and electrical safety, environmental conditions, and EMC requirements) is documented as result of step 3;
d) a table for comparison of nominal and actual network performance values.

4.1.4 Specific requirements for CPs

Additional information for a specific industrial network may be found in the respective installation profile.

4.1.5 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.2 Planning requirements

4.2.1 Safety

4.2.1.1 General

The planner shall take into consideration regulations for safety in communication networks with specific attention to mounting, cabling, verification, and validation.

The planner shall include all applicable requirements for safety in the cabling planning documentation.

4.2.1.2 Electrical safety

The proper implementation of the requirements of this document assumes that electrical installations are in accordance with the relevant standards within IEC 60364 (all parts), IEC 61010-2-201, IEC 61010-2-203 or local and national regulations as required.

4.2.1.3 Functional safety

Where digital communications are used to contribute to one or more safety functions, the communication system should have sufficient integrity (taking into account hardware, software, and the specified environment) to meet the safety integrity requirements of every safety function.

For example, wiring used to support safety instrumented systems may require special installation practice (e.g. complete segregation from all other cabling) and labelling (e.g. special conduit colouring) to meet enhanced integrity requirements.

The requirements for safety integrity may include special measures applicable to the several phases of the life cycle of the related communication media (see the relevant technology parts of the IEC 61784-3 and/or IEC 61784-5 (all parts)). The planner shall apply such special measures.

4.2.1.4 Intrinsic safety

Where required, the planner shall plan the network in accordance with applicable intrinsic safety standards and IEC 61158-2 and the applicable CPs of IEC 61784-1.

4.2.1.5 Safety of optical fibre communication systems

Optical fibre cabling shall be planned in accordance with the safety requirements of IEC 60825-2 or local regulations.

4.2.2 Security

Where communication networks in accordance with IEC 62443 are planned, the planner shall apply all additional ~~requirements for security~~ technical and organizational measures aimed at mitigating the specific security risk for the communication subset identified during the security design of the whole automation system.

~~EXAMPLE A typical request is to use additional protection against mechanical manipulation and electromagnetic emission.~~

The universal nature of generic cabling produces additional security concerns since the cabling may be used to provide applications that are managed by different groups within industrial premises. For example, generic cabling may provide basic telephony services, information technology and building control services in addition to the connections to the AIs. The prevention of accidental disruption to any of these services requires careful consideration.

~~Physical security requires the application of requirements described in 4.4.9.1, 4.4.9.6, 4.4.11, 5.2.1.2.~~

IEC 62443 breaks down the design of security within a system to security levels based on risk level. For each level there are different measures. For this purpose, cabling, planning and installation play a role in implementing countermeasures and are central to achieving physical and environmental security countermeasures, in accordance with Clause 4 and Clause 5, in general, and requirements described in 4.4.9.1 (Routing of cables), 4.4.9.6 (Installing redundant communication cables), 4.4.11 (Mechanical protection of cabling components), 5.2.1.2 (Protecting communication cables against potential mechanical damage), in particular.

Moreover, the first security level defined in IEC 62443 requires that a protection against unintentional failures be implemented. An important contribution to this protection comes from the application of the rules for installation verification and installation acceptance tests, installation administration and installation maintenance and troubleshooting, described in Clause 6, Clause 7 and Clause 8, which reduce the risk of intermittent system malfunction due to incorrect cabling (e.g. insufficient implemented protection from electromagnetic interferences, instable connections, etc.).

4.2.3 Environmental considerations and EMC

4.2.3.1 Description methodology

The planner shall provide a precise description of the environment to be used as a basis for the selection of components and for the mitigation requirements.

ISO/IEC 11801-1 applies an environmental assessment called “MICE” classification. This approach is recommended for all CPs because it allows the planner to describe the environmental conditions in a precise and unambiguous way.

The use of this approach is explained here and in Annex B for the benefit of the planner and the installer.

NOTE 1 The MICE classification system of ISO/IEC 11801-1 is not a component test specification.

NOTE 2 The MICE classification system of ISO/IEC 11801-1 does not replace existing international or national standards.

NOTE 3 Existing international or national standards for components contain the test requirements and schedules for product qualification.

4.2.3.2 Use of the described environment to produce a bill of material

The planner shall produce a bill of material of components that meets the targeted environment through the following steps.

a) Establish the ambient environmental conditions for each significantly different region within the application space (for example, beside the machine, in the control room, between the above).
b) Define the components that make up the communications system including their environmental specifications.
c) Define the additional mitigation to bridge between the component(s) specifications and the targeted environment, if the component does not meet the targeted environment.

The planner shall provide the environmental description either through the use of the MICE tables (that provides a precise classification of the environment) or by an equivalent methodology. The planner shall address the environmental requirements by specifying a combination of component selection and mitigation techniques to be applied (see Figure 6).

Products, such as enclosures, necessary to provide mitigation shall also be included in the bill of material.

Compatibility of components can be met by any combination of the following three methods:

- installation related isolation (for example protection with enclosure);
- separation (for example physical separation from other components);
- component enhancement (design enhancement of the component parameters, for example by adding a cable shield or external shield). The supplier of the equipment may provide enhancements to the components reducing the installation requirements.

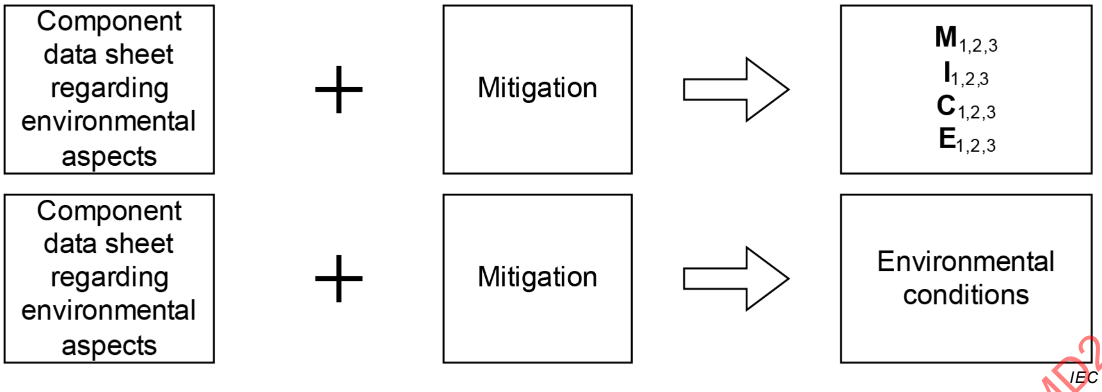


Figure 6 – How to meet environmental conditions

Figure 7 shows how the three methods (isolation, separation and enhancement) work together to provide a cost effective, technically feasible solution for a given application with regard to the environment. Examples of use of the MICE concept are provided in Annex B, where the meaning of the subscripts 1, 2, 3 is explained.

The planner, when consulting the device and cabling manufacturer, shall take into account the guidance provided in Clause B.6 for the correct selection of the device and cabling in relation to the environment EMI of the installation under consideration.

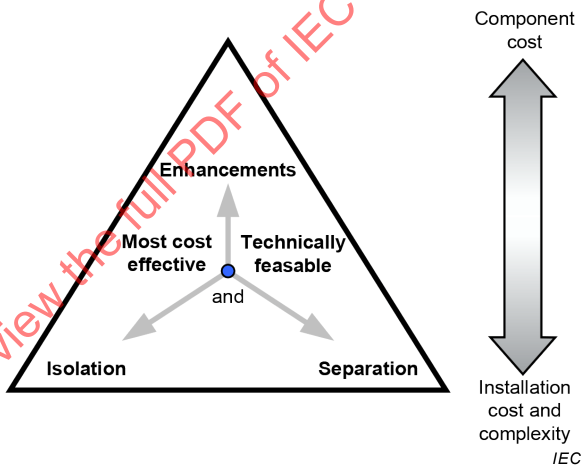


Figure 7 – How enhancement, isolation and separation work together

Passive optical components in the harsh industrial environment should be protected with suitable mitigation techniques or tested according to IEC 61753-1.

4.2.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.3 Network capabilities

4.3.1 Network topology

4.3.1.1 Common description

For the industrial AI networks, there are two fundamental themes.

a) Physical topology of the communication network, from a physical composition standpoint.

Hereafter the basic physical topologies of a network are divided in two groups:

– physical topology for passive networks;

– physical topology for active networks.

b) Logical topology of the communication network, from an information propagation standpoint. This is outside the scope of this document and may be covered by IEC 61784-1 and IEC 61784-2.

NOTE 1 As an example of the difference between the physical and the logical topology, a planner can select a physical star to be installed in order to support a logical ring topology.

The planner shall select the most appropriate physical topology on the basis of the application requirements (see also Annex C) and according to the topologies that are specified for the specific CP. The basic topologies defined in 4.3.1.2 and in 4.3.1.3, and combinations of them (see 4.3.1.4) are the appropriate physical topologies for AI networks.

NOTE 2 Not all fieldbuses support all the basic topologies and combination of them.

4.3.1.2 Basic physical topologies for passive networks

The basic physical topologies for passive network, represented in Figure 8, are the following.

- Bus
- Star

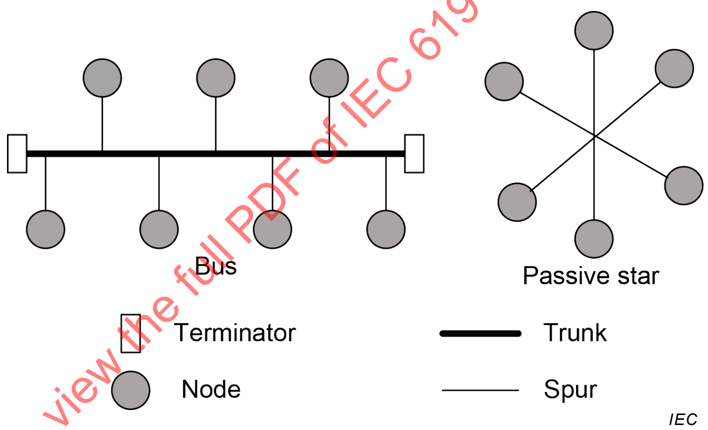


Figure 8 – Basic physical topologies for passive networks

4.3.1.3 Basic physical topologies for active networks

The basic physical topologies for active networks, represented in Figure 9, are the following.

- Star
- Ring
- Linear

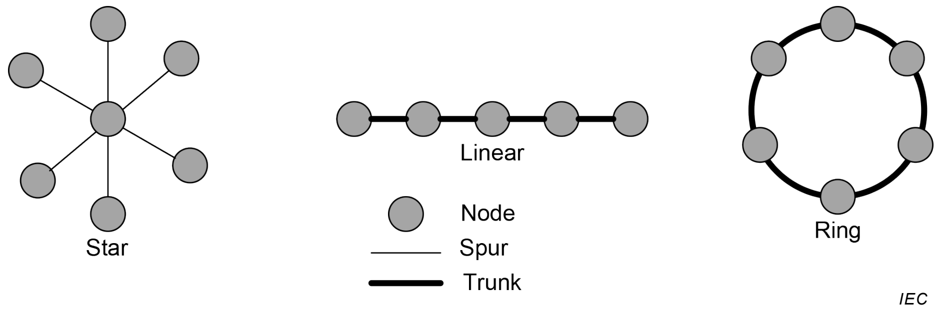


Figure 9 – Basic physical topologies for active networks

4.3.1.4 Combination of basic topologies

Combinations of basic topologies are permitted and are defined in the CP installation profile.

Figure 10 provides an example of a common configuration of two passive bus segments interconnected by an active bus repeater.

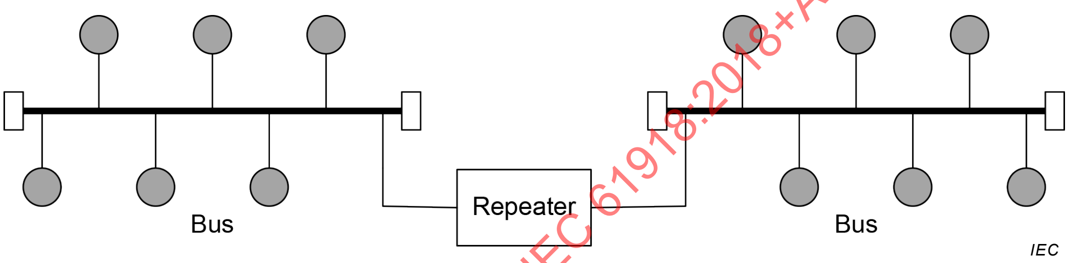


Figure 10 – Example of combination of basic topologies

A mesh configuration is composed of linear configurations where the active nodes are partially (as in Figure 53, with one linear configuration in green and a second one in blue) or totally directly interconnected.

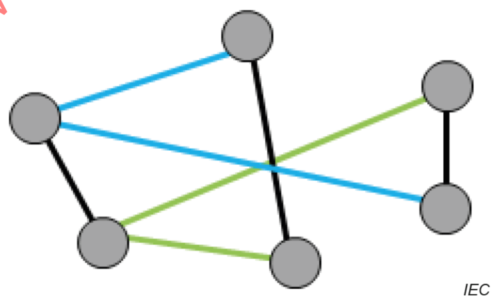


Figure 53 – Example of mesh topology

4.3.1.5 Specific requirements for CPs

Additional information regarding topology requirements for a specific industrial network may be found in the respective installation profile.

4.3.1.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

Generic cabling channels in accordance with ISO/IEC 11801-3 may constitute elements of the networks described in 4.3.1.2 to 4.3.1.5. Specific restrictions are detailed in ISO/IEC 11801-3 and may be expanded upon or modified by the respective installation profile.

4.3.2 Network characteristics

4.3.2.1 General

It is common practice to subnet an industrial AI network when there are a large number of devices to be connected.

Every network specification consists of the following basic characteristics:

- transfer rates;
- media type and performance;
- maximum number of devices (nodes) including repeaters per segment;
- maximum number of devices (nodes) including repeaters per network;
- maximum number of repeaters (that connect segments);
- maximum segment length.

NOTE Transfer rates can be expressed as bandwidth capacity or effective data throughput rates using the modulation and encoding methods of a specific Fieldbus technology. Requirements for effective data rate values can also include statements of maximum acceptable values for BER and burst errors (such as in 23.9 of IEC 61158-2:2014 and Annex K).

Media types consist of optical fibre cabling, balanced cabling (4-pair, 2-pair, 1-pair), wireless, and other CP specific media types. Wireless network installation is not within the scope of this document. Selection of physical media technologies should partner with architectural considerations, taking into account network topology, network characteristics, as well as data propagation and aggregation throughout the network.

Optical fibre is generally recommended where high bandwidth is needed or a high data integrity is required. Where powering is required or for reduced bandwidth or length compared to optical fibre, wire cabling is recommended. 4-pair is mostly recommended for connecting control and automation equipment. 1-pair (see Annex Q) is mostly limited to connecting control and automation equipment with field devices.

The planner should take into account EMI performance when selecting cabling types and spacings from types of conductors. In practice, need for EMI reduction equates to increase in spacing, which can translate to installation cost. Failure to consider EMI performance and mitigations can ultimately lead to areas of high disturbance at critical points in the network.

Comparative measurements (unshielded versus shielded) have shown that shielded constructions can provide a higher level of protection against EMI when applied according to equipment manufacturers specifications.

4.3.2.2 Network characteristics for balanced cabling not based on Ethernet

For balanced cabling not based on Ethernet, the planner shall use the basic network characteristics defined in the respective installation profile according to the templates given in Table 1.

Table 1 – Basic network characteristics for balanced cabling not based on Ethernet

Characteristic	CP x/y
Basic transmission technology	
Length / transmission speed	**Segment length** m
9 kbit/s to 33 kbit/s	
33 kbit/s to 93 kbit/s	
125 kbit/s	
187 kbit/s	
250 kbit/s	
500 kbit/s	
1,5 Mbit/s	
2 Mbit/s	
3 Mbit/s, 6 Mbit/s, 12 Mbit/s	
5 Mbit/s	
8 Mbit/s	
16 Mbit/s	
Maximum capacity	**Max. No.**
Devices/segment	
Devices/network	

4.3.2.3 Network characteristics for balanced cabling based on Ethernet

For balanced cabling based on Ethernet, the planner shall use the basic network characteristics defined in the respective installation profile according to the template given in Table 2.

NOTE The letter X in Table 2 is the reference to Annex X of the installation profile where the profile is specified.

Table 2 – Network characteristics for balanced cabling based on Ethernet

Characteristic	CP x/y
Supported data rates (Mbit/s)	
Supported channel length (m) [b]	
Number of connections in the channel (max.) [a] [b]	
Patch cord length (m) [a]	
Channel class per ISO/IEC 11801-3 (min.) [b]	
Cable category per ISO/IEC 11801-3 (min.) [c]	
Connecting HW category per ISO/IEC 11801-3 (min.)	
Cable types	

[a] See X. 4.4.3.2.

[b] For the purpose of this table, the channel definitions of ISO/IEC 11801-3 are applicable.

[c] For additional information, see IEC 61156 (all parts).

For balanced 1-pair networks, the requirements specified in Annex Q apply.

4.3.2.4 Network characteristics for optical fibre cabling

For optical fibre cabling, the planner shall use the basic network characteristics for each wavelength defined in the respective installation profile according to the templates given in Table 3 and to the conditions expressed hereafter.

For the purpose of this document, channel insertion loss and optical power budget are considered to be equivalent. The connecting hardware used for optical fibre cabling is as specified in X.4.4.2.5 of the relevant installation profile.

NOTE The letter X is the reference to Annex X of the installation profile where the profile is specified.

Table 3 – Network characteristics for optical fibre cabling

CP x/y		
Optical fibre type	**Description**	
Single mode silica	Bandwidth (MHz) or equivalent at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5
Multimode silica	Modal bandwidth (MHz × km) at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5
POF	Modal bandwidth (MHz × 100 m) at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5
Hard clad silica	Modal bandwidth (MHz × km) at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5
[a] This value is reduced by connections, splices and bends in accordance with formula (1) in 4.4.3.4.1.		

4.3.2.5 Specific network characteristics

Additional information regarding the characteristics of a specific industrial network may be found in the respective installation profile.

4.3.2.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

Certain generic cabling channels in accordance with ISO/IEC 11801-3 may provide transmission performance in support of the networks described by reference to the templates of 4.3.2.2 to 4.3.2.5. See ISO/IEC 11801-3 for further details.

4.4 Selection and use of cabling components

4.4.1 Cable selection

4.4.1.1 Common description

The planner shall ensure that cables provide the required transmission performance in the specified environment (by reference to the MICE classification system or equivalent, see 4.2.3.1).

Industrial cables can be subjected to extreme mechanical stresses.

EXAMPLE The cable can provide connectivity for festooning, "C" track (drag chains) or robotic flexing applications.

In these cases, the planner shall select the cabling in accordance with the needs of the intended application. The respective manufacturer's instructions shall be observed.

The planner may decide to use part of an existing generic cabling system to connect AI networks. In this case, it is the planner's responsibility to make sure that this cabling system meets the requirements for the application.

NOTE Generic cabling in accordance with ISO/IEC 11801-3 can be not suitable for some CPs.

The planner shall ensure that cables to be installed underground are suitable and satisfy the following requirements:

- local regulations;
- safety from lightning;
- resistance to damage from rodents;
- chemical resistance.

Metal cladding on optical fibre cables provides additional mechanical protection. The planner should select metal clad optical fibre cables for direct burial applications and other areas where mechanical protection is necessary.

If the equipment location requires the use of special cables and/or connecting elements not complying with the network-related requirements of this specification, the planner shall consult the cable/connector manufacturer to obtain the information necessary for determining the channel/permanent link length.

4.4.1.2 Copper cables

4.4.1.2.1 Balanced cables for Ethernet-based CPs

Balanced cables for Ethernet-based CPs shall meet the requirements of Table 2. For balanced 1-pair cables, the requirements specified in Annex Q apply.

The planner shall review the relevant installation profile for additional requirements or recommendations for balanced cables.

The planner shall have considered the following information when specifying the number of pairs in each balanced cable:

- all cables within a channel should be of the same pair count;
- two pair cabling is not generic and cannot support all applications (for example, if future plans are to migrate to higher data rates or PoE, then four pair cables should be considered);
- more than 4 pair count cables are not recommended for control applications;

- in an active channel and with cabling that uses ~~mixed 2 and 4 pair~~ cable elements with a different pair count in the same channel (e.g., 2- and 4-pair or 1- and 4-pair), all un-used pairs shall be terminated with the differential or common mode impedance of the cable at both ends (i.e. four pair cables shall not be housed in two pair connecting hardware). This requirement does not apply to cable constructions that use individual shielded pairs.

~~NOTE The balanced cables specified in the reference implementations of ISO/IEC 11801-3 contain 4 pairs and provide channel length of 100 m maximum.~~

For the channels where there is power sourcing equipment (PSE) connected to non-powered devices, the planner shall specify that the PSE function is disabled to prevent application of power.

The planner shall use the data defined in the respective installation profile according to the templates given in Table 4 and Table 5.

Table 4 – Information relevant to copper cable: fixed cables

Characteristic	CP x/y
Nominal impedance of cable (tolerance)	
DCR of conductors	
DCR of shield	
Number of conductors	
Shielding	
Colour code for conductor	
Jacket colour requirements	
Jacket material	
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	
Agency ratings	
Other characteristics [a]	

[a] Replace "Other characteristics" with the name of the other needed characteristics (one or more, as needed). Otherwise delete the row.

Table 5 – Information relevant to copper cable: cords

Characteristic	CP x/y
Nominal impedance of cable (tolerance)	
DCR of conductors	
DCR of shield	
Number of conductors	
Length	
Shielding	
Colour code for conductor	
Jacket colour requirements	
Jacket material	
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	
Agency ratings	
Other characteristics [a]	

[a] Replace "Other characteristics" with the name of the needed additional characteristics (one or more, as needed). Otherwise delete the row.

4.4.1.2.2 Copper cables for non-Ethernet-based CPs

Copper cables for non-Ethernet-based CPs, shall meet the requirements of Table 1 and any additional requirements or recommendations of the installation profile.

The planner shall use the data defined in the respective installation profile according to the templates given in Table 4 and Table 5.

4.4.1.3 Cables for wireless installation

Communication cables connecting to wireless devices shall conform to the requirements of this document.

4.4.1.4 Optical fibre cables

Optical fibre cables to support specific CPs shall meet the requirements or recommendations of the CP (see IEC 60794 (all parts)).

The planner shall select the appropriate optical fibre cable to support the required channel lengths and number of connections for the CP to be installed.

The planner shall review the relevant installation profile for additional requirements or recommendations for optical fibre cables.

The planner shall use the data defined in the respective installation profile according to the templates given in Table 6. The applicable standard is defined in the installation profiles with either a reference to IEC 60793 or IEC 60794, or OM1, OM2, OM3, OM4 or OS1, OS2. OM1, OM2, OM3 and OS1, OS2 are as specified in ISO/IEC 11801-1 and OM4 is as specified in IEC 60793-2-10~~:~~, type A1a.3 (A1-OM4).

NOTE Some additional information to be considered by the installer and maintenance personnel is given in 5.2.1.13 and in Clause 8 of this document.

Table 6 – Information relevant to optical fibre cables

Characteristic	9..10/125 µm single mode silica	50/125 µm multimode silica	62,5/125 µm multimode silica	980/1 000 µm step index POF	200/230 µm step index hard clad silica
Standard					
Attenuation per km (650 nm)					
Attenuation per km (820 nm)					
Attenuation per km (1 310 nm)					
Number of optical fibres					
Jacket colour requirements					
Jacket material					
Resistance to harsh environment (e.g. UV, oil resist, LS0H)					
Other characteristics [a]					

[a] Replace "Other characteristics" with the name of the needed other characteristics (one or more, as needed). Otherwise delete the row.

4.4.1.5 Special purpose balanced and optical fibre cables

The following cables provide support for special applications. The planner shall consider any additional cabling attributes required to provide the desired life cycle of the cabling system.

Some examples of special purpose balanced cables and optical fibre cables are the following:

a) festoon cables;
b) high flex cables;
c) high flex cables for three dimensional movement;
d) UV-resistant cables;
e) weld splatter cables.

Selection of high flex cables should take the following into account:

- cables are rated differently for rolling “C” track (also known as a drag chain) and robotic applications where the cable is moved in a bending flex way (also known as “tic-toc”);
- cables should only be used where needed, i.e. in the high flex area;
- increased attenuation of copper cables (for example due to conductor stranding) that may affect channel length;
- cables should be properly secured to the moving machinery to minimize bending, twisting and abrasion;
- specified cable bending radius shall be maintained;
- cables should be installed with connectors at each end for maintenance purposes;
- only approved lubricants shall be used to minimise jacket abrasion.

It is common for high flex cables to be used in robotic welding applications. In this case weld splatter sheath materials should be considered.

4.4.1.6 Specific requirements for CPs

Additional information regarding the cable requirements for a specific industrial network may be found in the respective installation profile.

If hybrid cables are supported for a network, the requirements shall be specified in the relevant installation profile.

4.4.1.7 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

ISO/IEC 11801-3 requires the components to be selected and used in order that the desired channel performance is provided within the specified environment.

ISO/IEC 11801-3 also

- specifies reference implementations which link particular component specifications to channel transmission performance;
- provides appropriate methods of component specification, for example by reference to detailed specifications produced by other IEC committees.

The planner shall ensure that the components specified and their use within a channel provides the required transmission performance.

The planner shall ensure that a maintenance system is in place to maintain channel performance during the operational life of the cabling.

4.4.2 Connecting hardware selection

4.4.2.1 Common description

The planner shall ensure that connectors provide the required transmission performance in the specified environment (by reference to the MICE classification system or equivalent, see 4.2.3.1).

The planner shall use the appropriate pin-pair assignment based on Annex H and the specific installation profile in use.

The wire colour codes for CP specific connectors are defined in Annex D.

4.4.2.2 Connecting hardware for balanced cabling CPs based on Ethernet

This document recognizes sealed connector housings variants 1 and 6 of IEC 61076-3-106 and sealed connector housing variant 14 described in IEC 61076-3-117 for the encapsulation of 8-way modular connector compliant with IEC 60603-7. In the case of applications requiring the non-sealed connectivity, 8-way modular connectors specified in IEC 60603-7 shall be used. The installation of the variant 1, 6 or 14 at the AO and in the AI is dependent on the selected CP. In addition, the M12-4 with D-coding connector described in IEC 61076-2-101 and the M12-8 with X-coding connector described in IEC 61076-2-109 may be used at the AO and in the AI.

NOTE The above connector variants (1, 6 and 14) are reverse compatible with cords as defined by ISO/IEC 11801-3 and ensure a reverse compatibility to IEC 60603-7. Therefore, the standard test equipment can be used for network validation and troubleshooting.

Devices and AOs shall be fitted with sockets. Cables shall be fitted with plugs to interface with devices and AOs.

The planner shall use the data defined in the respective installation profile according to the template given in Table 7.

Table 7 – Connectors for balanced cabling CPs based on Ethernet

	IEC 60603-7 series[a]		IEC 61076-3-106[b]		IEC 61076-3-117[b]	IEC 61076-2-101	IEC 61076-2-109
	shielded	unshielded	Var. 1	Var. 6	Var. 14	M12-4 with D-coding	M12-8 with X-coding
CP x/y							

[a] For the IEC 60603-7 series, the connector selection is based on the desired channel performance.

[b] Housings to protect connectors.

For balanced 1-pair connecting hardware the requirements specified in Annex Q apply.

4.4.2.3 Connecting hardware for copper cabling CPs not based on Ethernet

The planner shall use the data defined in the respective installation profile according to the templates given in Table 8. Detailed specifications for M12 connectors are standardised in IEC 60512-29-100.

Table 8 – Connectors for copper cabling CPs not based on Ethernet

	IEC 60807-2 or IEC 60807-3	IEC 61076-2-101			IEC 61169-8	ANSI/(NFPA) T3.5.29 R1-2007		Others		
	Sub-D	M12-5 with A-coding	M12-5 with B-coding	M12-n with X-coding	Coaxial (BNC)	M 18	7/8-16 UN-2B THD	Open style	Terminal block	Others
CP x/y										
NOTE For M12-5 connectors, there are many applications using these connectors that are not compatible and when mixed ~~may~~ can cause damage to the applications.										

4.4.2.4 Connecting hardware for wireless installation

None.

4.4.2.5 Connecting hardware for optical fibre cabling

For optical cable connectors of an industrial network, the planner shall use the data defined in the respective installation profile according to the template given in Table 9 and the Table 10. In Table 10, the relationship between FOC and optical fibre types is expressed in terms of the optical fibre cable that applies (see 4.4.1.4).

There are several standards to help select the correct connector solution for a given environment. The planner and or the installer should consult ISO/IEC 11801-1:2017 and or IEC 61753-1 and IEC 61753-1-3 for additional information on environmental classifications of environments for connectors.

Table 9 – Optical fibre connecting hardware

	IEC 61754-2	IEC 61754-4	IEC 61754-24	IEC 61754-20	IEC 61754-22	Others
	BFOC/2,5	SC	SC-RJ	LC	F-SMA	
CP x/y						
NOTE IEC 61754 series defines the optical fibre connector mechanical interfaces. Performance specifications for optical fibre connectors terminated to specific fibre types are standardised in the IEC 61753 series.						

Table 10 – Relationship between FOC and fibre types (CP x/y)

FOC	Fibre type					
	9..10/125 µm single mode silica	50/125 µm multimode silica	62,5/125 µm multimode silica	980/1 000 µm step index POF	200/230 µm step index hard clad silica	Others
BFOC/2,5						
SC						
SC-RJ						
LC						
F-SMA						
Others						

4.4.2.6 Specific requirements for CPs

Additional information regarding the connecting hardware requirements for a specific industrial network may be found in the respective installation profile.

4.4.2.7 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See 4.4.1.7.

4.4.3 Connections within a channel/permanent link

4.4.3.1 Common description

For the purposes of 4.4.3, the terms channel and permanent link as defined in ISO/IEC 11801-1 are modified as in 3.1.22 and 3.1.60 in order to allow them be used for CPs in accordance with IEC 61784-5 (all parts).

The planner shall request that the maximum channel lengths as defined by the specific installation profile for the specific cabling media is not exceeded. However, the quality of service depends on the length of the channel and the number of connections and splices within it (see 4.4.3.2.3).

As the number of connections and splices in the channel increases so does the insertion loss, which then decreases the signal to noise ratio of the channel.

For balanced cabling, the planner shall request that unused pairs in an active channel be terminated in accordance with 4.4.1.2.

The planner shall ensure that the impact of the number of connections within the channel is taken into account as described in 4.4.3 for 4-pair cabling. For 1-pair cabling, the requirements specified in Annex Q apply. With regard to the number of connections in a channel, the reference implementations as described in ISO/IEC 11801-3 ~~are limited to 4~~ have a limited number of connections (e.g., 4 for 4-pair and 10 for 1-pair). If the planning requires more ~~than 4~~ connections than the corresponding reference implementation, then additional analysis may be required. Channel performance measurements may be required to assure that the channel meets the requirements of the application.

The planner shall ensure that an appropriate maintenance system is in place to maintain channel performance during the operational life of the cabling.

4.4.3.2 Balanced cabling connections and splices for CPs based on Ethernet

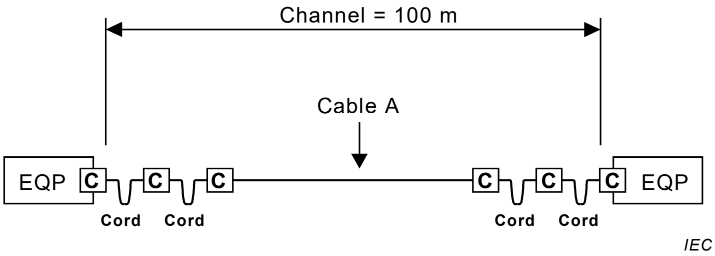
4.4.3.2.1 Common description

Ethernet-based networks shall comply with the following rules.

- The reference implementations as described in ISO/IEC 11801-3 (with specified structure, components and performance).
- The transmission performance shall be in accordance with the relevant class requirements as defined in ISO/IEC 11801-3. It shall be noted that these classes include requirements for TCL, ELTCTL and coupling attenuation with respect to MICE classification (E1, E2 or E3).
- Configurations beyond the reference implementations that are supported for a CP shall be fully described in the CP installation profile.

a) 4-pair basic reference implementation

Figure 11 shows the model used to correlate cabling dimensions specified in 4.4.3 with the channel specifications in ISO/IEC 11801-3. The cabling channel shown contains two connections at each end and two cords at each end of the channel. For the purposes of 4.4.3, jumpers are treated as cords.



Key

C = connection

EQP = equipment

Figure 11 – Basic reference implementation model

The basic reference implementation approach of Table 11 allows the length of the fixed cable A to be adjusted to compensate for variable cord lengths and channel operating temperature.

Table 11 – Basic reference implementation formulas

Category	Component		
	Class D	Class E	Class F
5	*C* = (113 – 2×*N* – *F*×*Y*) / *X* [a]	-	-
6	*C* = (115 – *N* – *F*×*Y*) / *X*	*C* = (106 – *N* – *F*×*Y*) / *X*	-
7	*C* = (119 – *N* – *F*×*Y*) / *X*	*C* = (109 – *N* – *F*×*Y*) / *X*	*C* = (106 – *N* – *F*×*Y*) / *X*

For operating temperatures above 20 °C, the cable length *C* should be reduced by 0,2 % per °C for shielded cables and 0,4 % per °C (20 °C to 40 °C) and 0,6 % per °C (> 40 °C to 60 °C) for unshielded cables. Where the operating temperature exceeds 60 °C, then manufacturers' information shall be consulted regarding the required reductions in cable length.

NOTE The required channel performance is provided using the formulas provided in this table and based upon a statistical approach of performance modelling.

[a] where

C is the length of the fixed cable A (m);

N is the number of connections (subject to maximum of 4, otherwise NEXT, Return Loss and ELFEXT performance should be verified);

F is the combined length of cords and jumpers (m);

X is the ratio of the insertion loss of the fixed cable A (dB/m) to the insertion loss of the relevant category of cable (dB/m);

Y is the ratio of insertion loss of the cords/jumpers (dB/m) to the insertion loss of the relevant category of cable (dB/m).

In Table 11, it is assumed that

- the maximum channel length is 100 m;
- the fixed cable A may have a different insertion loss specification than the relevant category of cable specified in IEC 61156 (all parts);
- the flexible cable within the cords may have a different insertion loss specification than that used in the fixed cable;
- the cables within all the cords in the channel have a common insertion loss specification;
- all cables and cords are subject to the same temperature conditions;

- cable A may be constructed using the same cable types that are used in cords. In this case the proper de-rating shall be used (see Table 13).

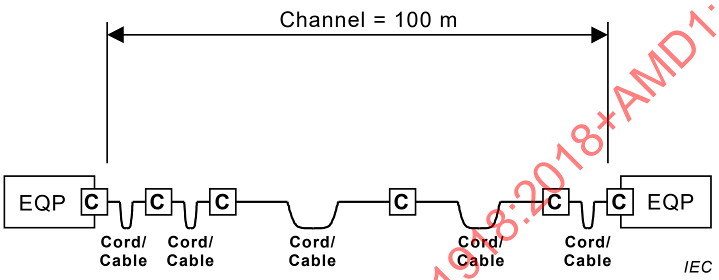
The length of the cable A shall be determined by the formulas defined in Table 11.

When four connections are used in a channel, the length of the fixed cable A should be at least 15 m. The maximum length of the fixed cable A will depend on the total length of cords to be supported within a channel. The maximum lengths of cords shall be fixed and during the operation of the installed cabling, a management system should be implemented to ensure that the cords used to create the channel conform to these design limits.

b) 4-pair enhanced reference implementation

Figure 12 shows the model used to correlate cabling dimensions specified in 4.4.3 with the channel specifications in ISO/IEC 11801-3. The channel cabling shown contains four connections. For the purposes of 4.4.3, jumpers are equivalent to cords.

A channel may be assembled with cords and cables in any order.



Key

C = connection

EQP = equipment

Figure 12 – Enhanced reference implementation model

In Table 12, it is assumed that

a) the maximum channel length is 100 m;

b) all the cables may have a different insertion loss specification than the relevant category of cable specified in IEC 61156 (all parts);

c) each of the cables may have different insertion loss specifications;

d) each of the cables may be subject to different temperature conditions.

The length of the cords used within a channel of a given class shall be determined by the formulas defined in Table 12 and Table 13.

Where a proposed implementation would result in a cable separating two pair of connections within the channel with a length less than 15/Y (m), then validation shall be performed to confirm channel performance.

NOTE Y_i is defined in Table 12.

The planner shall require that, during the operation of the installed cabling, the maintenance organisation ensure that the cords used to construct, update or repair the channel conform to the design rules of the channel.

Table 12 – Enhanced reference implementation formulas

Category	Component		
	Class D	Class E	Class F
5	$\Sigma_{(i=1 \text{ to } j)}\ F_i \times Y_i \times Z_i \le 113 - 2 \times N$ [a]	-	-
6	$\Sigma_{(i=1 \text{ to } j)}\ F_i \times Y_i \times Z_i \le 115 - N$	$\Sigma_{(i=1 \text{ to } j)}\ F_i \times Y_i \times Z_i \le 106 - N$	
7	$\Sigma_{(i=1 \text{ to } j)}\ F_i \times Y_i \times Z_i \le 119 - N$	$\Sigma_{(i=1 \text{ to } j)}\ F_i \times Y_i \times Z_i \le 109 - N$	$\Sigma_{(i=1 \text{ to } j)}\ F_i \times Y_i \times Z_i \le 106 - N$
NOTE The required channel performance is defined using the formulas provided in this table and based upon a statistical approach of performance modelling.			
[a] where *I* is the cable section from 1 to j (subject to a minimum of 1 and a maximum of 5); *N* is the number of connections (subject to maximum of 4, otherwise NEXT, Return Loss and ELFEXT performance should be verified); F_i is the length of the cable (m); Y_i is the ratio of the insertion loss of the cable (dB/m) to the insertion loss of the relevant category of cable (dB/m); Z_i is the derating of insertion loss of the cords (dB/m) for operating temperatures above 20 °C, defined in Table 13.			

Table 13 – Correction factor Z for operating temperature above 20 °C

Cable construction	Correction factor Z	
	20 °C < *T* < 40 °C	40 °C < *T* < 60 °C
Shielded	1 + 0,002 × (*T* – 20)	1 + 0,002 × (*T* – 20)
Unshielded	1 + 0,004 × (*T* – 20)	1 + 0,006 × (*T* – 20)
Where the operating temperature exceeds 60 °C, then manufacturers' information shall be consulted regarding the appropriate factors.		

In the case where end connections differ from those specified for the standard channel, the planner shall request that the test equipment is calibrated in accordance with the equipment manufacturer's instructions and the proper test heads.

c) **End-to-end link**

End-to-end link is as described in Annex O.

d) **Balanced 1-pair reference implementation and cabling**

For 1-pair reference implementation and cabling, the requirements specified in Annex Q apply.

4.4.3.2.2 Connections minimum distance

Any requirements within the specific CP installation profile for minimum distance between connections shall be applied.

4.4.3.2.3 Balanced cabling splices

Splices shall only be used as a means of temporary repair. Splices shall be done by means that maintain channel performance and environmental integrity. The number of connections shall be taken into account. The recommended solution is to use a plug and jack combination with appropriate environmental integrity. The repaired cable segment should be tested with the appropriate field tester.

4.4.3.2.4 Balanced cabling bulkhead connections

A bulkhead connection that does not have the transmission performance of a single connection shall be counted as two connections.

When the bulkhead connection supports 4 pair to 2 pair conversion (e.g. 8-way modular to M12), accommodations shall be made to terminate the unused pairs differentially. Connection to earth is not allowed either through a capacitor or direct.

NOTE Additional information on bulkhead connection is provided in Annex J. The content of Annex J differs from that of ISO/IEC 11801-3.

A bulkhead cable gland may be used instead of a bulkhead connection when the use of the bulkhead connection is not compatible with the limit of connections in the channel.

4.4.3.2.5 Balanced cabling J-J coupler (J-J adaptor)

A J-J coupler connection that does not have the transmission performance of a single connection shall be counted as two connections in the channel.

J-J couplers are suitable to connect fixed cabling and flexible cabling, for example, for rolling c-track within a machine. J-J couplers are also suitable to provide the connections in a conveyor belt composed of several modules that are plugged together when they are put into operation. Connections in support of replacement of high flex segments shall be counted in the overall channel limits for the number of allowed connections.

4.4.3.3 Copper cabling connections and splices for CPs not based on Ethernet

4.4.3.3.1 Common description

The number of allowed connections versus the fieldbus length shall be as described in the relevant CP.

4.4.3.3.2 Connections minimum distance

See 4.4.3.2.2.

4.4.3.3.3 Copper cabling splices

See 4.4.3.2.3.

4.4.3.3.4 Copper cabling bulkhead connections

See 4.4.3.2.4.

4.4.3.3.5 Copper cabling J-J couplers (J-J adaptors)

See 4.4.3.2.5.

4.4.3.4 Optical fibre cabling connections and splices for CPs based on Ethernet

4.4.3.4.1 Common description

The maximum channel insertion loss specified for the CP (by reference to the ISO/IEC/IEEE 8802-3:2021) defines the possible configurations of the cabling at the specified wavelength as in formula (1).

$$L = 1000 \times \left[A - \sum_{i=1}^{J} M_i - \sum_{i=1}^{K} S_i \right] / C \qquad (1)$$

where

L is the channel length (m);

A is the maximum channel insertion loss/optical power budget (dB);

M_i is the insertion loss specification of each connection (dB);

S_i is the insertion loss specification of each splice (dB);

J is the number of connections in the channel;

K is the number of splices in the channel;

C is the cable attenuation coefficient (dB/km).

The planner shall apply any requirements concerning maximum channel lengths together with numbers of, or specification of, component within the specific CP. Reference should be made to the relevant installation profile (IEC 61784-5 (all parts)) to determine if additional requirements exist.

The optical fibre cable used in the channel should be long enough for the intended installation to prevent having connections and splices. The planner shall instruct the installer to take measures to ensure that the bending of the optical fibre cable does not fall below the minimum bending radius specified for the cable (see 5.2.1.2 and 5.2.1.6).

Further details of bulkhead connections are given in 4.4.3.4.3.

4.4.3.4.2 Optical fibre splices

There are two methods for performing optical splices: mechanical and fusion. They both provide for different losses that have an impact on the insertion loss of the channel. The number of splices allowed is based on the optical power budget of the system and shall be accounted for in the channel loss budget.

4.4.3.4.3 Optical fibre bulkhead connections

The insertion loss of an optical fibre bulkhead connection typically is equivalent to that of one connection.

4.4.3.4.4 Optical fibre J-J couplers (or adaptors)

The insertion loss of an optical fibre J-J coupler or adaptor typically is equivalent to that of one connection. Where it is not, the additional connections shall be considered in the applied formula (see Table 11 and Table 12).

4.4.3.5 Optical fibre cabling connections and splices for CPs not based on Ethernet

The number of allowed connections and splices is limited by the maximum allowable channel attenuation and/or power budget.

The number of allowed connections and splices versus the fieldbus length shall be as described in the relevant CP installation profile.

4.4.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

No additional requirements.

4.4.4 Terminators

4.4.4.1 Common description

Terminators reduce reflections and help to reduce radiations and noise susceptibility in a cabling system. The planner shall consult the CP for the requirements for terminators and their values.

See 4.4.1.2 for additional requirements regarding the termination of all un-used pairs.

4.4.4.2 Specific requirements for CPs

Additional information regarding the terminator requirements for a specific industrial network may be found in the respective installation profile.

4.4.4.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

No additional requirements.

4.4.5 Device location and connection

4.4.5.1 Common description

The devices should be located to provide adequate access for maintenance and troubleshooting consistent with the required channel performance. In addition environmental conditions, routing of the cable and connectivity considerations shall be given (see 4.4.11.1).

4.4.5.2 Specific requirements for CPs

Additional information regarding the device location and connection requirements for a specific industrial network may be found in the respective installation profile.

4.4.5.3 Specific requirements for wireless installation

None.

4.4.5.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

Generic cabling shall only be installed in areas where critical applications will not be subject to environmental conditions typical of the automation islands.

Generic cabling installed in automation islands shall only serve applications (voice, video, etc.) that are not dangerously affected by the environmental conditions typical of the automation islands.

4.4.6 Coding and labelling

4.4.6.1 Common description

Coding or labelling should be used in the plant (and referred to in the as-implemented cabling documentation) in such a way to facilitate the work of inspection and replacement of the network components. Colour coding provides easy identification between optical fibre cabling and balanced cabling.

NOTE See Clause 7 for additional information.

4.4.6.2 Additional requirements for CPs

Cables and AOs should be labelled in accordance with the system drawings. Labelling of connectors and/or cables (balanced and optical fibre) should be used for easy identification. Security shall be taken into account when deciding coding and labelling.

Means for identifying optical fibre polarity shall be provided.

4.4.6.3 Specific requirements for CPs

Additional information regarding coding and labelling requirements for a specific industrial network may be found in the respective installation profile.

4.4.6.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.7 Earthing and bonding of equipment and devices and shielded cabling

4.4.7.1 Common description

4.4.7.1.1 Basic requirements

When portions of generic cabling are used to support communication for a given CP, those portions of generic cabling shall conform to the requirements of the CP.

The earthing and bonding of equipment and the use of shielded cabling are very important aspects of the cabling installation.

Earth potential differences between cabling end points will induce noise in the cabling system. This is especially true in shielded cabling systems. Controlling earth currents is extremely important in reducing interference caused by earth offsets. Shield currents shall be mitigated by using a proper earthing system and or proper shield earthing techniques as defined in this document and the relevant CPs. If this requirement cannot be met, then alternate media, such as unshielded cables, optical fibre cables, or wireless, shall be considered.

Building and plant earthing wiring systems are implemented according to local, national or international regulations and standards (such as IEC 60364-4-41 and IEC 60364-5-54). If conformance is required, then the network planner/installer and verifier shall obtain confirmation that the facility conforms to the applicable standards and the relevant CP.

4.4.7.1.2 Planner tasks

The planner shall perform the following tasks.

- **Requirement 1**
  – The planner shall check with the owner of the building and plant the implemented configuration of the earthing system of the building and plant and the value of the earth resistance.
- **Requirement 2**

  For the connections to the existing building and plant earthing system, the network installation planner shall specify the following requirements for proper connection.

  – A quality of the earthing connections requirement as defined in 5.7.1.

  A common bonding network (CBN) with the required earth impedance and high current carrying capacity formed by all metallic constructional components shall be available.

  – In order to insure long-term reliability, appropriate measures shall be performed to protect earthing cables and connections against corrosion.

Methods for controlling potential differences in an earth system and selection of the earthing and bonding systems shall be as described in 4.4.7.1.3.

4.4.7.1.3 Methods for controlling potential differences in the earth system

The planner shall design the earthing of the industrial communication network in accordance with this document and the relevant installation profile. IEC TR 61000-5-2 gives additional guidance.

There are two proven earthing methods: equipotential and star (see 4.4.7.3). The planner shall use one of these to reduce the effects of earth offsets.

If this is not possible, then alternate transmission media shall be used (such as unshielded cables, optical fibre cables, or wireless).

4.4.7.1.4 Selection of the earthing and bonding systems

The planner should have a complete understanding of the condition of the existing earthing and bonding system of the building/plant in the network coverage area. If there is an adequate earthing and bonding system present, the complete system can be handled without division into earth sub-systems. If this is not the case, then the system should be split into earthing sub-systems. Each earthing sub-system may then use any of the proven earthing and bonding methods as required by the applicable CP installation profile. The planner should provide advice to the machine tool builder regarding the earthing scheme implemented in the facility and to design the earthing of the machine according to the scheme in the facility and the specific installation profile. The flowchart in Figure 14 is provided to help the planner in determining how to proceed.

The earthing and bonding system shall be constructed by cables, bus bars, and other components in accordance with EN 50310 and shall not consist of pathways and building steel. Pathways and building system shall be bonded to the earthing and bonding system.

The planner shall document the chosen earthing system (~~equipotential~~ mesh earthing or star earthing) for the complete communication network. Annex E recalls the reasons for using a specific system for power network.

4.4.7.2 Bonding and earthing of enclosures and pathways

4.4.7.2.1 Equalisation and earthing conductor sizing and length

The equalisation conductors and earthing conductors shall have a resistance < 1 Ω (see 5.7.1).

The planner should require that the length of all equalization conductors and earthing conductors be cut to minimum lengths. Coiling of excess grounding and equalization conductors is not permitted as this decreases the effectiveness of the grounding and equalization conductors. Figure 13 shows the relationship between the cross-sectional area and the maximum length of the conductor.

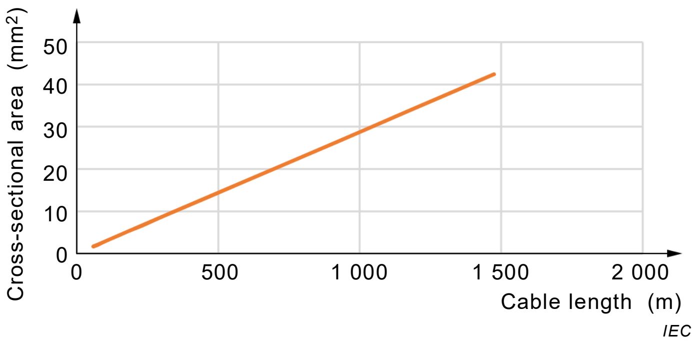


Figure 13 – Equalisation and earthing conductor cross-sectional versus maximum length

Table 14 shows maximum length values that correspond to typical standard cross-sectional areas expressed in mm^2 (see Annex F for the complete list of IEC 60228 and AWG values). These maximum length values are based on providing a maximum resistance of 0,6 Ω in order to ensure that the maximum resistance value of 1 Ω is not exceeded between the enclosure and the pre-existing earthing and bonding point.

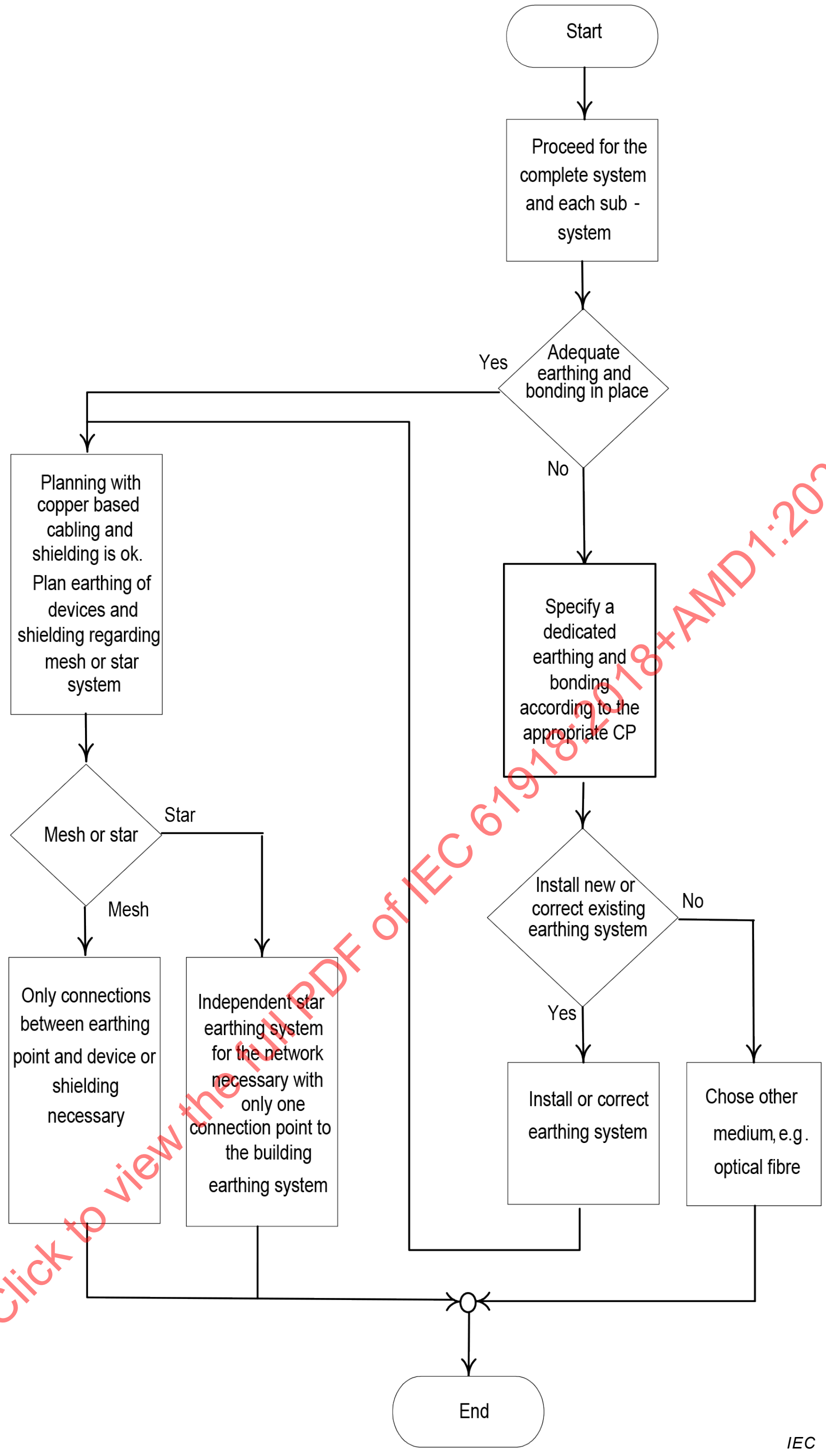


Figure 14 – Selection of the earthing and bonding systems

NOTE Long earthing conductors could increase earth impedance, rendering the earthing ineffective in lightning events.

For needed length equalization, conductors and earthing conductors shall have a cross-sectional area with a value not less than the value shown in Table 14 for a maximum lengths that is higher than the one requested. The length of earth straps should be no less than 25 mm (1 inch). Local regulations may require additional earthing conductor requirements.

Table 14 – Equalisation and earthing conductor sizing and length

Cross-sectional areas mm²		Maximum length m
IEC 60228	AWG	a
	8,36 (8 AWG)	291
10		349
	10,5 (7 AWG)	368
	13,3 (6 AWG)	461
16		556
	16,8 (5 AWG)	582
	21,1 (4 AWG)	736
25		870

[a] Length of a conductor having a resistance R = 0,6 Ω.

4.4.7.2.2 Bonding straps and sizing

Bonding straps shall be constructed of copper or zinc plated steel (see Table 15 which provides data taken from IEC 60364-5-54).

The bonding straps should preferably be stranded to ensure that the connection is also effective at high frequencies as a result of the large surface area.

Table 15 – Bonding straps cross-section

Material	Minimum cross-section mm²
Copper	6
Zinc plated steel	50

Table 16 (with data taken from IEC 60364-5-54) provides requirements for bonding plate's surface protection.

Table 16 – Bonding plates surface protection

Material	Surface protection	Thickness µm
Copper	Bare	None
	Tin-coated	1 to 5
	Zinc-coated	20 to 40

4.4.7.2.3 Surface preparation and methods

The cabling planning documentation shall require that all connections to metallic surfaces be prepared in a way to provide a low resistance of the connection and enduring protection against corrosion. Subclause 5.7.2.3 provides additional guidance to the installers on making good connections to metallic surfaces.

4.4.7.2.4 Bonding and earthing

The planner shall require the following.

a) Earthing connections for the cabinets shall not be daisy chained.

b) Where two independently moving metallic pathways are separated, a flexible bonding strap shall be used to bond the two metallic sub pathways together (see Figure 31).

c) Where two metallic pathways are mechanically connected using solid metal straps, a separate flexible bonding strap may be used.

d) Expansion joints and joint connections shall be bridged by flexible bonding straps (see Figure 31).

e) All inactive metal parts, particularly in the immediate vicinity of automation components and communication cables, shall be bonded to the earthing system. This includes all metal parts of cabinets, construction and machine parts, etc., that do not have any electrical conducting function in the automation system.

f) If an equipotential system is required, metallic conductive cable pathways shall be included in the equipotential bonding of the system and between the individual system sections. The planner shall specify how often the pathways shall be connected to the equipotential bonding system.

g) The individual segments of the cable pathways shall be connected at low impedance with each other.

h) Earthing conductors shall be kept as short as possible.

i) Excess lengths of earthing and bonding conductors shall not be coiled.

j) Earthing conductors and equalisation conductors shall be placed nearest to the metallic pathway where they are installed, to reduce the impedance of the earth circuit (Figure 15). Attention shall be paid to the fact that the noise changes the impedance of the earthing conductors and equalisation conductors in function of its frequency. The graph in Figure 16 shows the consequences of increasing the length of the earthing and or the equalizations conductor without increasing the wire gauge.

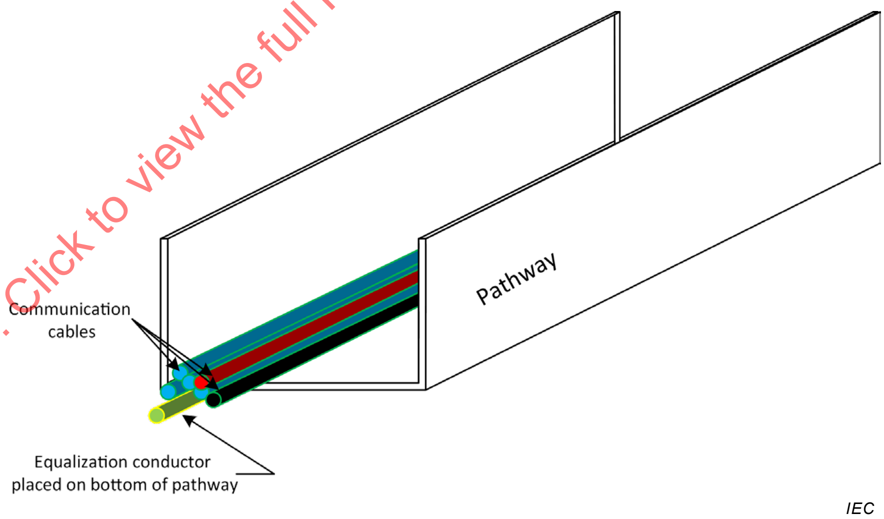


Figure 15 – Placement of equalisation conductors

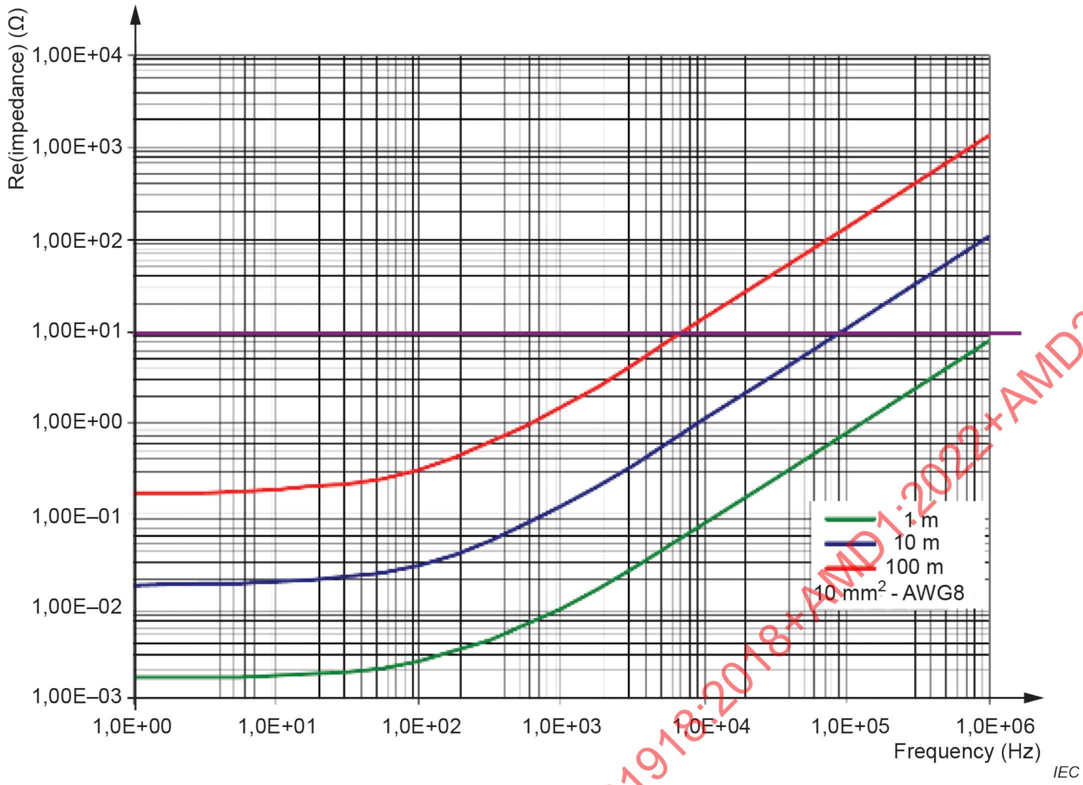


Figure 16 – Impedance of the earthing conductors and equalisation conductors versus noise frequency

4.4.7.3 Earthing methods

4.4.7.3.1 ~~Equipotential~~ Mesh

Figure 17 shows an example of wiring for bonding enclosures, pathways and wiring of the earths arranged as a mesh to implement an equipotential earthing configuration.

The potential equalization cables shall be specified in accordance with 4.4.7.2.

If earth current cannot be controlled, this may cause component failure or communications faults. In this case, alternate media should be considered.

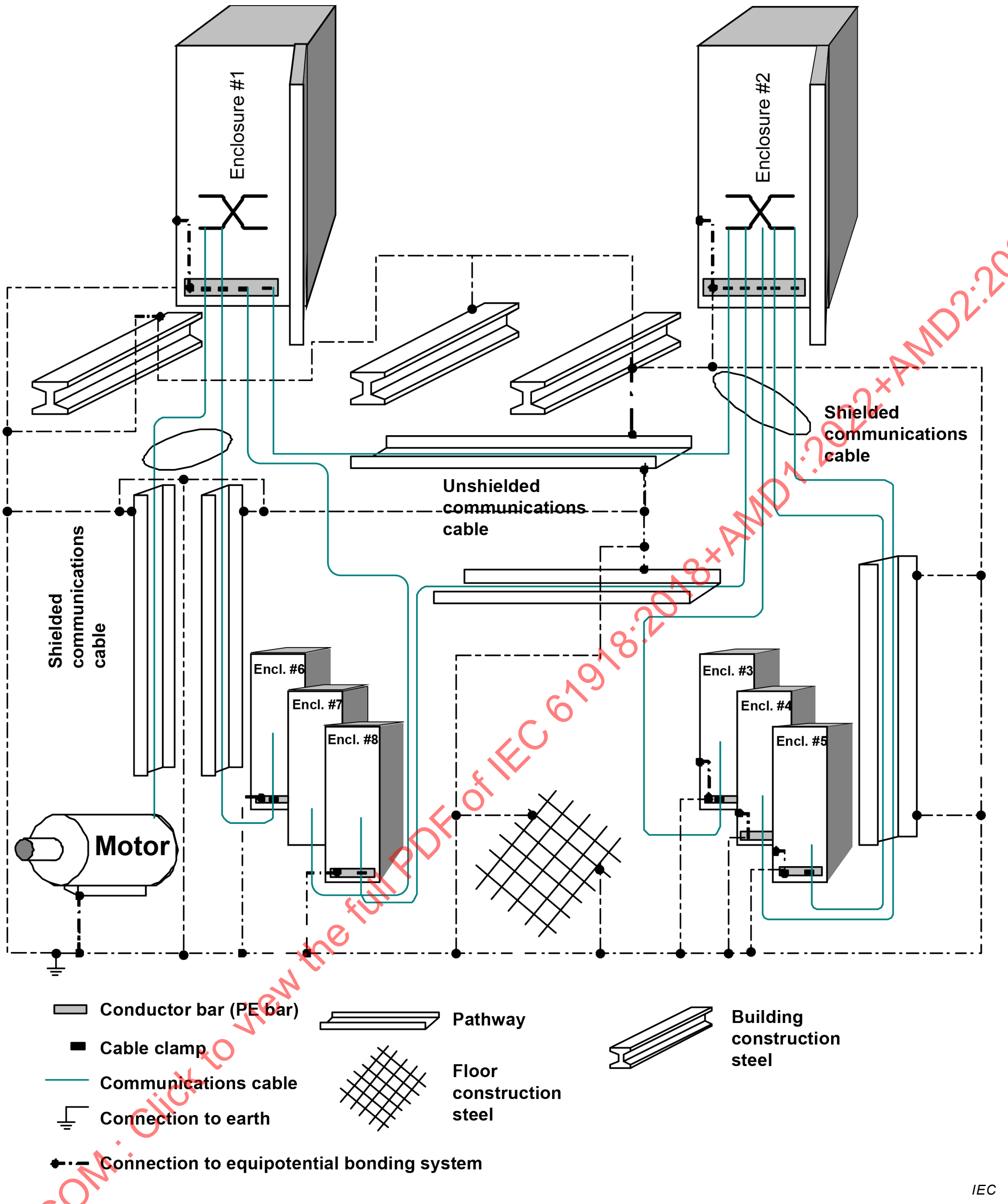


Figure 17 – Wiring for bonding and earthing in ~~an equipotential~~ a mesh configuration

Local, national or international safety earthing standards shall be applied.

NOTE Safety always takes precedence over EMC.

4.4.7.3.2 Star

Currents in earth paths generated by high currents can be controlled by the means of a star earthing system and by isolating the signal earth from the equipment earth. This is accomplished by providing two star earths, one for the equipment and a second for the communication equipment. Shields for the communication equipment shall be referenced only to the signal earth and no equipment shall be referenced to the signal earth. Each of the star earths of the two systems shall converge to one point within the building, as shown in Figure 18.

When the devices are required to be connected to a functional earth system that is isolated from the protective earth system at the enclosures, the planner shall specify the method to be used for the isolation. Isolated bus bars can be used to create a signal earth or functional earth (see Figure 33).

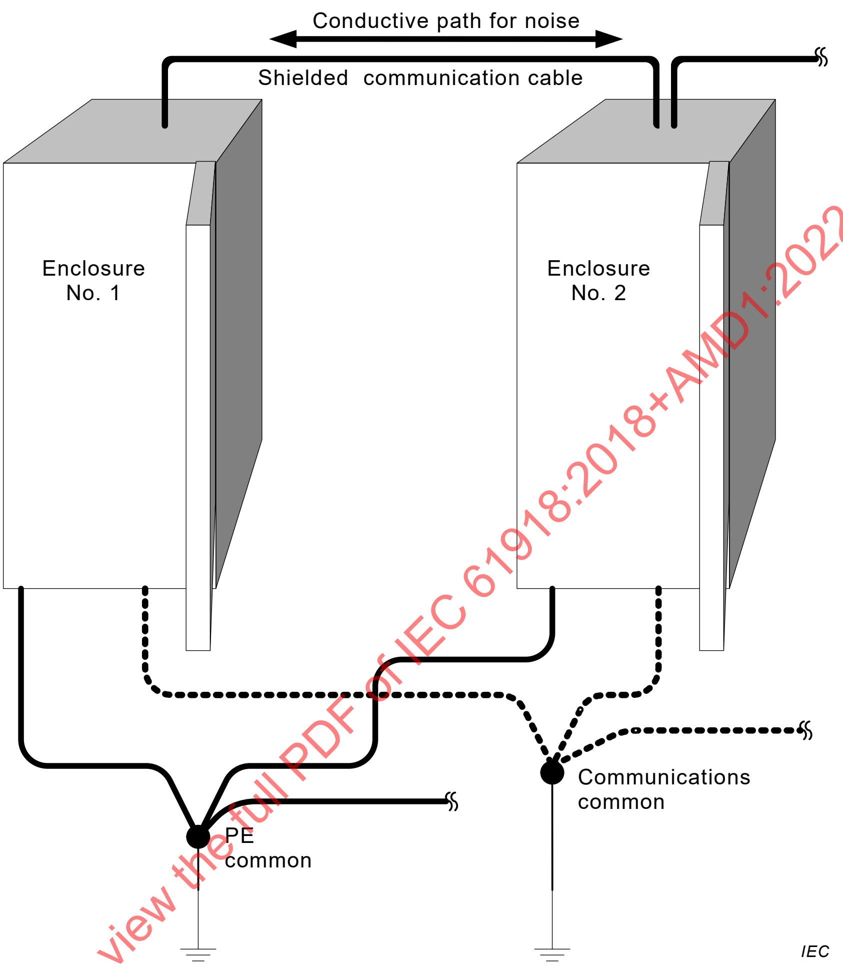


Figure 18 – Wiring of the earths in a star earthing configuration

4.4.7.3.3 Earthing of equipment (devices)

Equipment is normally earth connected, whereby the equipment's functional earth (M) is connected to the protective earth (PE) over a large area (see Figure 19). In exceptional circumstances, equipment can be arranged as a non-earthed system. This may be necessary if high short-circuit currents can occur (induction furnaces, etc.). In a non-earthed system, it is necessary to provide an insulation-monitoring device with a voltage limiter as shown in Figure 20. The term "non-earthed" is also used if a parallel RC circuit is fitted between the communication shield and earth. Many devices are fitted with a parallel RC circuit of this type to improve the interference immunity. This should be considered when choosing an earth-leakage monitor. In addition, the non-earthed arrangement ensures that uncontrolled equalisation currents do not damage or disrupt communication devices on the bus. The relevant safety regulations shall be observed.

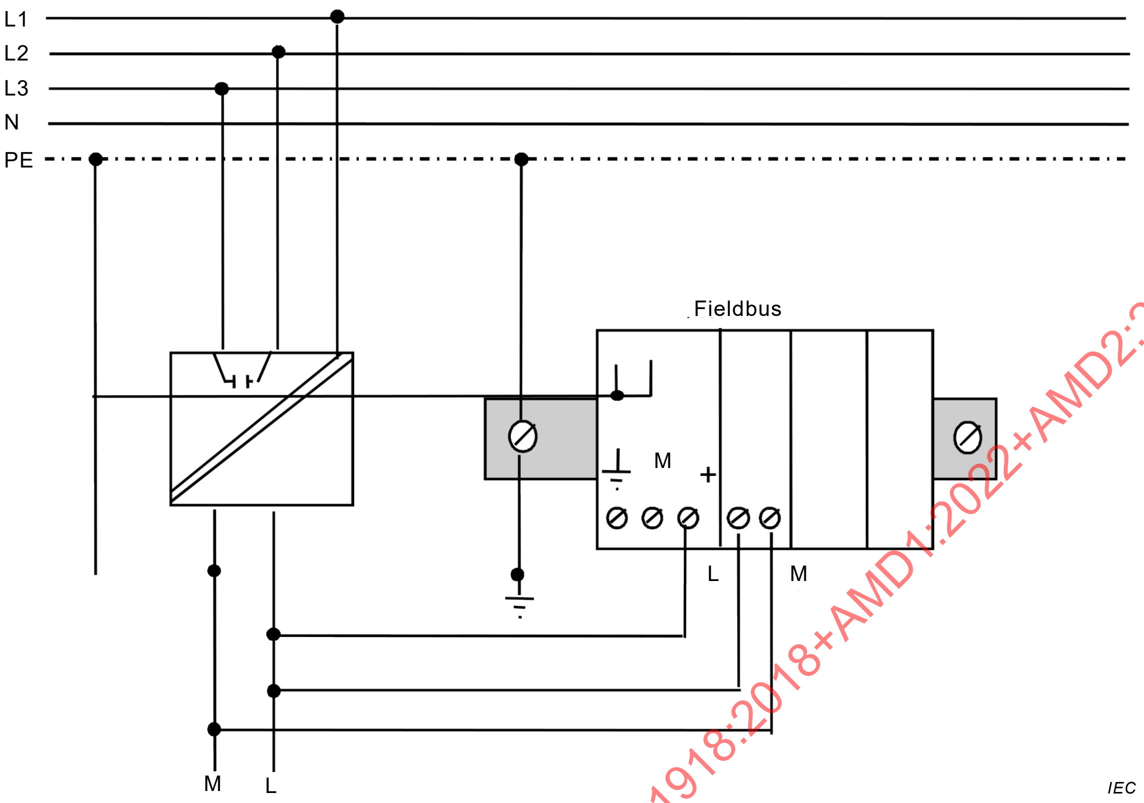


Figure 19 – Schematic diagram of a field device with direct earthing

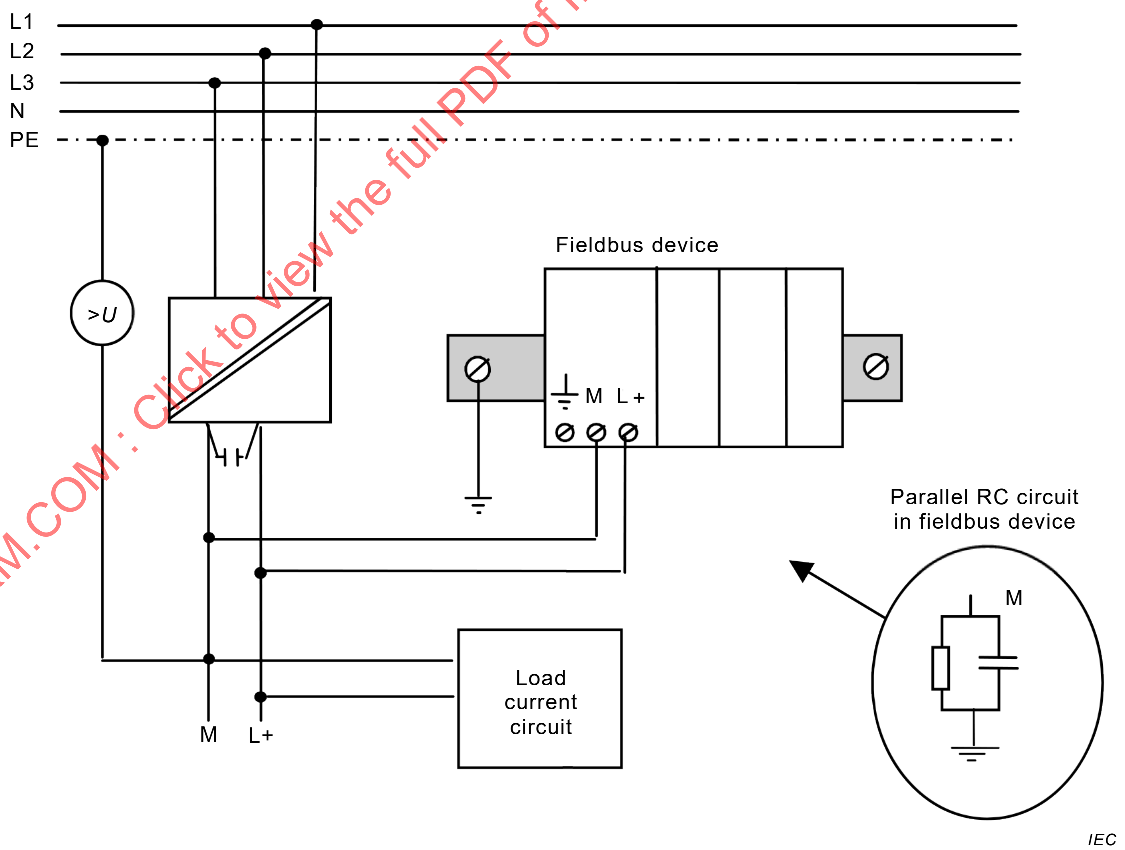


Figure 20 – Schematic diagram of a field device with parallel RC circuit earthing

4.4.7.3.4 Copper bus bars

Bus bars shall be used for the interconnection of earthing conductors.

Bus bars shall be selected and interconnected in accordance with local, national and international regulations and standards.

Bus bars shall be constructed of copper or copper alloys having a minimum conductivity of $5,52 \times 10^{7}$ S/m (95 % IACS) when annealed as specified by International Annealed Copper Standard and shall be finished with either tin coated surfaces or galvanically stabilized surfaces.

The bus bar shall be sized to carry noise currents and fault currents, which are anticipated in the installation environment, and to provide the mechanical capability for connection of the earthing conductors.

The bus bar impedance is seen in series to all earthing conductors connected to it. For fault current capability, the bus bar cross sectional area shall be at least five times the cross sectional area of the earthing conductor connected to the bus bar; considering the largest earthing conductor listed in Table 14 it shall be at least 125 mm^2. A maximum useful thickness of 9,25 mm is determined by the skin effect at 60 Hz. The minimum thickness value shall be 5 mm for mechanical capability; in this case, the minimum width shall be 25 mm. The bus bar width shall provide full coverage of the connecting hardware.

The bus bar length shall be as needed to support the number of connection of all the earthing conductors, with the maximum length given by formula (2).

$$L_{ma}x = Z_{max} \times P \times \partial \times 10^{-6} / \rho \qquad (2)$$

where

L_{max} is the maximum length in m;

Z_{max} is the maximum impedance in Ω;

P is the perimeter of the cross section of the bus bar, in mm;

∂ is the skin depth in mm at a given frequency; for copper, its value is 65,4 mm/$\sqrt{v}$ where v is the unit less value of the frequency in Hz and for copper alloy annealed as specified above is 67,6 mm/$\sqrt{v}$;

ρ is the resistivity of the conductor. For copper, its value is $1,68\ 10^{-8}\ \Omega \times m$ (at 20 °C) and for copper alloy annealed as specified above is $1,81\ 10^{-8}\ \Omega \times m$ (at 20 °C).

EXAMPLE 1 L_{max} = 3,6 m, with Z_{max}= 0,1 Ω at 50 MHz for a copper bus bar having a sectional perimeter of 60 mm.

EXAMPLE 2 L_{max} = 0,7 m, with Z_{max}= 0,1 Ω at 1 GHz for a copper bus bar having a sectional perimeter of 60 mm.

Bus bars should be supplied with pre-punched holes for use with cable terminating lugs.

The bus bar shall be used in accordance with 5.7.2.3. When it is necessary to isolate a copper bus bar, the isolation to the local earth shall be > 2 MΩ.

4.4.7.4 Shield earthing

4.4.7.4.1 Non-earthing or parallel RC

The planner shall specify if the installer shall use shield termination earthed with a parallel RC circuit (see Figure 35). In addition, the planner shall make aware the installer of the fact that non-earthed shield termination could affect the integrity of the shield due to the dangerous noise currents caused by the earth offset.

When the communication shields are required to be earthed directly at both ends, then the bonding method shown in Figure 17 shall be used.

4.4.7.4.2 Direct

The planner shall specify if the installer shall use the direct shield earthing, as represented in 5.7.4.3.

If the voltage offset between two communicating devices, which are directly connected to earth, exceeds 1 V at 50/60 Hz, then an equalization conductor shall be added to mitigate the voltage offsets that might otherwise create current through communication shields (see Figure 38). The cross-sectional area shall be in accordance with 4.4.7.2.1, 4.4.7.2.4 and 5.7.2.1. The planner shall document the requirements for this conductor in the cabling planning documentation.

4.4.7.4.3 Derivatives of direct and parallel RC

The planner shall specify which derivatives of direct and of parallel RC shield earthing shall be used by the installer. Examples of derivatives are provided in 5.7.4.4.

4.4.7.5 Specific requirements for CPs

Additional information regarding earthing and shielding requirements for a specific industrial network may be found in the respective installation profile.

4.4.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.8 Storage and transportation of cables

4.4.8.1 Common description

The planner shall require that manufacturer's handling and storage requirements be met during transportation, storage and installing in accordance with the specified local environmental conditions. To protect cable ends from corrosion, the cables should be kept sealed at both ends until installed and terminated.

4.4.8.2 Specific requirements for CPs

Additional information regarding storage and transportation requirements for a specific industrial network may be found in the respective installation profile.

4.4.8.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.9 Routing of cables

4.4.9.1 Common description

Subclause 4.4.9 describes the requirements for CPs cable routing inside buildings and enclosures and outside buildings and provides guidance on the routing of earthing conductors, communication cables and pathways.

NOTE 1 The requirements for routing of cables as they relate to generic cabling are provided in ISO/IEC 14673-2.

- Cable routes shall be selected to minimize noise coupling and crosstalk.
- Excess cables shall be dressed to minimise noise coupling from adjacent radiators, i.e. shaped like an 8 with a length of 0,3 m to 0,5 m and maintaining correct bending radius.

- Cables (optical fibre and balanced) shall be routed in such a way that they are protected from damage.
- Cables shall be grouped according to the circuit types as defined in Table 17.
- Cable routes for networks supporting functional safety systems should be implemented in accordance with the specified precautions. It could help using unique labelling and colouring to uniquely identify this cabling.

In addition the planner shall request not to bundle cables, because this may lead to heat build-up.

For the placement and protection of cables other than pre-manufactured assemblies (see 4.4.9.2) the planner shall require the use of cable pathways. Cable pathways shall be in accordance with ISO/IEC 14763-2:2012. The selection of the cable pathway system shall take into account the environmental conditions. The cable supplier's instructions shall be consulted to confirm that the selected pathway system is appropriate for the cable to be installed.

The planner shall request that the pathway systems used for EMC purposes are installed in accordance with the following rules (see Figure 31).

- A solid metallic wall construction shall be used. Meshed grating structures are only allowed if they provide the required level of EMC protection. Wire pathways and pathways with vents shall be avoided.
- Pathways shall be connected by using rigid metal straps with maximum coverage of the gap.
- The connection with braided straps is only allowed when the connected two parts of the pathway system are expected to move independently from each other.

The planner should request that a single braided strap between two parts of the pathway system is not used due to degraded electromagnetic performance caused by high local impedance.

NOTE 2 From frequencies of a few MHz upwards, a 10 cm braided strap between the two parts of the cable management system would degrade the impedance by more than a factor of 10.

Appropriate cable pathways and pathway systems shall be specified to ensure that cables are protected from damage and that suppliers' specifications for bending radius, tensile strength, crush resistance and temperature range are complied with during installation and operation.

Information technology cables containing flammable material (for example polyethylene sheaths) shall either be

a) terminated inside the building, within 2 m (or an alternative distance if defined by national or local regulations) of the point of internal penetration of the fire barrier (for example, floor/ceiling/wall), or
b) installed within trunking or conduit that is considered as fire barrier in accordance with local fire regulations.

4.4.9.2 Cable routing of assemblies

The planner shall not define cable routes that require installing cables near the following:

- lights,
- motors,
- drive controllers,
- arc welders,
- induction heaters,
- RF fields (transmitters),

- antennas.

The planner shall assure that pre-manufactured subassemblies of an automation system shall be designed in accordance with 4.4.10.

The appropriate high flex cable shall be used in a rolling "C" track application. Cables shall be rated appropriately for use in applications requiring constant movement of cables such as robotic applications where the cable is moved in a bending flex fashion (see 4.4.1.5).

4.4.9.3 Requirements for cable routing inside enclosures

The planner shall specify:

a) the requirements for the pathways to be used (for example, continuous metallic, non-continuous metallic, non-metallic);

b) that the cables shall be separated into individual bundles according to the circuit type as defined in Table 17 of 4.4.10;

c) that the cable shield shall be continuous and terminated in accordance with the manufactures instructions and CP installation profile.

4.4.9.4 Cable routing inside buildings

In addition to the requirements specified in 4.4.9.1, the planner shall require the following.

a) Communication cables routed inside buildings shall be separated from other cable circuits as specified in Table 17.

b) When installed in metallic pathways, the pathways shall be earthed and bonded in accordance with Figure 16.

c) If communication cables share the same pathway with other cable circuits, they may require isolation by means of metallic partitions. The metallic partition shall be selected in accordance with the behaviour needed from an EMC point of view (see Figure B.5).

d) If only one metallic pathway is available for the several cable circuit types, communication cables and low-voltage power cables or the individual cable circuit types shall be isolated from each other by a metallic partition. The partition shall be directly connected to the pathway.

4.4.9.5 Cable routing outside and between buildings

The rules described in 4.4.9.4 also apply for installing cabling outside buildings. Cables installed between buildings shall be segregated for physical protection (e.g. by using a plastic pipe).

Copper cabling installed above earth shall be protected from lightning where appropriate.

The planner should consider the use of optical fibre cables for connections between buildings and between buildings and external facilities where lightning is a problem and/or where there is a large potential earth offset between the buildings and external facilities.

4.4.9.6 Installing redundant communication cables

Redundant cables should always be installed in separate cable routes in order to prevent simultaneous damage. Labels and distinctive cable/conduit colouring should be used as a means of distinguishing between redundant cables (see 4.4.6). The planner may require additional measures in accordance with IEC 62439.

4.4.10 Separation of circuits

Table 17 defines the minimum distances between circuit types inside and outside buildings.

Requirements in Table 17 apply to all cabling.

Table 17 – Cable circuit types and minimum distances

Circuit type	Cables for	Distance for routing outside enclosure	Distance for routing inside enclosure or metallic pathway
AC power lines of greater than 100 kVA High-power digital AC I/O High-power digital DC I/O Power connections (conductors) from motion drives to motors	Motors Motor drives Secondary spark welders, power mains	0,6 m (24 in)	0,3 m (12 in)
Analog I/O lines and analog circuits Low-power digital AC/DC I/O lines Communication cables for control AC power lines of 20 A or more, but only up to 100 kVA	Switched I/O Solenoid Contactors	0,3 m (12 in)	0,15 m (6 in)
Low-voltage DC power lines Communication cables to connect between system components within the same enclosure Process signals (≤25 V) Unscreened DC voltages (≤60 V) Unscreened AC voltages (≤25 V) Conductors of less than 20 A	DC power supplies Low-voltage DC I/O	0,15 m (6 in)	0,08 m (3 in)
Electric light and power	Minimum distance: 8 cm (3 in): 0 V to 100 V: 8 cm (3 in) 101 V to 200 V: 11 cm (4 in) 201 V to 300 V: 13 cm (5 in) 301 V to 400 V: 16 cm (6 in)		

4.4.11 Mechanical protection of cabling components

4.4.11.1 Common description

Install cabling components in areas that provide protection from damage from machine movement including tow motors.

Additional protection may be required to prevent damage from falling objects, liquid, heat and sparks.

The connectors specified in the installation profile shall be used in the bulkhead connection assemblies.

4.4.11.2 Specific requirements for CPs

Additional information regarding mechanical protection of cabling components requirements for a specific industrial network may be found in the respective installation profile.

4.4.11.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.12 Installation in special areas

4.4.12.1 Common description

Cable construction or protection shall be selected based on characteristics of the area or application. For example, weld-spatter applications require weld-spatter cabling or protective sheathes over the cabling.

Documents for installation implementation shall be provided.

4.4.12.2 Specific requirements for CPs

Additional information regarding installation on special areas requirements for a specific industrial network may be found in the respective installation profile.

4.4.12.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.5 Cabling planning documentation

4.5.1 Common description

Cabling planning documentation shall be produced based upon the requirements of 4.1, 4.2, 4.3, and 4.4 and shall contain the elements listed in 4.5.2, 4.5.3, and 4.5.4 as appropriate, that shall be collected in documents organised and named in accordance with IEC 62708.

4.5.2 Cabling planning documentation for CPs

The cabling planning documentation should contain the following information:

- specified environment;
- location of each AO;
- location of interconnections;
- location of connection for device;
- topology;
- earthing, bonding, and shielding requirements;
- cable type (shielded, unshielded, optical fibre, etc.);
- additional cable requirements to meet the specified environment (flex, liquid or dust ingress rating, temp, etc.);
- length of cable section;
- pathways type (cable tray, conduit, duct, metallic rack, etc.);
- placement instructions for the cables (routing);
- labelling instructions for AO and cables;
- type of connector, including sealing requirements, for the specified environment, and pin pair assignment;
- connector installation requirements;
- required mitigation;
- required channel/ permanent link performance;
- life cycle of cabling;
- designation of the areas containing optical fibre cabling in accordance with IEC 60825-2;
- list of tests required;

- a table for comparison of nominal and actual network performance values;
- list of spare parts;
- planner's compliance statement (see 4.1.3).

4.5.3 Network certification documentation

If electrical safety certification is required, then the planner shall define the required documents and the list of actions to be taken to obtain the certification and the required documents.

4.5.4 Cabling planning documentation for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.6 Verification of cabling planning specification

The planner shall verify that the cabling planning work is fully and correctly documented as described in 4.1.3 and specifically shall verify the following:

- components for the design match the specified environment;
- adequate plant/building earthing system exists to support the required communication performance.

5 Installation implementation

5.1 General requirements

5.1.1 Common description

The installation shall be performed in accordance with the cabling planning documentation (see 4.5). The installer shall consult with the planner before deviating from the installation specification. All agreed deviations shall be recorded in the cabling planning documentation.

The requirements specified in this Clause 5 for the CPs also apply for the installation implementation of balanced 1-pair networks specified in Annex Q.

Additional requirements are specified in Clause Q.3.

5.1.2 Installation of CPs

For cabling in support of CPs specified in IEC 61784 (all parts), the installation personnel (termed "the installer" in this document) shall be familiar with the appropriate installation profile of IEC 61784-5 (all parts).

5.1.3 Installation of generic cabling in industrial premises

For generic cabling in accordance with ISO/IEC 11801-3, the requirements and recommendations for installation shall be in accordance with ISO/IEC 14763-2.

5.2 Cable installation

5.2.1 General requirements for all cabling types

5.2.1.1 Storage and installation

The cabling components shall be transported, stored, and installed in accordance with the manufacturer's guidelines and 4.4.8.

In addition, requirements in the cabling planning documentation (4.4.8) shall be applied.

5.2.1.2 Protecting communication cables against potential mechanical damage

Communication cables shall not be subject to mechanical loads that exceed the manufacturer's specifications and the values or range of values defined in the installation profile according to the templates given in Table 18, Table 19, Table 20, and Table 21. Cable pathways and pathway systems specified by the planner shall be installed in such a way to ensure that cables are protected from damage and that suppliers' specifications for bending radius, tensile strength, crush resistance and temperature range are complied with during installation.

NOTE Examples of values or of range of values are provided in the installation profiles of CPs.

Table 18 – Parameters for balanced cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Table 19 – Parameters for silica optical fibre cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Table 20 – Parameters for POF optical fibre cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Table 21 – Parameters for hard clad silica optical fibre cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Communication cables should be protected by a continuous enclosed metallic conduit or by a steel cable tunnel in pathway areas of building and machine sections as well in the region of transport routes and throughways.

The cable supplier's instructions shall be consulted to confirm that the selected pathway system is appropriate for the cable to be installed.

Pathway systems shall be as specified by the planner and installed to eliminate the risk of damage from sharp edges or corners. Edge protection should be used as shown in Figure 21. Where required, the installer shall install pathways which provide protection from water or other contaminant liquids.

Pathways shall be kept clean and free from obstruction with all separators and bridging pieces in place before the installation of cabling. Access points shall not be obstructed.

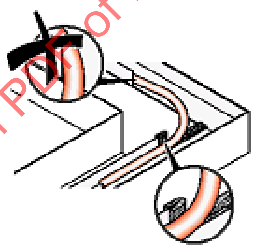


Figure 21 – Insert edge protector

Where the cable is to be pulled within shared pathways, the installer shall take precautions to prevent damage to both new and existing cables or structures.

Redundant cables should always be installed in separate cable routes in order to prevent simultaneous damage through the occurrence of the same event (see 4.4.9.6).

5.2.1.3 Avoid forming loops

When pulling cables into pathways, the installer shall use a suitable cable spool management method to prevent damage caused by torsion and looping (see Figure 22).

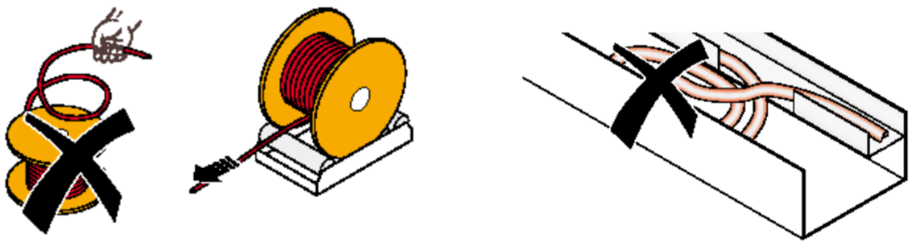


Figure 22 – Use an uncoiling device and avoid forming loop

5.2.1.4 Torsion (twisting)

Torsional stress can result in shifting individual cable construction elements and therefore may have a negative influence on the electrical properties of the cable. For this reason, communication cables shall not be twisted as shown in Figure 23, unless they are specially designed cables for torsional strain (for example in robotic applications).

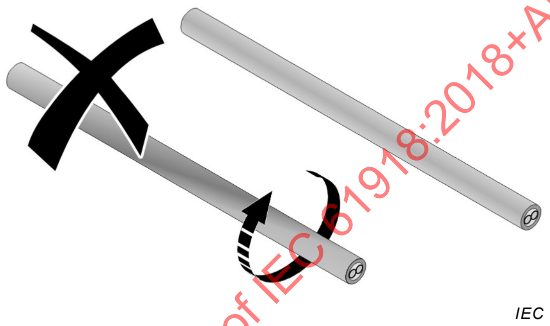


Figure 23 – Avoid torsion

5.2.1.5 Tensile strength (on installed cables)

When installing additional cables in pathways, the installer shall use installation methods that ensure that the tensile strength limits of the installed cables are not exceeded.

5.2.1.6 Bending radius

The minimum-bending radius of a cable is as specified in 5.2.1.2, in accordance with the manufacturer's data sheet. The bending radius shall not fall below the specification at any time.

NOTE 1 Failure to observe this requirement could result in permanent degradation in the cable's electrical or optical performance.

NOTE 2 The bending radius of a cable is affected by the following.

- Bending radius is greater while pulling it under tensile load than in a resting, installed state.
- Bending radius only applies for the flat side when bending flattened cables. Bending over the rounded side requires much greater radii.

It is recommended to secure cables with cable clamps when installed at a right angle and with proper strain relief as shown in Figure 24.

NOTE 3 Over-tightening the clamps could crush the cable.

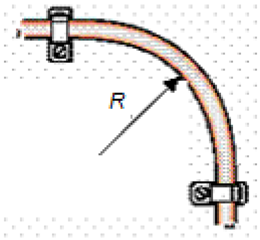


Figure 24 – Maintain minimum bending radius

5.2.1.7 Pull force

The permitted pull force of a cable is as specified in 5.2.1.2, in accordance with the manufacturer's data sheet. The pull force acting on the cable shall not exceed the maximum tensile strength of the cable during handling (for example rewinding) or when installed. Cables shall not be pulled by the individual wires or optical fibres as shown in Figure 25.

Install a pulling grip to the end of the cable to be pulled. This helps to reduce the strain on the cable while pulling into pathways. Wire rollers should be used to reduce the strain on the cable while pulling into the pathway.

Figure 25 – Do not pull by the individual wires

5.2.1.8 Fitting strain relief

A strain relief component shall be fitted at a distance of about 1 m from the connecting point of all cables subject to tensile forces (see Figure 26).

NOTE 1 Cable clamps attached to shielding sheaths are not sufficient as strain relief.

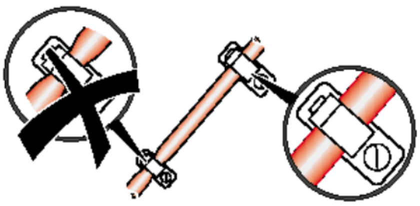


Figure 26 – Use cable clamps with a large (wide) surface

Cables shall be properly strain relieved when hanging from ceilings in pendant applications.

Cable clamps shall be used to secure cables in place within control cabinets.

NOTE 2 Over-tightening the clamps could crush the cable.

Cables shall be secured using fabric hook-and-loop or plastic fastening elements with a large surface to avoid deforming the cables. The fastening elements should have a width of at least 5 mm (0,197 in) and should be fastened without power tools.

5.2.1.9 Installing cables in cabinet and enclosures

Cable wire glands with bending protection or other suitable methods shall be used to prevent cable damage due to exceeding the minimum bending radius of the cable (see Figure 27).

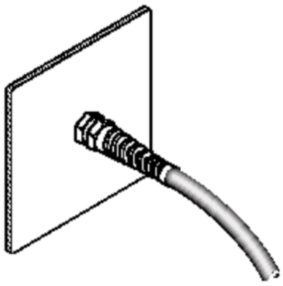


Figure 27 – Cable gland with bending protection

5.2.1.10 Installation on moving parts

Where cables are installed on or between moving parts (for example doors in industrial enclosures/control cabinets), they shall be protected by appropriate fittings to prevent the specified bending radius being compromised (see Figure 28).

5.2.1.11 Cable crush

Cables shall be protected from being crushed. Proper placement of cables or mechanical protection shall be used.

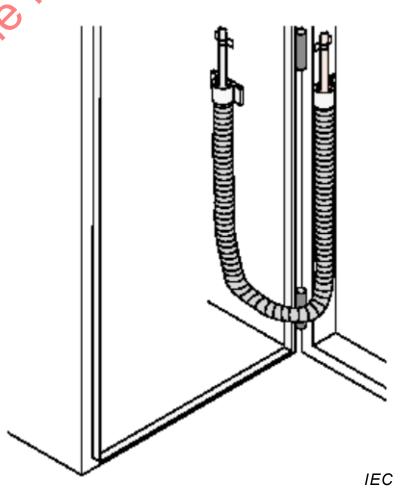


Figure 28 – Spiral tube

5.2.1.12 Installation of continuous flexing cables

Where cables are installed on rolling “C tracks” they shall be laid straight and parallel to the movement of the track. In addition, the separation rules from other circuits shall be observed. The appropriate high flex cable shall be used in a rolling "C" track application. Continuous flexing cables shall be installed in accordance with 4.4.1.5.

5.2.1.13 Additional instructions for the installation of optical fibre cables

5.2.1.13.1 Use cable pulling tools

Cable pulling tools shall only be used if

- specified in the cables suppliers instructions;
- it is applied to the constructional elements of the cables as specified in the cable supplier's instructions.

5.2.1.13.2 Cautions for handling optical fibre cables

The installation of optical fibre cabling shall be performed in accordance with the safety requirement of IEC 60825-2 or local regulations.

Open accessible optical fibre ends shall be kept away from skin and eyes.

It is good practice to follow the following recommendations:

a) installers and maintenance personnel should never look directly into optical fibre ends with either non-protected eye or microscope;
b) when viewing the optical fibre connector, the installer should be sure that the opposite optical fibre end is disconnected from the transceiver or light source.

5.2.1.13.3 Keeping plugs clean

Protective caps shall be applied to all exposed optical fibre plugs and adaptors to prevent contamination and damage to optical fibre end-faces.

5.2.1.13.4 Attenuation change under load

When mixing optical cables with other cable types, care should be taken as to the order of the cable installation to protect the cables from damage.

NOTE This is to protect optical fibre cables against increased bending and tensile loads as, for example, when balanced cables are replaced in the shared cable pathway.

5.2.1.13.5 Strain relief

Strain relief devices shall be used to reduce mechanical strain on the cable connector interface.

5.2.1.13.6 EMC ruggedness

Optical fibre cables, even if without metallic sheathing or amour, are resistant to electromagnetic influences. If permissible under local regulations, optical fibre cables may be directly mixed with other circuits (for example 230/400 V supply).

5.2.1.13.7 Crush resistance

Metallic sheathing or armour provides mechanical protection for fibre optic cables. When conductive protection is used on optical fibre cables, care shall be used in mixing with other circuits of high voltage.

5.2.2 Installation and routing

5.2.2.1 Common description

The installer shall ensure that the cables are compatible with the environmental conditions of the proposed route. For help in classifying the environment, see 4.2.3 and Annex B.

Particular attention is drawn to the following:

- when routing cables in extreme temperature areas, the cables being installed shall be suitable for both the installation temperature and operational temperature of the local environments;
- when routing cables through wet areas, the cables installed shall be suitable for wet locations;
- when routing cables in aggressive chemicals or gaseous areas, the cables installed shall be suitable for the specific chemicals in the environment.

The routing of cables shall take into account the presence, or potential presence, of electromagnetic interference. Unless appropriate components are selected or mitigation techniques are applied:

- cables shall be routed away from high EMI sources such as motors, motor drives, arc welders, induction heaters, etc.;
- cables shall not be routed in parallel with other noise carrying conductors including mains power.

The installer shall take measures to prevent any flammable materials that are present within cables (for example petroleum gel) leaking in pathways, closures or at any point of termination.

Where cables contain liquid or gel filling materials it is advisable to use protective caps (or equivalent) over exposed ends of the cable. This is particularly important where there may be considerable delays between installation of the cable and final termination.

When cabling with remote powering is used, the effects of heat on the cabling shall be considered as specified in Annex P.

The installer shall make every attempt to place earthing and equalization conductors as close to the metallic pathway as possible. Copper communications conductors should be located above the earthing and equalization conductors.

As for the optical fibre cables, the installer shall observe the minimum cabling path loss requirements (cables and connectors) to insure proper functioning channel. In addition, the instructions of the cable, plug connector and device manufacturer shall be observed.

The installer should place fibre cables either in a separate pathway or in such a way that they will not be damaged by cable loading or during maintenance (e.g. as in Figure 29).

Labels shall be applied in accordance with the cabling planning documentation.

5.2.2.2 Separation of circuits

To avoid negative effects on communication due to EMI, minimum separation distances shall be observed between cables of different circuits as defined by the planner according to requirements given in 4.4.10.

Communication cables should be installed in a separate pathway away from other circuits to reduce the effects of EMI on the communication cables. In shared pathways, communication cables shall be isolated from other circuits by means of metallic barriers as specified by the planner (see Figure B.5).

Figure 29 provides an example of separation for optical fibre cables.

NOTE Separation provides a number of advantages:

- improvement of the EMC;

- protection of existing cables from damage caused by pulling additional cables in the pathway;
- easier localisation if troubleshooting becomes necessary.

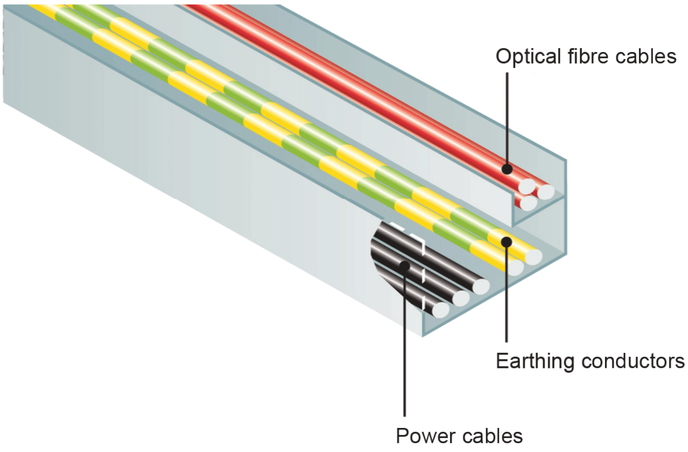


Figure 29 – Separate cable pathways

5.2.3 Specific requirements for CPs

Additional information regarding the cable installation requirements for a specific industrial network may be found in the respective installation profile.

5.2.4 Specific requirements for wireless installation

None.

5.2.5 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

5.3 Connector installation

5.3.1 Common description

Cables shall be terminated in accordance with the instructions provided by the manufacturer/supplier of the connecting hardware. If special tools are required for the termination, then only those recommended by the manufacturer shall be used.

Following termination, the cable elements shall be arranged in a manner that allows access to individual connectors, joints and cable elements with minimal disruption to neighbouring components during subsequent repair, expansion or extension of the installed cabling.

The connector pin-pair designation shall be in accordance with the cabling planning documentation.

When making cables or cord sets, the installer shall refer to Annex H for the appropriate connector and connector wiring.

The following common mistakes shall be avoided:

a) cutting the insulation of the wire, when stripping the cable. If the installer damages the insulation, he/she shall cut off the end of the cable and start over;
b) failure to put the connector shell or boot on in the correct order of the connector installation;

c) un-twisting the pairs of symmetrical multi-core cables too far back. This is important for maintaining system performance in balanced cabling systems;

d) incorrect placement of conductors into the connector.

In addition, for terminating unshielded and shielded twisted pairs cable ends, the following recommendations and the basic rules described in 5.3.2 and 5.3.3 should be applied.

Trim conductors before installing into the connector body as short as possible. The length of the jacket shall be long enough to fit inside the connector back end.

Labels shall be applied in accordance with the cabling planning documentation.

5.3.2 Shielded connectors

The cable shield shall provide a 360 degree shield around the cable along its entire length (a shielding contact applied only through the drain wire has little effect at high frequencies). Cable shields shall be terminated at all termination points.

At each termination point:

a) special attention shall be paid to the assembly of connection elements. The shield contact shall be applied over 360° according to the Faraday cage principle. The shield shall be terminated to provide a low impedance termination;

b) the shielding shall continue through an appropriate shield connection; normal pin contacts alone shall not be used;

c) discontinuities in the shielding shall be avoided, such as even small holes in the shield, pigtails, loops;

d) shield connections shall be firmly fixed, for instance by strapping or clamping;

e) shields shall not be used as a strain relief;

f) shields shall be earthed in accordance with the cabling planning documentation and the relevant CPs requirements.

Shielded connectors shall be installed in accordance with connector and cordset termination procedures given in Annex H and Annex I.

5.3.3 Unshielded connectors

Install connectors according to planner's recommendations and manufacturer's information.

Unshielded connectors shall be installed in accordance with connector and cordset termination procedures given in Annex H and Annex I.

5.3.4 Specific requirements for CPs

Additional information regarding the connector installation requirements for a specific industrial network may be found in the respective installation profile.

5.3.5 Specific requirements for wireless installation

None.

5.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

5.4 Terminator installation

5.4.1 Common description

The installation of terminators shall be in accordance with the cabling planning documentation.

NOTE Improper termination of any balanced cable element or shield can degrade transmission performance, increase emissions and reduce immunity (taken from 10.1.6 of ISO/IEC 11801-1:2017).

5.4.2 Specific requirements for CPs

Additional information regarding the terminator installation requirements for a specific industrial network may be found in the respective installation profile.

5.5 Device installation

5.5.1 Common description

The installer, once agreed with the planner, shall make a note on the as-implemented cabling documentation regarding placement of devices that deviates from the cabling planning documentation.

5.5.2 Specific requirements for CPs

Additional information regarding the device installation requirements for a specific industrial network may be found in the respective installation profile.

5.6 Coding and labelling

5.6.1 Common description

Coding and labelling shall be applied in accordance with planner's requirements.

5.6.2 Specific requirements for CPs

Additional information regarding the coding and labelling installation requirements for a specific industrial network may be found in the respective installation profile.

5.7 Earthing and bonding of equipment and devices and shield cabling

5.7.1 Common description

The installer shall perform the earthing of the installation (including equipment, pathways, devices and cable shields) in accordance with the cabling planning documentation, as detailed in 5.7, and should apply the recommendations of IEC TR 61000-5-2.

Where required by the cabling planning documentation, the installer shall ensure that earthing conductors meet the following specifications.

- The resistive earth impedance should be less than 0,6 Ω and shall be less than 1 Ω. The resistive earth is measured between any two points at which communication devices or cable shields are earthed.

NOTE 1 Inductive factors of the earth conductors will raise the effective earth impedance during high frequency events (see Annex B).

NOTE 2 A low resistance is not a sufficient condition to guarantee functional performance with respect to communication errors.

The installer shall also ensure that connection resistance to the earth bus is $< 0,005\ \Omega$ (see 5.7.2.3).

Labels shall be applied in accordance with the cabling planning documentation.

5.7.2 Bonding and earthing of enclosures and pathways

5.7.2.1 Equalisation and earthing conductor sizing and length

Placement of the grounding and equalization conductors shall be in accordance with the planner's instructions. If conductor-sizing requirements are not defined in the cabling planning documentation, then the installer shall use the cable cross-section values defined in 4.4.7.2.1.

The earthing conductor length shall be cut to minimum length to complete the connection.

Excess earthing and bonding conductors shall be cut and shall not be coiled. In fact coiling increases their inductance and impedance and decreases the effectiveness of the grounding circuit.

The graphs in Figure 30 show the consequences to the impedance as a result of increasing the spacing between the earthing conductor and the metallic pathway. The installer shall take into account the fact that the equalization and earthing circuit become less effective as the impedance raises with the spacing changing from 1 mm to 10 mm or to 100 mm, etc..

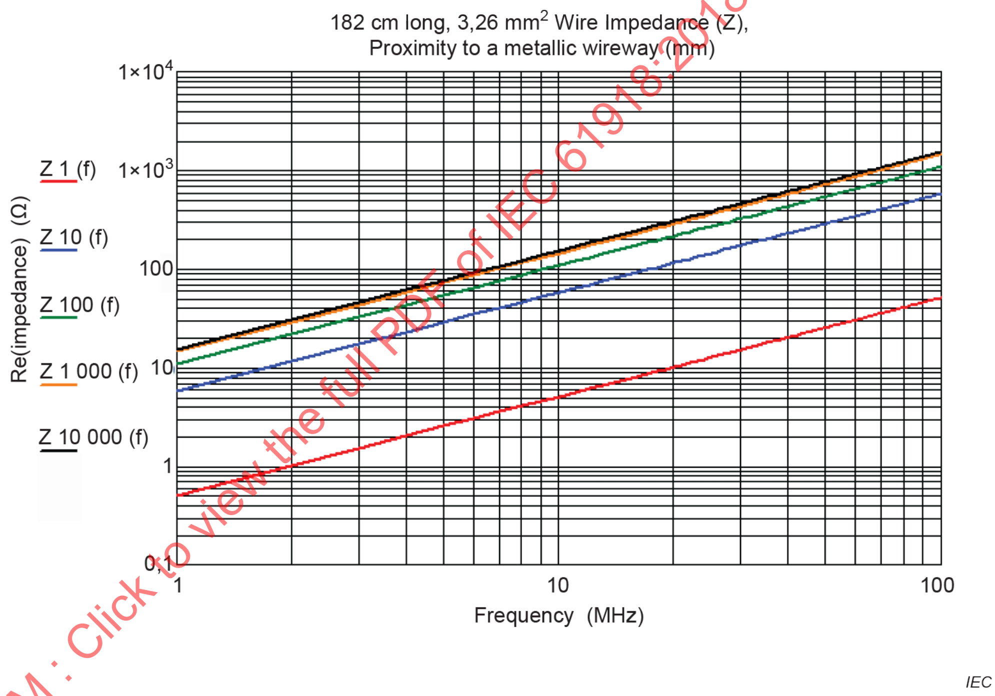


Figure 30 – Impedance of the earthing circuit as a function of distance from the metallic pathway

An earthing conductor shall not be placed into a metallic conduit unless the conductor is bonded at each end of the metallic conduit.

NOTE Omitting the bonding requirement increases the earthing conductor's impedance and defeats its effectiveness as a low impedance earth path for noise.

5.7.2.2 Bonding straps and sizing

If bonding straps requirements are not defined in the cabling planning documentation, then the installer shall use the bonding strap sizes defined in Figure 31.

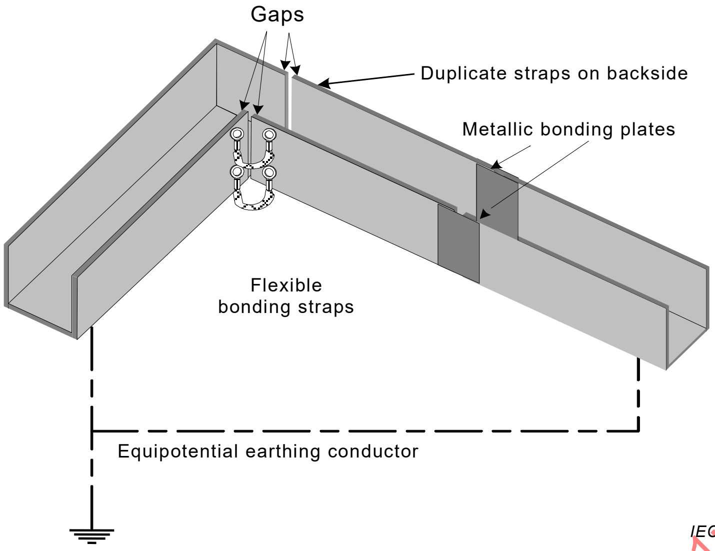


Figure 31 – Use of flexible bonding straps at movable metallic pathways

Figure 31 clarifies how the installer shall use the flexible bonding straps and the metallic bonding straps in accordance with the planner requirements specified in 4.4.7.2.4.

5.7.2.3 Surface preparation and methods

Figure 32 shows examples of proper mechanical implementation of earthing connections.

Figure 32 a) shows how to connect a sub plate to a back plate; Figure 32 b) shows how to connect an earthing conductor to a bus bar or to a sub plate; Figure 32 c) shows how to connect an earth bus bar to a back panel; Figure 32 d) shows how to connect an isolated earth bus bar to a back panel.

The installer shall perform the following, when installing earthing hardware:

- clean any paint and oxidation from all contacts and mating surfaces before affixing the earthing conductors;
- use either internal tooth star washers or flat washer as shown in Figure 32.

The connections to earth shall be protected against corrosion to ensure long-term stability.

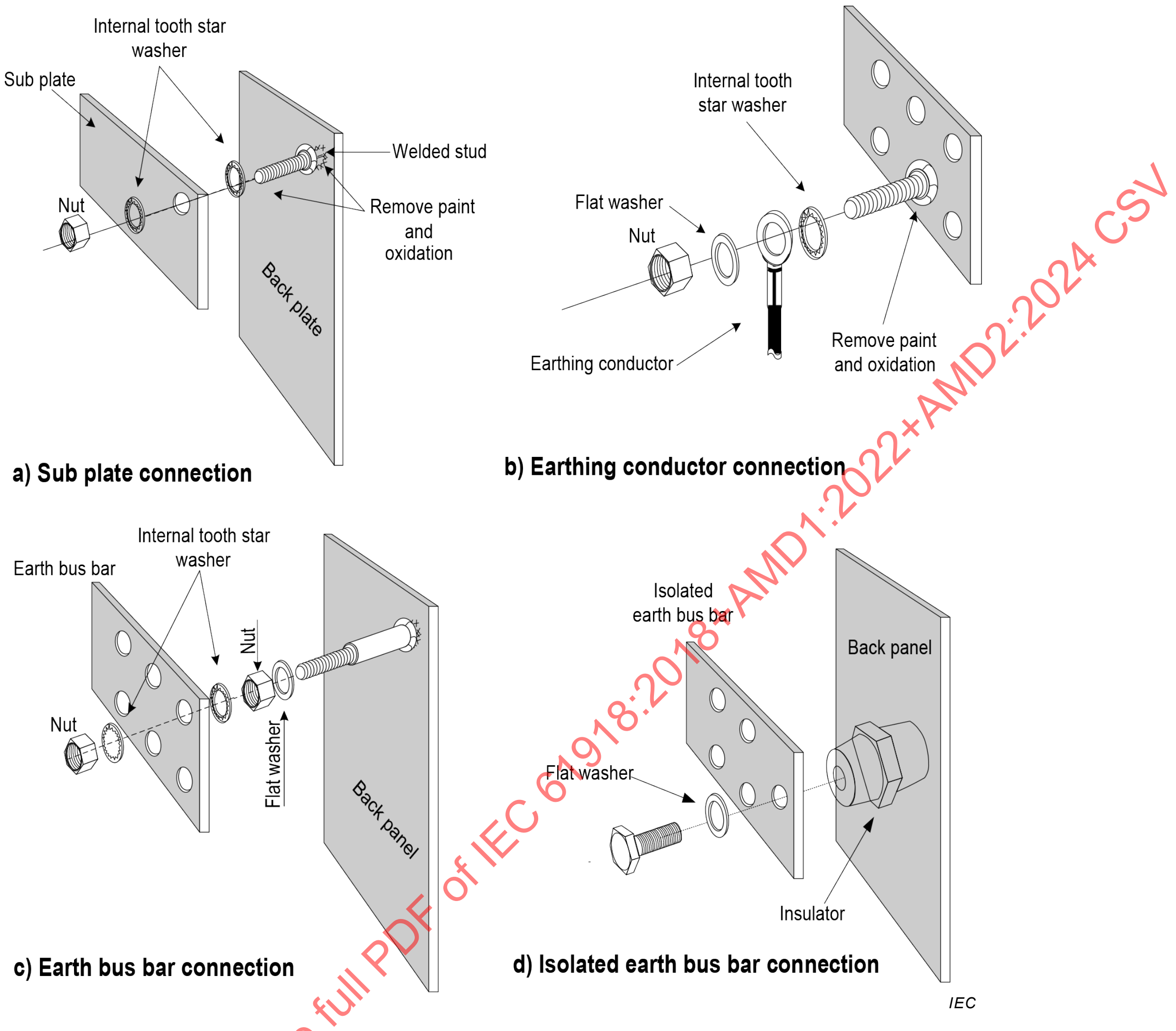


Figure 32 – Surface preparation for earthing and bonding electromechanical connections

5.7.3 Earthing methods

5.7.3.1 Equipotential

When installing enclosures and communication devices, in addition to what is defined by the planner, the installer shall ensure the following as well as what is specified in 5.7.2.2.

a) The potential equalization rail is earthed in each industrial enclosure/control cabinet and connected to the potential equalization rails of the other control cabinets.

b) Each part of the installed network and devices shall be electrically connected to the potential equalization system/functional earth at as many places as possible, as defined by the planner. The earthing conductor, trays, parts of machines or supporting structures, and any additional equipotential bonding conductors should be integrated in the potential equalization system.

5.7.3.2 Star

Where the cabling planning documentation specifies a star earthing system, and the devices are required to be connected to a functional earth system that is isolated from the protective earth system, the method specified by the planner shall be used with the addition of the following specifications: bus bars provide a convenient star earthing point for star earthing systems.

A method to reduce the length of the earthing conductors in a star earthing system requires connecting a work cell to a common star connection and then connecting this common star connection to the building earthing system, thus helping to eliminate earth offsets within a local work cell. If shielded communication cables travel from one work area to another, then the associated earths shall be part of the star earth system.

5.7.3.3 Earthing of equipment (devices)

5.7.3.3.1 Non-earthing or parallel RC

When the cabling planning documentation requires that devices are isolated from earth, then the leakage current shall be in accordance with the relevant installation profile.

If a parallel RC circuit is used between earth and the device, it shall be installed in accordance with the cabling planning documentation and the relevant communication profile. The value of the RC shall be in accordance with the relevant communications profile. The installer shall confirm the presence of the parallel RC circuit to ensure that the device is properly isolated. The isolated standoff shown in Figure 33 may be required to prevent shorting of the RC circuit.

5.7.3.3.2 Direct

The direct connection to earth shall be established in accordance with specifications provided in 5.7.1.

5.7.3.3.3 Installing copper bus bars

Where the cabling planning documentation specifies the use of isolated bus bars, the requirements specified by the planner shall be used with the addition of the following specifications.

– Figure 33 shows an example of the connection points provided by isolated bus bars.
– If the communication components are DIN rail mounted, then insulators for the DIN rails shall be used (see the example in Figure 34).

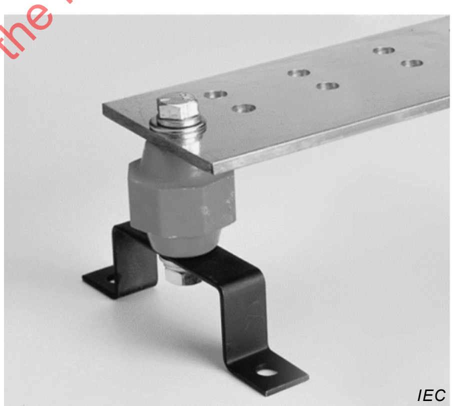


Figure 33 – Example of isolated bus bar

Figure 34 – Example of isolator for mounting DIN rails

5.7.4 Shield earthing methods

5.7.4.1 General

When shielded cables are used, the housing of the device, and also the control cabinet in which the fieldbus device is mounted, shall have the same earth potential by providing a large-area metallic contact to earth (use, for example, copper to ensure a good connection).

It is important that communication cabling shields do not conduct noise currents due to earth offset and improper earthing of devices and enclosures. Noise currents in the cabling shield would cause disruptions in the communication network.

Subclauses 5.7.4.2 to 5.7.4.4 provide a description of earthing techniques that have been proved to help reduce communication faults due to earth offsets where shields might be terminated. The reader is encouraged to consider other standards such as IEC 60364 with regards to the proper termination of screened cables and exposed metallic structures.

5.7.4.2 Parallel RC

Parallel RC earthing of a shield is done by using a combination of R and C as represented in Figure 35.

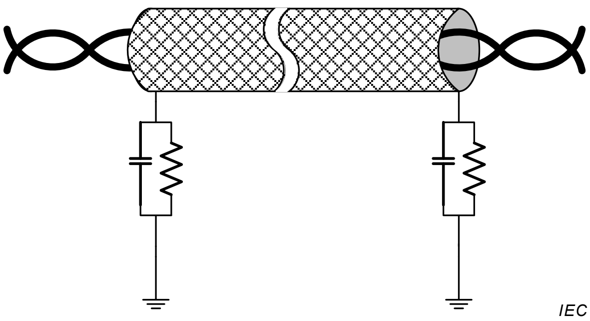


Figure 35 – Parallel RC shield earthing

5.7.4.3 Direct

Direct earthing of shield is as represented in Figure 36.

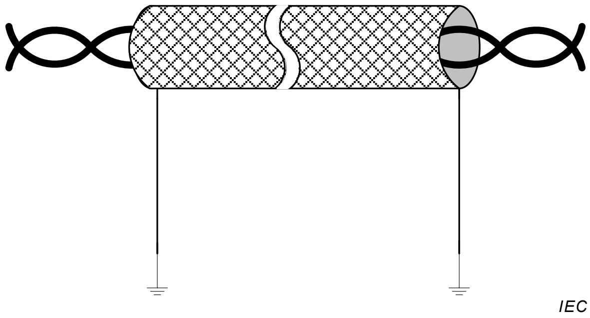


Figure 36 – Direct shield earthing

In addition, the installer shall observe the following points.

a) Do not damage the cable shielding foils and braids while stripping the outer sheath of the cable.

b) Cable contacts may only be established to the copper braided shielding sheaths, not to the aluminium foil-shielding sheaths, which are often also present. The foil-shielding sheath is usually fastened on one side to a plastic film to increase its tear resistance; therefore it is non-conductive.

c) Metallic cable clips for fasten braided shielding shall be selected to match the dimension of the cable (see Figure 37). The installer shall be aware of the following:

   1) this connection, if it is too tight, permanently damages the cable by degrading the transmission performance; and,

   2) if it is too loose, introduces noise in the system.

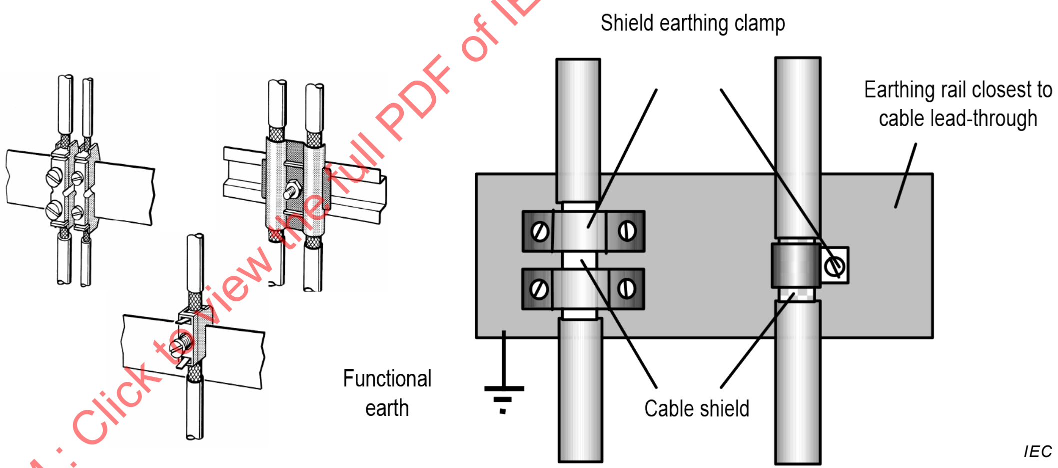


Figure 37 – Examples for shielding application

d) Tin plated or galvanically stabilized surfaces are ideal for establishing a good contact. With galvanized surfaces, the necessary contact shall be established by using a suitable screw connection. Contact points with painted surfaces are not suitable.

e) Shielding sheath clamps/contacts should not be used as strain relief, unless explicitly designed for such purpose. The contact could come loose or tear off.

Figure 38 shows how the installer shall use the equalization conductor to mitigate voltage offsets, as required by the planner (see 4.4.7.4.2).

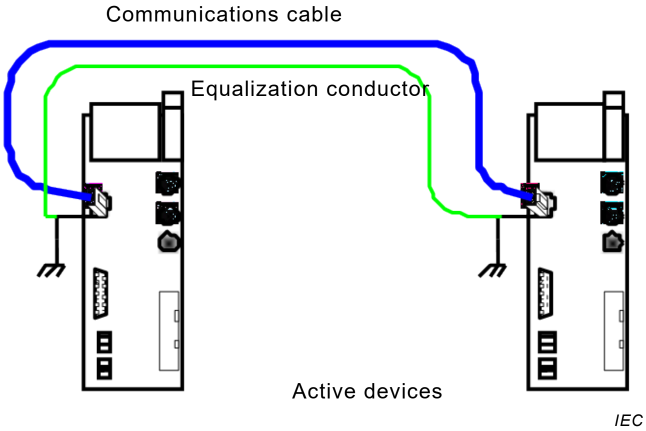


Figure 38 – Voltage offset mitigation

5.7.4.4 Derivatives of direct and parallel RC

Examples of derivative of direct and parallel RC earthing of shield are provided in Figure 39 and Figure 40.

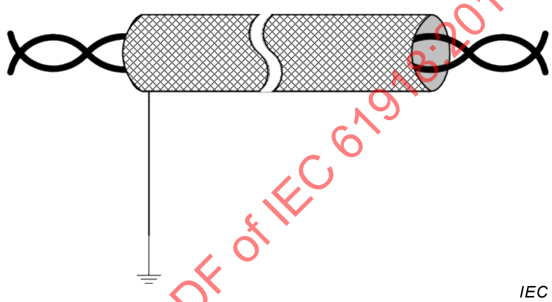


Figure 39 – First example of derivatives of shield earthing

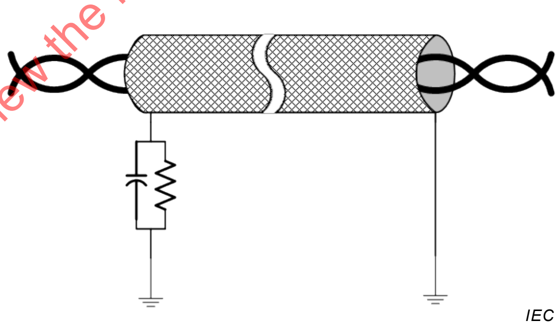


Figure 40 – Second example of derivatives of shield earthing

5.7.5 Specific requirements for CPs

Additional information regarding the earthing and shielding installation requirements for a specific industrial network may be found in the respective installation profile.

5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

5.8 As-implemented cabling documentation

The installer shall document the result of the network installation. The as-implemented cabling documentation should include at least the following items, to be collected in documents organised and named in accordance with IEC 62708:

a) inventory of installed components;
b) cable routing;
c) used labelling;
d) location for the devices to connect to the network;
e) implemented channels.

6 Installation verification and installation acceptance test

6.1 General

Clause 6 addresses the verification and installation acceptance test of an installed cabling infrastructure.

Installation verification comprises the inspection of the cabling infrastructure and the testing of related aspects such as earthing systems against the following verification requirements:

a) the cabling planning documentation including deviations and additions as agreed by the planner;
b) the appropriate installation profile of IEC 61784-5 (all parts) or ISO/IEC 11801-3 (in the case of generic cabling);
c) the requirements of Clause 5.

Acceptance testing ensures that the installation is capable of supporting the required application and includes

- inspection of the installed cabling;
- cabling transmission performance tests against the cabling planning documentation and any recorded deviations.

For cabling in support of CPs within IEC 61784 (all parts), the personnel performing the testing shall be familiar with the appropriate CP installation profile or ISO/IEC 11801-3 (in the case of generic cabling).

The requirements specified in this Clause 6 for the CPs also apply for the installation implementation of balanced 1-pair networks specified in Annex Q.

Additional requirements for balanced 1-pair network are specified in Clause Q.4.

6.2 Installation verification

6.2.1 General

The verifier shall check (with a visual inspection and some simple measurements) that the entire network is installed in full accordance with the cabling planning documentation and that the as-implemented cabling documentation is complete and correct as required.

Verification is also done after each additional connection is made or after adds, maintenance, changes and moves.

NOTE The work of the verifier is usually done by the installer himself at the end of the installation.

Items to be verified according to cabling planning documentation are listed in the subclauses of 6.2.

These verification action items are aimed to ensure the network is installed in accordance with the cabling planning documentation and supports future maintenance and/or troubleshooting activities.

The schematic in Figure 41 is provided to guide the installation verification process.

Test tools should be selected based on the needs and the requirements of the specific CP. Commercial test tools may be available.

6.2.2 Verification according to cabling planning documentation

Each installed cabling should be verified, against the requirements provided in 6.2.3 and the checklists in Annex G, for proper installation.

Additional information regarding the installation verification requirements for a specific industrial network may be found in the respective installation profile.

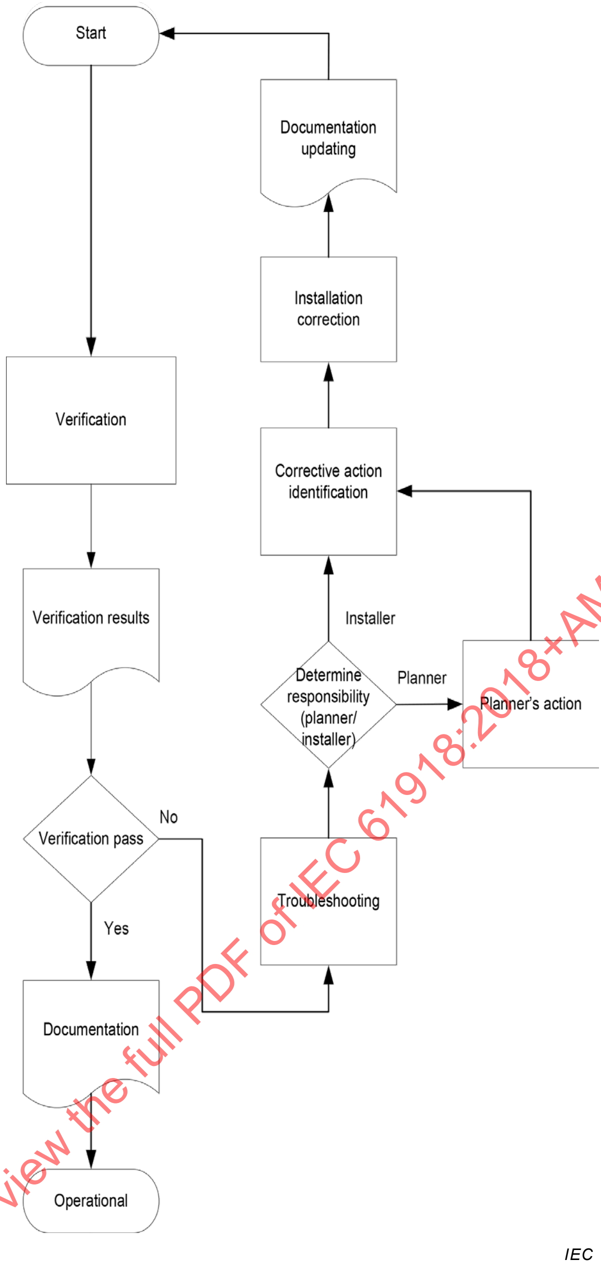


Figure 41 – Installation verification process

6.2.3 Verification of earthing and bonding

6.2.3.1 General

All earthing and bonding connections shall be in accordance with the cabling planning documentation and shall be verified to meet the minimum resistance requirements specified in 6.2.3.

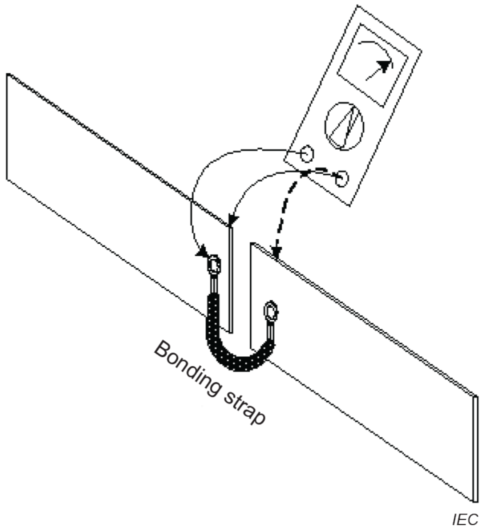


Figure 42 – Test of earthing connections

Test (see Figure 42), with the use of a suitable voltmeter (or oscilloscope), that the resistance or voltage offset between any installed earthing and bonding connection and one pre-existing earthing and bonding point is in accordance with requirements in 5.7.1 and 5.7.2 with communications cables connected or 1 V respectively without communications cables connected. The mechanical connection between a bonding or earthing conductor and any metal surface shall have a resistance less than 0,005 Ω. If distance prohibits this test, then visual verification of earthing requirements should be used in conjunction with verification of resistance measurements at the connection points. Visual verification should include verification of proper conductor size of earth and bonding conductors in accordance with the cabling planning documentation. If the above conditions cannot be met, then the earthing system should be corrected or alternate media shall be considered (unshielded cables, optical fibre cables, or wireless).

The requirements specified in 6.2 apply to all equipment, equipment enclosures and telecommunications rooms.

Proper installation of copper bus bars shall be verified. If isolated from building steel at point of mounting, verify that isolation resistance is > 2 MΩ between the bus bar and the point of mounting. If directly mounted to building steel, verify that resistance is < 0,005 Ω between the bus bar and the building steel.

Verify that conductor connecting the bus bars together is in accordance with the planner's requirement defined in line with 4.4.7.3.4 in particular. Verify proper conductor size and that bonding resistance is ≤ 0,005 Ω between wire and bus bar.

Verify correct implementation of the star configuration or the equipotential configuration.

Verify that excess earthing and bonding conductors have been removed and not coiled.

6.2.3.2 Specific requirements for earthing and bonding

Additional information regarding the earthing and bonding verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.4 Verification of shield earthing

Subclause 6.2.4 applies when shielded cables or cables with shielded elements or units are used. Only basic guidance is provided.

The procedures necessary to provide adequate earthing for both electrical safety and EMC are subject to national and local regulations, are dependent on proper workmanship, and are at times only accomplished with installation-specific engineering.

Note that improper termination of shields may degrade safety and/or performance.

When shields shall be earthed they shall be verified according to the requirements of the appropriate CP installation profile. In the absence of specific guidance, the connection shall be verified to be ≤ 0,005 Ω between the shield and the point where it is bonded to earth.

6.2.5 Verification of cabling system

6.2.5.1 Verification of cable routing

Visual inspection should verify that the cable routing is in accordance with the planner's requirement and routing techniques.

NOTE Depending on the CP or network being installed there are specific topology limits (see Clause 4 and the respective CP installation profile for supported topologies). The cabling planning documentation defines the topology for the network to be installed.

Visual inspection of the network should include verification that

- the cabling has been installed with the proper isolation and separation from circuits as defined by this document and the local regulations (see 4.4.10), and
- excess communications cable is in accordance with 4.4.9.1.

6.2.5.2 Verification of cable protection and proper strain relief

Verify that cables entering and exiting enclosures maintain seal, proper strain relief, and drip loops, where appropriate.

6.2.6 Cable selection verification

6.2.6.1 Common description

Verification should include verifying that the installed components are in accordance with the cabling planning documentation and as-implemented documentation.

6.2.6.2 Specific requirements for CPs

Additional information regarding the cable selection verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.6.3 Specific requirements for wireless installation

None.

6.2.7 Connector verification

6.2.7.1 Common description

Connector verification includes the following two requirements:

- the connectors are in accordance with the cabling planning documentation;
- the connector has been installed in accordance with the installation profile and the manufacturer's data sheet.

6.2.7.2 Specific requirements for CPs

Additional information regarding the connector verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.7.3 Specific requirements for wireless installation

None.

6.2.8 Connection verification

6.2.8.1 Common description

The verifier shall verify proper number of connections, connectors used and wire mapping.

6.2.8.2 Number of connections and connectors

Verify proper number of connections and connectors used, as specified in the cabling planning documentation, especially the number of permitted connections.

6.2.8.3 Wire mapping

The verifier shall verify that the wire mapping is in accordance with the cabling planning documentation. Test method is given in ~~5.3.2.2~~ 5.3.3.2 of IEC 61935-1:~~2015~~2019.

Wire mapping is intended to verify pin-to-pin termination at each end and check for installation connectivity errors. For each of the conductors in the cable, the wire map indicates:

- continuity to the remote end;
- shorts between any two or more conductors;
- reverse pairs;
- split pairs;
- transposed pairs;
- any other incorrect wiring.

Figure 43 and Figure 44 provide examples of pin and pair grouping assignments. Incorrect pairings are represented in Figure 45.

A reverse pair occurs when the polarity of one wire pair is reversed at one end of the permanent link (also called a tip/ring reversal).

A transposed pair occurs when the two conductors in a wire pair are connected to the position for a different pair at the remote connection.

NOTE 1 Pair transpositions are sometimes referred to as crossed pairs.

Split pairs occur when pin-to-pin continuity is maintained, but physical pairs are separated.

NOTE 2 When testing 2 pair systems, a connector conversion for the cable tester can be needed to support the M12 connector. In addition, this hardware will need to support 2 pair cables with the correct wiring configuration.

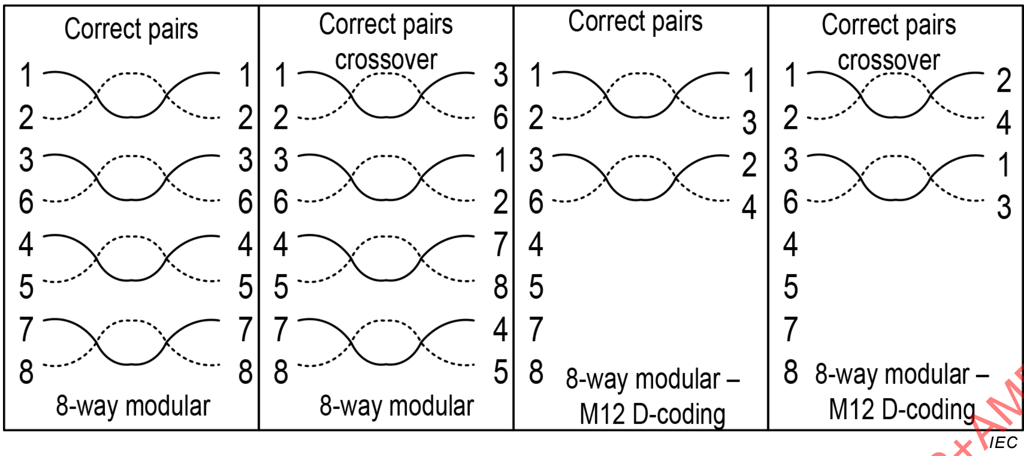


Figure 43 – Pin and pair grouping assignments for two eight position IEC 60603-7 subparts and four position IEC 60603-7 series to IEC 61076-2-101 connectors

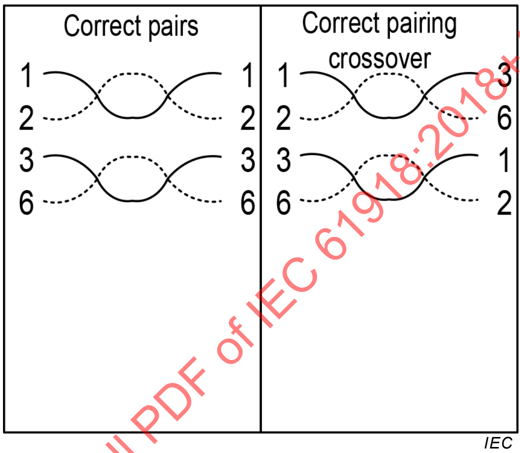


Figure 44 – Two pair 8-way modular connector

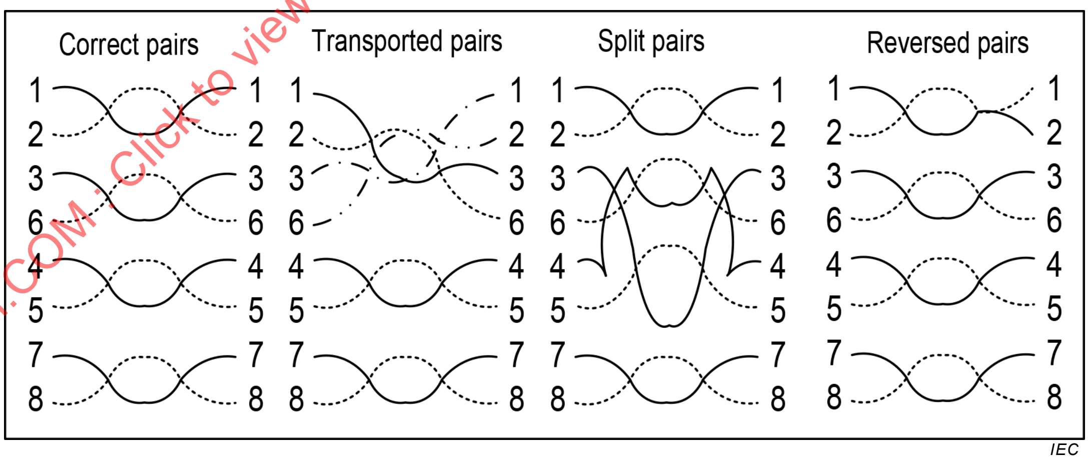


Figure 45 – Transposed pairs, split pairs and reversed pair

For balanced 1-pair applications, the requirements specified in Q.4.2 apply.

6.2.9 Terminator verification

6.2.9.1 Common description

The verification process shall include visual and electrical verification, (i.e. terminator values, placement and protection) in accordance with cabling planning documentation.

6.2.9.2 Specific requirements for CPs

Additional information regarding the terminator verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.10 Coding and labelling verification

6.2.10.1 Common description

The verifier shall verify the presence of the label and that the label contains the text required in the cabling planning documentation. Where required, the verifier shall verify that the label is constructed of durable material with permanent readable text.

6.2.10.2 Specific coding and labelling verification requirements

Additional information regarding the coding and labelling verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.11 Verification report

Successful completion of verification shall be documented in a final verification report. The report shall include copy of the checklists (see Annex G) filled in by the verifier.

6.3 Installation acceptance test

6.3.1 General

The organisation in charge of the acceptance testing shall assess the network ability to support the required applications. “Acceptance test” is a process meant to ensure that the implementation conforms to the standard as detailed in the cabling planning documentation (see 4.5).

The acceptance test personnel shall

a) check that the cabling planning documentation, with recorded deviations and additions, is complete and correct as required;

b) include a visual inspection of the network installation to ensure that the network is properly installed (see 6.2.4, 6.2.5, 6.2.6, 6.2.6.3, 6.2.9, 6.2.10);

c) perform the validation of the network through a defined list of measurements and provide the documentation of the results of the measurements.

NOTE 1 The record of positive test results is an important point of reference for the maintenance and troubleshooting work.

NOTE 2 The term “validation” in this document has the specific meaning described in 3.1.84.

There are many commercially available tools to help validate the performance of the cabling system. Test tools should be selected based on fieldbus, test coverage and precision desired.

The tester shall perform network testing in accordance with the acceptance test requirements as detailed in 6.3.2 (Ethernet-based cabling) and 6.3.3 (non-Ethernet-based cabling).

The resulting test records provide a documented network validation.

The flowchart in Figure 46 is provided to guide the validation process.

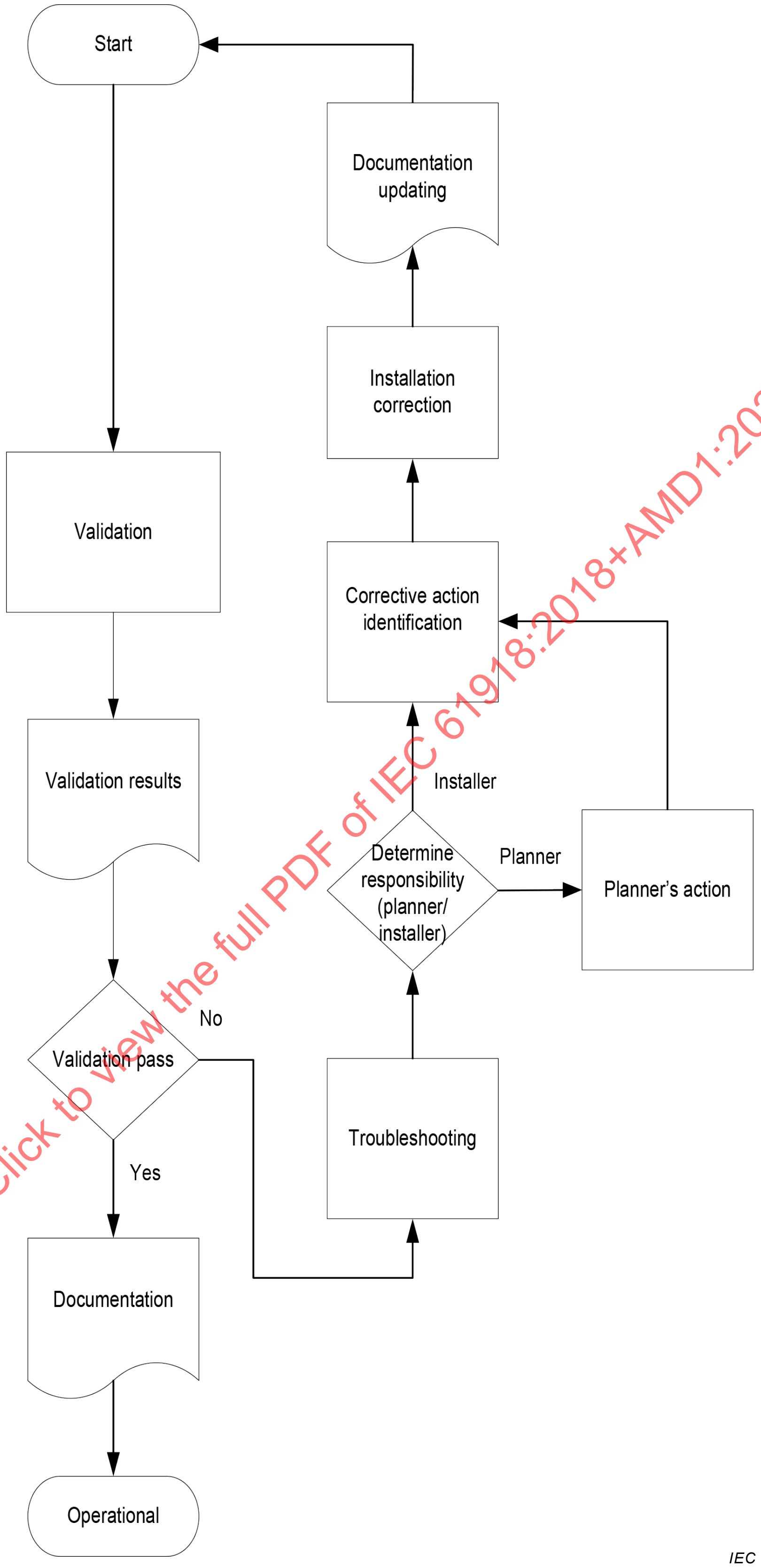


Figure 46 – Validation process

6.3.2 Acceptance test of Ethernet-based cabling

6.3.2.1 Validation of balanced cabling for CPs based on Ethernet

6.3.2.1.1 Common description

The transmission performance of cabling channels (see Figure 47) as described in Clause 4 can only be determined if the cables or cords connecting the installed cabling to the devices are present. The type of connecting hardware that terminates these cables or cords may influence the selection of test equipment.

The transmission performance of permanent links (see Figure 48) can only be determined using specific test cords. The type of connecting hardware that terminates these cables or cords may influence the selection of test cords and equipment.

Where the CP is specified to be supported by a transmission performance class as defined in ISO/IEC 11801-3, the test methods of ISO/IEC 11801-3 may be applied to the channel.

A permanent link test, against the applicable requirements of the appropriate transmission class of ISO/IEC 11801-3, should only be applied where the cabling components subsequently attached to the permanent link to form the transmission channel have been proven to maintain the required channel performance class of ISO/IEC 11801-3.

The requirements for test equipment to perform testing in accordance with ISO/IEC 11801-3 are specified in IEC 61935-1 and ISO/IEC 14763-4 for End-to-end link (see Figure 49). This equipment is required to produce specific documentation covering both transmission performance and conductor mapping.

NOTE Test equipment in accordance with IEC 61935-1 may require modification to allow effective testing of 2-pair balanced cabling.

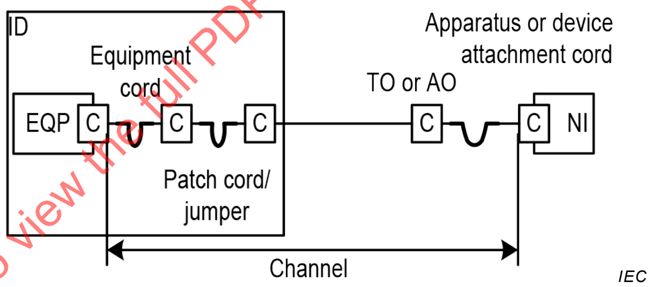


Figure 47 – Schematic representation of the channel

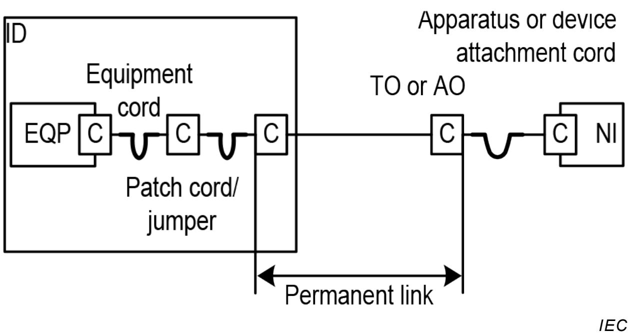


Figure 48 – Schematic representation of the permanent link

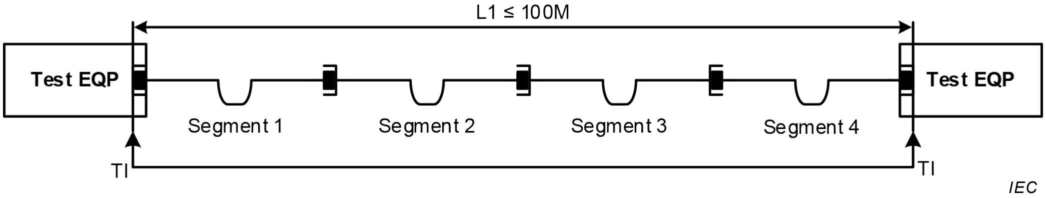


Figure 49 – Schematic representation of an E2E link

Equipment in accordance with IEC 61935-1 may be applicable for testing of channels and permanent links against other Ethernet performance criteria (such as those stipulated in other standards). However, also in these cases, a permanent link test against the applicable requirements should be applied, only where the cabling components subsequently attached to the permanent link to form the transmission channel have been proven to maintain the required channel performance.

Figure 49 shows the schematic representation of a four segments, five connections E2E link. The keys of this figure are described in Annex O where other configurations of E2E links are specified.

The test of E2E link shall be performed in accordance with ISO/IEC 14763-4. Annex O describes how to test E2E link.

Other channel or permanent link performance requirements shall be applied as detailed in the relevant CP installation profile.

Field test equipment for Ethernet-based networks including connection adapters shall meet the appropriate channel and accuracy level as defined in IEC 61935-1.

6.3.2.1.2 Transmission performance test parameters

The parameters for which field tests are specified in ISO/IEC 11801-3 and for which support exists in IEC 61935-1:~~2015~~2019 and IEC 61935-1-1:2019 are as follows:

a) return loss;

b) insertion loss;

c) near-end crosstalk loss (NEXT);

d) far-end crosstalk loss (FEXT);

e) power sum near-end crosstalk loss (PSNEXT);

f) attenuation crosstalk ratio (ACR);

g) power sum attenuation crosstalk ratio (PSACR);

h) equal-level far-end crosstalk loss (ELFEXT);

i) power sum equal-level far-end crosstalk loss (PSELFEXT);

j) DC loop resistance;

k) propagation delay skew;

l) delay skew;

m) unbalance attenuation, near-end (TCL);

n) unbalance attenuation, far-end (ELTCTL).

Items m) and n) above apply where requirements are given in the relevant CP.

NOTE 1 This list assumes that wire map and length have been successfully verified since:

- errors in pair-pin mapping would result in identified failures of transmission performance;

- channel/permanent link length is not a transmission performance test parameter (but may be important for maintaining accurate installation documentation).

NOTE 2 Continuity is not included since errors in pair-pin mapping would result in identified failures of transmission performance.

NOTE 3 This list can be amended in subsequent editions of the above standards.

The results of the tests shall be recorded into the acceptance test report.

6.3.2.1.3 Specific requirements for CPs based on Ethernet

Additional information regarding validation requirements for a specific CP may be found in the respective installation profile.

6.3.2.2 Validation of optical fibre cabling for CPs based on Ethernet

6.3.2.2.1 Common description

The transmission performance of cabling channels as described in Clause 4 can only be determined if the cables or cords connecting the installed cabling to the devices are present. The type of connecting hardware that terminates these cables or cords may influence the selection of test cords and test equipment.

The transmission performance of permanent links can only be determined using specific test cords. The type of connecting hardware that terminates these cables or cords may influence the selection of test cords and equipment.

Channel or permanent link performance requirements shall be applied as detailed, and at the wavelengths specified, in the relevant CP.

As a minimum, the following parameters shall be measured:

- optical fibre polarity;
- permanent link or channel insertion loss;
- length.

The test methods of ISO/IEC 14763-3 shall be applied. Cabling lengths may be determined using test equipment that operates in the time-domain or from cable markings.

Permanent link tests, against the applicable requirements should only be applied where the cabling components subsequently attached to the permanent link to form the transmission channel have been proven to maintain the required channel performance.

6.3.2.2.2 Specific requirements for optical fibre cabling CPs

Additional information regarding the optical fibre cabling validation requirements for a specific CP may be found in the respective installation profile.

6.3.2.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

The installed generic cabling for industrial premises shall be tested in accordance with the methods specified in ISO/IEC 11801-3 against requirements of the relevant transmission performance class of ISO/IEC 11801-3.

6.3.3 Acceptance test of non-Ethernet-based cabling

6.3.3.1 Copper cabling for non-Ethernet-based CPs

6.3.3.1.1 Common description

The measurements for cabling validation are required in the relevant CP installation profile. Hereafter is a list of measurements that may be required in the CP installation profiles:

a) loop resistance (see cabling specifications);
b) DCR of data line (see cabling specifications);
c) DCR of shield (see cabling specifications);
d) DCR between data lines (result shall be “open”);
e) DCR between data lines and shield (result shall be “open”);
f) cable length by a tester or inspection;
g) DCR between shield and the bonding surface (result is dependent on shield earthing method implemented);
h) terminator value (see the CP installation profile).

Annex N provides a procedure applicable for DCR measurements of the installed cabling to validate:

- loop resistance;
- DCR of data line;
- DCR of shield;
- absence of shorts between wires;
- absence of shorts between wire and shield.

6.3.3.1.2 Specific requirements for copper cabling for non-Ethernet-based CPs

Additional information regarding the non-Ethernet-based balanced cabling validation requirements for a specific industrial network may be found in the respective installation profile.

6.3.3.2 Optical fibre cabling for non-Ethernet-based CPs

6.3.3.2.1 Common description

See 6.3.2.2.1.

6.3.3.2.2 Specific requirements for non-Ethernet-based CPs

Additional information regarding the non-Ethernet-based optical fibre cabling validation requirements for a specific industrial network may be found in the respective installation profile.

6.3.3.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

The installed generic cabling for industrial premises shall be tested in accordance with the methods specified in ISO/IEC 11801-3 against requirements of the relevant transmission performance class of ISO/IEC 11801-3.

6.3.4 Specific requirements for wireless installation

None.

6.3.5 Acceptance test report

Successful completion of acceptance test shall be documented in a final report.

The report shall include a copy of all the checklists filled in by the person in charge of the acceptance test.

7 Installation administration

7.1 General

The operability of a communication network infrastructure is based on an effective administration. Each network owner shall establish and maintain administration procedures either based on company requirements or based on available standards.

Clause 7 does not recommend specific rules for the administration of the network. Clause 7 provides basic principles and examples from which a suitable administration system shall be developed and maintained.

Administration of the cabling considers the cabling along its life cycle, which includes

- adding and removing bus segments;
- adding and removing connection points including attachment cords, AOs and TOs.

NOTE Additional information on administration of networks is available in EN 50174-1 and EIA/TIA 568.

The specific requirements for the installation administration shall be provided as follows.

a) The specific requirements for the administration of generic cabling for industrial premises are specified in ISO/IEC 14763-2:2012.
b) The specific requirements for the administration of a CP cabling are provided in the relevant installation profile.

7.2 Fields covered by the administration

The administration of a network is done along the life cycle of the network. In Clause 7, the term “fieldbus infrastructure” covers the information-technical cabling as well as the applications and equipment linked to it.

The administration covers the following fields:

- basic principles for the administration system;
- working procedures;
- installation location identification;
- labelling;
- documentation.

7.3 Basic principles for the administration system

The administration system of the cabling system is established in such a way:

- to be consistent with the administration system of the other systems of the plant;
- that labelling for the cabling systems is consistent with the labelling of the other systems in the plant (for example electrical cabling of a machine);
- that suitable information of other management systems can be integrated that clearly state the place of equipment or of the cabling. Its place descriptions are to be taken over into the system of cabling management;

- that recordings of the cabling management are linked with each other and with recordings of other building services, such as lighting, power supply, heating, and building plans.

7.4 Working procedures

Working procedures are established in such a way as to guarantee that the following issues are fixed in detail.

a) The extent and the format of the documentation, which is required after the planning, the implementation of installation, the verification and validation, the operation and the maintenance of the installation.

b) The handing-over of this documentation from the contractor to the operating authority of the fieldbus infrastructure.

c) The duration of the storage of this documentation.

d) The updating of this documentation to reflect any changes or corrections of the cabling along its life cycle. Actions to be performed for the updating of the documentation are

   – invalid documentation is marked as such;

   – every time a change or correction is made, all concerned recordings are updated in such a way that multiple updates are understandable;

   – copies of these recordings are marked as "copy";

   – copies of these recordings, or a warning notice, are included in the working procedures to update them;

   – the time of each change or correction is recorded in the documentation;

   – a defined method is applied for revision control (for example revision lettering is used in the documentation);

   – changes and corrections in the documentation of an interface are considered for possible changes and corrections of the equipment connected to the interface;

   – the labelling and marking are kept in accordance with the documentation, after each change or correction;

   – up-to-date documentation is made available to operation, maintenance and authorized personnel.

e) Required inventory of spare parts and test equipment needed to support the network.

f) The locations where support documentation can be found, if support documentation is collocated or duplicated in multiple locations.

7.5 Device location labelling

The following is usually adopted.

a) Every device location is identified with an appropriate labelling.

b) The labelling material is selected in accordance with the environment.

c) All device locations are marked at a suitable spot, for example area at the entrance.

7.6 Component cabling labelling

A consistent approach to labelling is recommended. All major components of the cabling system are usually labelled. For example the cable ends should be labelled to uniquely identify each cable, including starting and ending locations.

The following list represents good practice.

a) Labels are either, part of the component, attached to the component, or in the vicinity of the component.

b) Where required, components have more than one label (for example, cables are usually labelled at each end).

c) Labels are attached in such a manner that they are easily accessible, readable and changeable.

d) Labels remain legible during the prospective life span of the cabling.

e) The labelling materials are selected based on the environment.

f) Labelling reflects the most current configuration.

g) Documentation, labelling and network configuration are consistent.

The content and the format of the labelling are usually specified on the basis of technical and organizational criteria: the label print shall contain clear and legible information.

The labelling normally contains:

- a unique identifier (for example: sub elements of a multi-element component);
- a description of the type of the component;
- an installation location identification;
- additional information.

Information about the structure and content of the labelling is provided in the documentation.

The components to be labelled are as follows:

1) Cables
   – Every cable should have clear labelling.
   – Cables should be labelled at each of their ends.
   – All branch connections should be uniquely identified with a label.
   – For optical fibre cables with multiple optical fibres, the individual optical fibres are to be identified by either colour coding or by labelling.
2) Connection point
   – Each connection point should be labelled. For example, a terminal block should be clearly identified in the documentation and at the terminal block.
3) Earthing and potential equalization
   – Each connection of the earthing and potential equalization should have a label.
4) Active elements of a network
   – Every element should have a label.
5) Cable pathways
   – Every cable pathways should have a label.

7.7 Documentation

The documentation of the cabling usually includes the following elements to be collected in documents organised and named in accordance with IEC 62708:

a) System drawings.

b) Site plans, building layouts and location drawings, which contain the identification and location of connection points, cable routing, cables, equipment and safety equipment.

c) Schematic diagram and other information which show the electrical connections and summaries of cables, connection points, connections for equipment, earthing and potential equalization, the segment lengths, marking and location of all components.

d) Provisions for recording the incoming inspection results, including the result of a comparison between the list of material ordered and the list of material received. In addition, provisions for recording discrepancies or damaged material.

e) Installation verification and acceptance test report.

f) Details regarding the installed earthing system already in use and measurements taken as documented in cabling planning documentation.

g) Recordings about the cable routing as specified in the cabling planning documentation and in the as-implemented cabling documentation.

h) A list of components used with the order number of the manufacturer, the type designation of the field bus organization or the standardised material designations with the respective quantity and the assigned labels.

i) A list of the required spare parts, cables, cable sets, connectors, tools, measuring instruments, measuring cables, equipment, etc.

j) Recordings about date of installation date of inspections, maintenance, servicing, updates, and exchange of each component.

k) Documentation of the components provided by manufacture or supplier (such as installation manuals, etc.).

7.8 Specific requirements for administration

Additional information regarding the administration requirements for a specific industrial network may be found in the respective installation profile.

8 Installation maintenance and installation troubleshooting

8.1 General

Each network owner shall establish and maintain maintenance and troubleshooting procedures, over the full life cycle of the network, by selecting the appropriate procedures out of the options described in Clause 8 and represented in Figure 50.

Clause 8 is also applicable for high availability networks as specified in IEC 62439. Installation of high availability networks shall provide at least the following:

- maintenance documentation that explains the specific redundancy techniques used by the installed network to ensure continuity of operation during the failure and repair of any single component or cable element;
- maintenance procedures to ensure that diagnosis and restoration actions for a faulty part of a network do not affect performance of the non-faulty parts of the network which are continuing to support the user applications.

A proper maintenance procedure applied to fieldbus networks allows maximising MTBF. Proper troubleshooting procedure, repair methods, diagnostic tools and personal training allows minimising MTTR.

The owner of the network shall decide to which extent it is convenient for him to invest in diagnostic tools and the training of his maintenance and troubleshooting personnel to use these tools.

For further advice on network administration, see Clause 7. Clause 7 describes procedures for updating the documentation that supports the maintenance and troubleshooting work.

The requirements and the recommendations of Clause 8 may be applied for the generic cabling in addition to those of ISO/IEC 11801-3.

8.2 Maintenance

8.2.1 Scheduled maintenance

The scheduled maintenance is a kind of preventive maintenance performed on each component in order to discover degradation of the component before a failure occurs and to restore the component to a state in which it can perform the required function. The interval (defined in terms of time or number of actions) between the interventions is defined based on the characteristics of the component and information provided by the manufacturer. The key drawback of this method is that on each component the interventions are performed regularly, irrespective of the actual condition of the component. This results in some waste of time and money, because in many cases the component results confirm it to be working correctly.

Scheduled maintenance of the network will help in maximizing the MTBF.

There are the two following types of interventions to schedule.

a) Visual inspection and check-up.

   Visual inspection and check-up are performed by comparing the result of the inspection and of the check-up with the reference information (baseline, resulted from the acceptance tests) and performance limits recorded in the maintenance documentation.

   The documentation for the visual inspection and check-up lists includes:

   1) components to be inspected/ checked-up (for example, the cabling in use, redundant cabling, cable routing, earthing system);
   2) time interval or number of actions for the visual inspection and check-up of each component;
   3) the baseline, performance limits and pass-fail criteria for each component;
   4) tools.

   If a corrective action is needed, the process described in 8.2.3 applies.

b) Component replacement/adjustment.

   Intervention to replace/adjust the component to keep it in a defined acceptable condition (for example after the transmission of a defined number of data frames reset all active components). This maintenance intervention is specifically applicable to components that have critical behaviour (for example, limited life).

   The documentation for this maintenance intervention lists:

   1) the critical components;
   2) time interval or number of actions (for example data frames transmitted) for replacement/ adjustment of each component;
   3) procedure for replacement/adjustment of each component;
   4) tools and spare parts.

If a corrective action is needed, the process described in 8.2.3 applies.

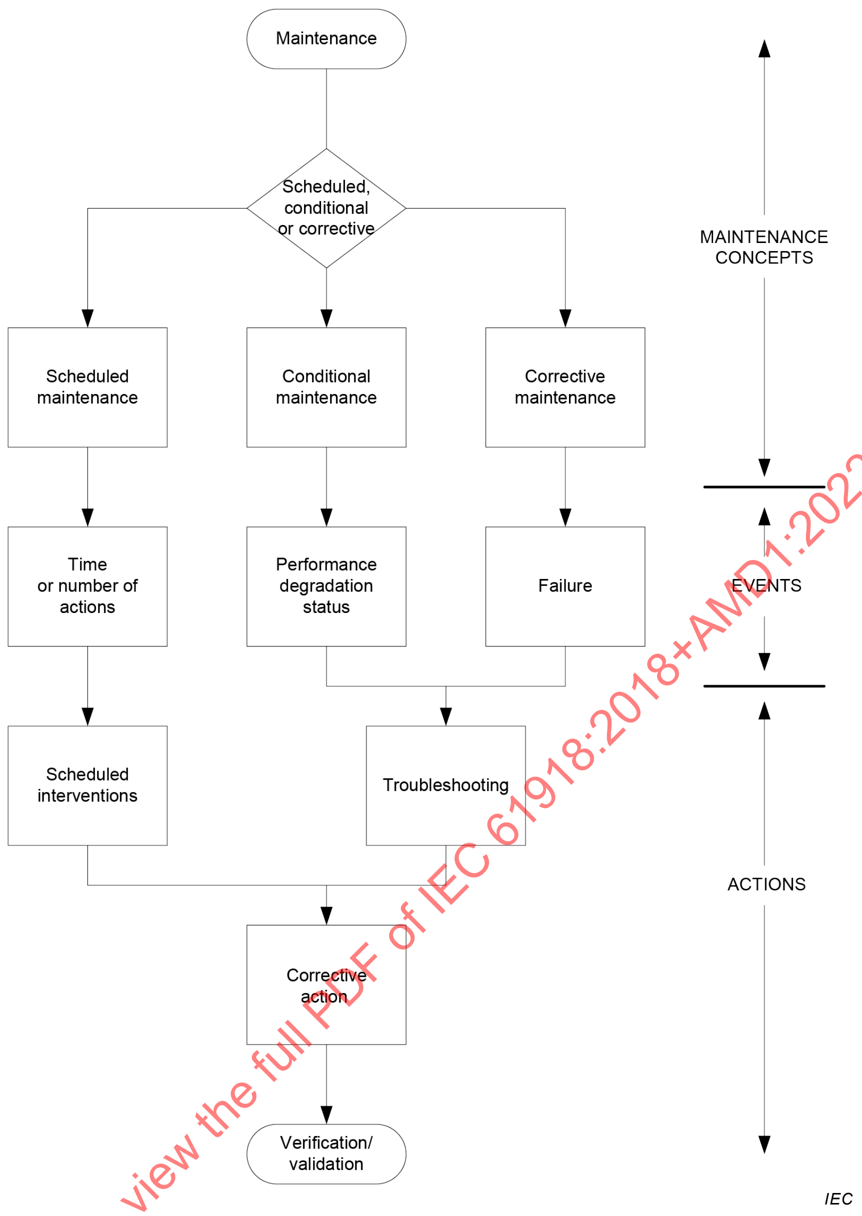


Figure 50 – Communication network maintenance

8.2.2 Condition-based maintenance

Condition-based maintenance is a kind of preventive maintenance performed on each component based on the known conditions of the components to maintain. The intervention is performed in a component only when a degradation is documented that could result in a fault of the network. If the conditions of the components are monitored on-line the degradation can be detected in real time and the intervention can be performed timely and before the degradation goes beyond the acceptable limit. Compared with scheduled maintenance, condition-based maintenance usually requires much less time and money for maintenance personnel support.

Condition-based maintenance of the network will help in maximizing the MTBF. Investment in suitable on-line diagnostic tools and training of the maintenance personnel will help to minimise the MTTR.

Examples of degradations are the following:

a) the resistance to earth exceeds a defined value (for example 1 Ω);

b) the BER between two components exceeds a defined value (for example1 × 10^{-9}).

If a corrective action is needed, the process described in 8.2.3 applies.

8.2.3 Corrective maintenance

The corrective intervention on a component after a failure occurred is aimed to restore the component to a state in which it can perform the required function.

Once a failure occurs, the maintenance personnel:

- troubleshoots the network failure (see 8.3);
- performs the corrective actions described in the maintenance documentation.

The documentation for this maintenance intervention lists:

a) procedures for repairing or replacing failed components, based on documentation provided by the supplier;
b) spare parts;
c) procedures for correcting network faults;
d) procedures for the verification and validation of the network after the corrective intervention, in accordance with selected Clause 6 requirements.

The result of the intervention is usually considered for updating the maintenance specification, in accordance with Clause 7 requirements.

8.3 Troubleshooting

8.3.1 General description

Troubleshooting starts after a failure or performance degradation of a network occurs (see Figure 50).

The troubleshooting organisation begins their activity by establishing the needed documentation and by the training of the troubleshooting personnel.

The documentation for troubleshooting intervention lists:

a) guidance for systematic network troubleshooting, such as with a checklist or a flow diagram, based on documentation provided by the supplier;
b) guidance for troubleshooting components based on documentation provided by the supplier;
c) test tools for the specific network.

8.3.2 Evaluation of the problem

The answers to the following questions usually help to create a clear understanding of the problem and allow efficient troubleshooting of the network.

- Is the complete network documentation available?
- Were there any recent changes in the network infrastructure?
- How was the problem identified?
- Since when is the problem identified?
- Was the concerned application already working failure free?
- Which users/devices are affected by the problem?
- Are there certain time frames when the problem occurs?

- Is the problem reproducible?
- Have there been previous attempts to correct the problem?

8.3.3 Typical problems

Problems usually encountered by the maintenance personnel are described in Table 22 and Table 23. When troubleshooting unshielded installations, EMC influence can be quantified through field-testing of TCL and ELTCTL transmission parameters. If needed, noise impact reduction may be achieved by identification of at-risk components and selection of replacement components with superior performance.

Table 22 – Typical problems in a network with balanced cabling

Problem	Most probable cause	Corrective action
Failed communications and/or high error rates	Loose termination or bad connector (or terminal) contacts	Locate and correct intermittent connection
	EMC influence from other devices, poor grounding, improper separation from emitting devices or cables	Locate and correct grounding, identify improper separation or shielding, use optical fibre
	Corrosion of shielding contacts	Locate and replace the damaged components with either the proper protection or compatible components
	Mechanical stress in cables or connections	Install mechanical support and strain relief
Intermittent communications for a short time and/or burst error rates	EMC influence from other devices	Correlate the communication problem with physical or environmental events. Locate and take corrective actions (mitigation, etc.)
	Loose termination or bad connector (or terminal) contacts, such as vibration or temperature influence	Locate and replace the damaged components with either the proper protection or compatible components
	Corrosion of shielding contacts	Locate and replace the damaged components with either the proper protection or compatible components
	Mechanical stress in cables or connections	Install mechanical support and strain relief
	Condensing liquids between the electrical contacts	Clean the connectors. Replace the damaged components with either the proper protection or compatible components
Fault report from the balanced cabling diagnostic equipment: return loss too large	One is using cables or cords with incorrect impedance, for example different from 100 Ω for Ethernet systems	Use the proper components
Fault report from the balanced cabling diagnostic equipment: Cable length too large, attenuation or loop resistance too large	One is using cables or cords with a smaller wire size or longer length as allowed for the application. An injury is also possible	Use the proper components and cable length or replace the components
Fault report from the balanced cabling diagnostic equipment: NEXT, PSNEXT, ACR, PSACR, ELFEXT, PSELFEXT	One is using connectors, cables or cords without the expected quality. An injury is also possible	Use the proper components and cable length or replace the components

Table 23 – Typical problems in a network with optical fibre cabling

Problem	Most probable cause	Corrective action
Failed communications and/or high error rates	Loose termination or bad connector (or splice) contacts, such as vibration or temperature influence	Locate and correct intermittent connection
	Optical fibre attenuation increases (aging or dust)	Clean the end of the optical fibre using proper cleaning procedures. Replace the damaged components with either the proper protection or compatible components
	Transmitter power degradation (aging)	Replace the module

Problem	Most probable cause	Corrective action
	Liquids or condensing liquids between the optical fibre ends	Clean and protect the optical fibre ends using proper cleaning procedures. Replace the damaged components with either the proper protection or compatible components
	Mechanical stress in cables or connections	Install mechanical support and strain relief
No power is measured at an optical source	The optical source is defective	Replace the module
	The module is without electrical power	Power up the module
	A cord is defective	Replace the cord
Fault report from the optical fibre diagnostic equipment: power loss is more than expected	The optical fibres are connected to the wrong ports on the testing unit	Refer to labelling and documentation for the correct wiring scheme and correct if necessary
	The optical fibres are swapped at one end of the link	Refer to labelling and documentation for the correct wiring scheme and correct if necessary
	A cord is broken	Retest using a different set of cords
	There is one or more dirty connections in the link	Clean all optical fibre connector ends and retest
	The number of connectors, adapters or splices set in tester SETUP is too low	Correct according to the documentation of the network
	The reference power level is incorrect	Set the reference again using the same patch cords to be used for testing
	A cord or optical fibre segment has the wrong core size. For example one is using 62,5 µm patch cords to connect to a 50 µm optical fibre. Or one is using multimode patch cords or adapters to connect to single mode optical fibre	Use the proper components in the channel for the described wavelength and optical fibre size
Fault report from the optical fibre diagnostic equipment: a known length of cable measures too long or too short	The index of refraction is not set correctly for the optical fibre under test	Set the index of refraction to give the correct length for a known length of optical fibre

8.3.4 Troubleshooting procedure

The procedure in Figure 51 is an example of a generic troubleshooting procedure that could be adapted to most common networks.

The troubleshooting procedure shown in Figure 51 applies if a procedure is not available.

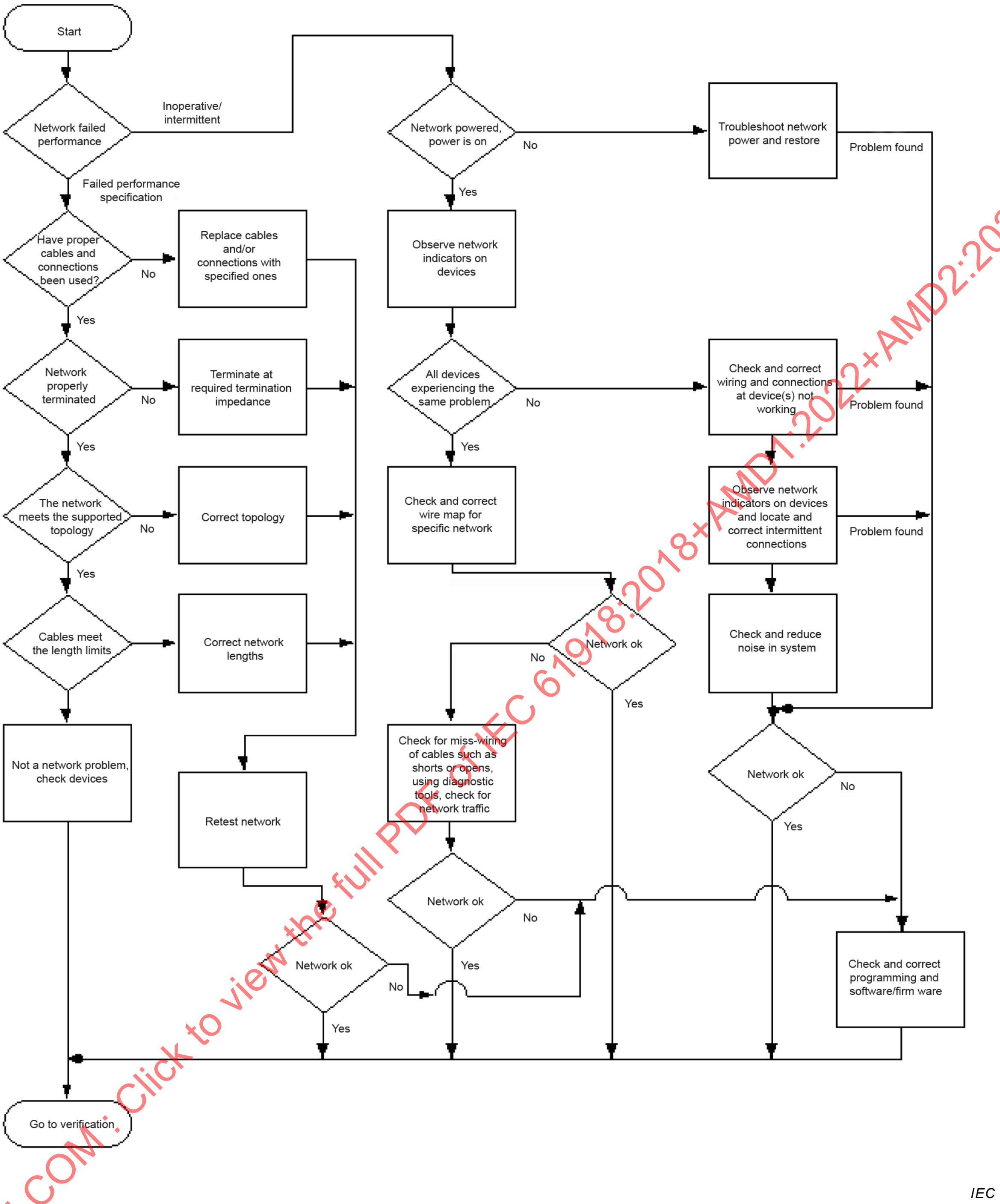


Figure 51 – Troubleshooting procedure

8.3.5 Simplified troubleshooting procedure

The procedure in Figure 52 is an example of simplified troubleshooting procedure that is sufficient in many cases. This procedure does not require the use of specific tools. It applies if a specific procedure is not established.

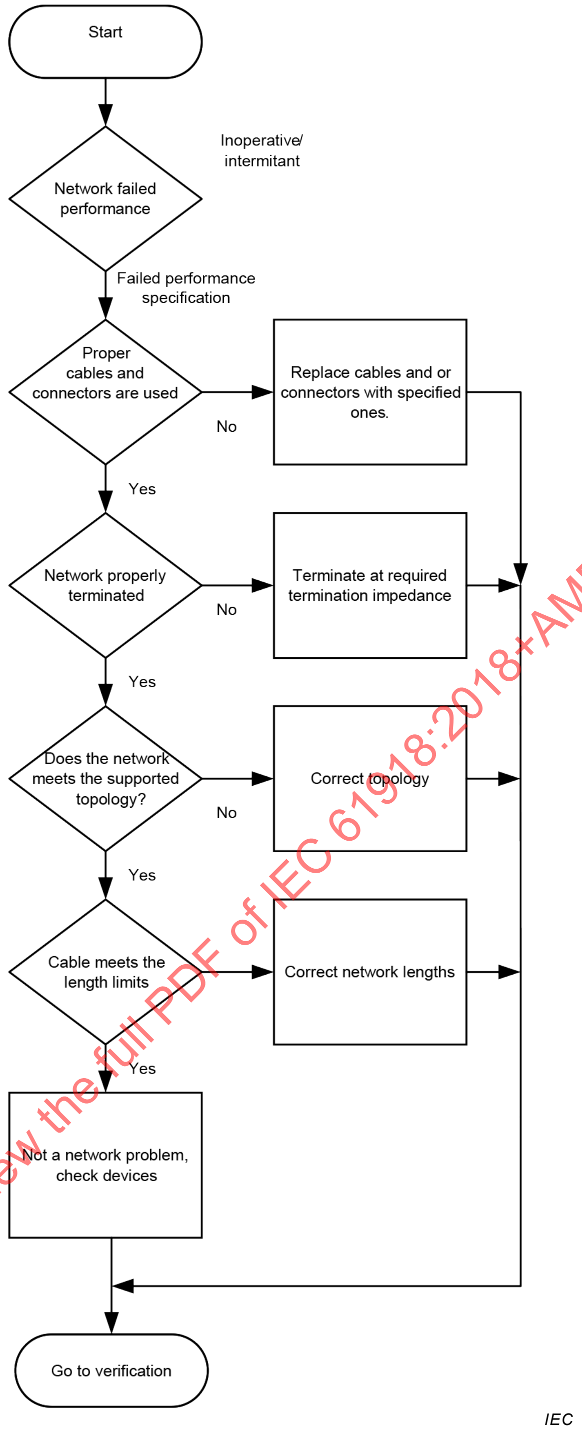


Figure 52 – Fault detection without special tools

If a corrective action is needed at the end of the troubleshooting, the process described in 8.2.3 applies.

8.4 Specific requirements for maintenance and troubleshooting

Additional information regarding the troubleshooting requirements for a specific industrial network may be found in the respective installation profile.

Annex A
(informative)

Overview of generic cabling for industrial premises

Within industrial premises, generic cabling enables a fixed cabling infrastructure to be installed to support a wide range of information technology and monitoring applications. The design of this cabling is specified in ISO/IEC 11801-3.

The generic nature of the cabling is delivered by:

- the specification of a flexible cabling structure comprising a series of cabling subsystems that can be connected together either passively, using cords, or actively using transmission equipment;
- a minimum level of transmission performance within each of the series of cabling subsystems used to distribute the applications.

The termination points of generic cabling that are distributed throughout the premises, called the TO, enables the connection of a variety of applications to the cabling. The applications supported are detailed in ISO/IEC 11801-3 and include telephony and local area networks. Where the TO is installed in locations associated with AIs, the type of applications detailed in this document may also be supported.

As generic cabling is intended to support a wide range of applications, the specification of the TO in ISO/IEC 11801-3 is restricted to specific interfaces for balanced cabling and optical fibre cabling. This restriction is intended to optimise the interoperability of cords and portable terminal equipment that may be connected to the TO.

Where a designated connection from generic cabling to specific communication cabling within an AI is desired, an AO specified within this document may replace the TO and the cabling is considered non-generic.

NOTE ISO/IEC 11801-3 also contains information in support of non-generic cabling structures that may support the implementations of specific CPF.

Annex B
(informative)

MICE description methodology

B.1 General

The MICE environmental classification is specified in ISO/IEC 11801-1:2017.

The background to the development of the approach is given in ISO/IEC TR 29106:2007/AMD1:2012.

A recommendation for the wider application of this approach by the installation planner and installer is given in Clause 4. Information provided with Annex B is intended just as a first guidance on the use of the MICE system. For the application of the MICE system, the specifications provided with the most recent versions of the above standard and technical report take precedence.

B.2 Overview of MICE

The MICE concept is a concept in which an environment within an installation can be classified in terms of environmental and EMI levels. The MICE table (see Table B.5) defines 3 levels for each component of the MICE classification: Mechanical, Ingress, Climatic and Electromagnetic (thus the name MICE). The three classifications are graphically shown in Figure B.1. These classifications begin at generally the lowest ($M_1I_1C_1E_1$) which best describes most office spaces and extends to a highest level that best describes a typical industrial space ($M_3I_3C_3E_3$).

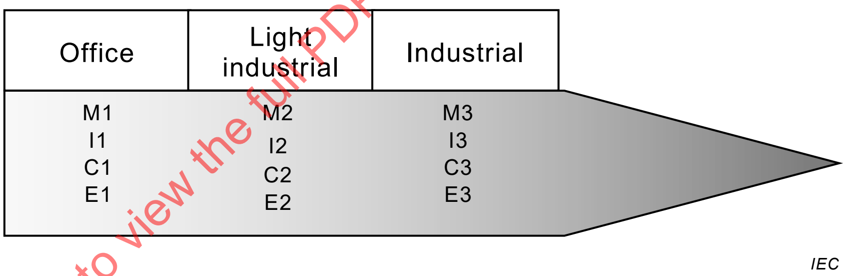


Figure B.1 – MICE classifications

Figure B.2 is an example of typical industrial areas. Further, the AI may expand to include the entire factory floor. Figure B.2 indicates typical MICE classifications for the three primary areas within a factory. Not all areas fall exclusively into one classification, for example, an AI may have mechanical shock at >150 ms^{-2} whereby it may be classified as a M_3. The environment may only have light dust consistent with the levels in I_2. The temperature where the cables and equipment are routed/installed may be 65 °C with the Climatic classification C_2 as defined by the MICE table. The machinery in the AI may consist of welding robots, in which the EMI is most likely in the E_3 classification. The MICE environment can then be summarised as M_3, I_2, C_2 and E_2.

NOTE The terms used in Figure B.2 are specific to Annex B.

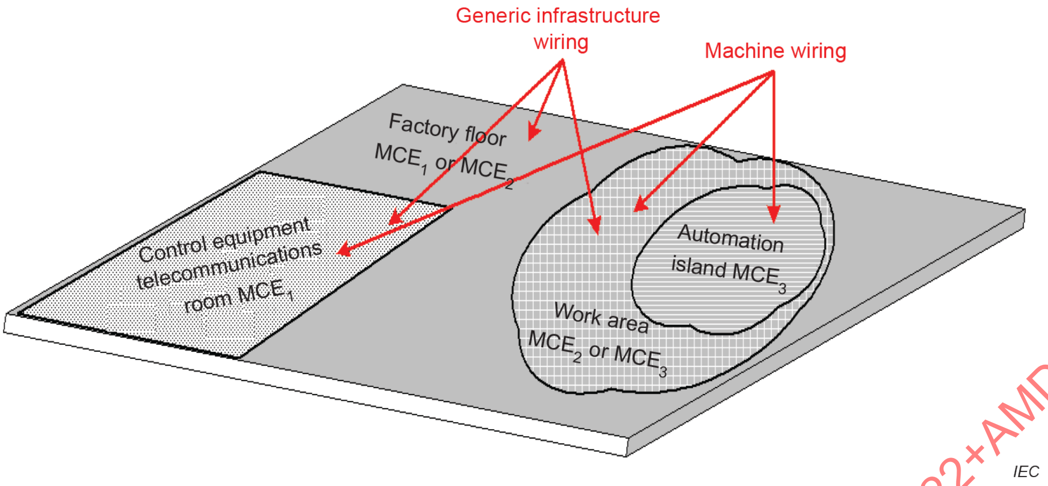


Figure B.2 – Example MICE classifications within a facility

B.3 Examples of use of the MICE concept

B.3.1 Common description

The planner should be aware of the environment and EMC levels in the areas in which the cabling and equipment will be installed. By systematically classifying the installation coverage area, decisions can be made on component selections and additional mitigation needs. Cabling systems can be designed using all enhanced components in which no mitigation is required or a combination of enhancements and mitigation may be chosen. In some cases, this may restrict flexibility or may create a cost and/or availability issue. This concept allows the designer to balance component cost (and availability) with mitigation costs thereby designing the most robust cost-effective cabling system, as shown in Figure B.3. Mitigation can be broken down into two forms, separation and isolation. The following examples will help to solidify the importance of mitigation. Mitigation simply converts one MICE area into another that is compatible with the cabling components and equipment to be installed.

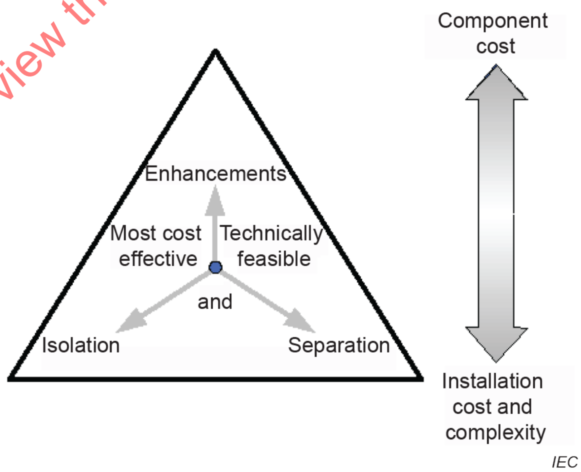


Figure B.3 – Enhancement, isolation and separation

B.3.2 Examples of mitigation

B.3.2.1 Example 1

The targeted MICE area is specified in Table B.1. The desired component has been determined to be compatible with a MICE environment as described in the left column of

Table B.1. The environment to which the component should be installed in is described in the second column of Table B.1. By inspection of the component and environment parameters "M" and "E" do not match, requiring mitigation. Parameters "I" and "C" exceed the environmental condition and therefore need action.

Table B.1 – Example 1 of targeted MICE area

Component	Environment
M_1	M_3
I_3	I_1
C_3	C_2
E_2	E_3

Since the component does not map directly in to the environment, the environment should be mitigated. The harsh M_3 environment can be converted to an M_1 local to the component by shock mounting the equipment in an enclosure. The high EMI can be reduced by using a metallic EMI, shock mounted, enclosure as indicated in Figure B.4. Both M_3 and E_3 problems are solved.

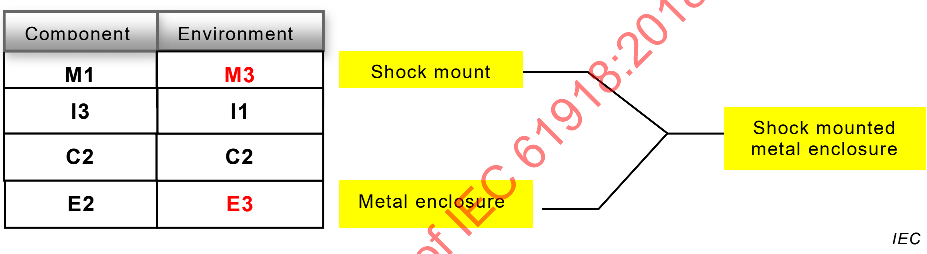


Figure B.4 – Example 1 of mitigation

B.3.2.2 Example 2

This is an example of a cable installation where the environment is described as in Table B.2. By inspection, it can be seen that the cable does not match the environmental conditions for EMI (E). Therefore, some form of mitigation is required.

Table B.2 – Example 2 of targeted MICE area

Component	Environment
M_1	M_1
I_3	I_1
C_2	C_2
E_2	E_3

Since the cable selected does not meet the EMI requirements, then some mitigation is required. Mitigation can be solved two ways, separation and/or isolation. The drawing in Figure B.5 shows how this can be done in a pathway.

Component	Environment
M1	**M1**
I3	**I1**
C2	**C2**
E2	**E3**

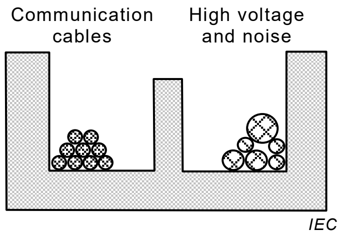


Figure B.5 – Example 2 of mitigation

By providing physical separation between the high EMI conductors and the communication cabling, the noise coupling will be reduced. An additional reduction in noise coupling can be achieved by adding a metallic wall between the conductors thus providing isolation. Either or both of these two methods may be independently sufficient to reduce the noise coupling or may be required together.

B.4 Determining E classification

In a factory environment the electromagnetic disturbances present wide range of frequencies. In addition, there is a range of electromagnetic disturbance coupling mechanisms. Figure B.6 is provided as guidance in determining the frequency range of common electromagnetic disturbance generating devices found in an AI. Devices not only generate harmful fundamental frequencies, they also generate harmonics that can be just as disruptive to communication networks. The grey part of the bars indicates the additional range caused by the third harmonic.

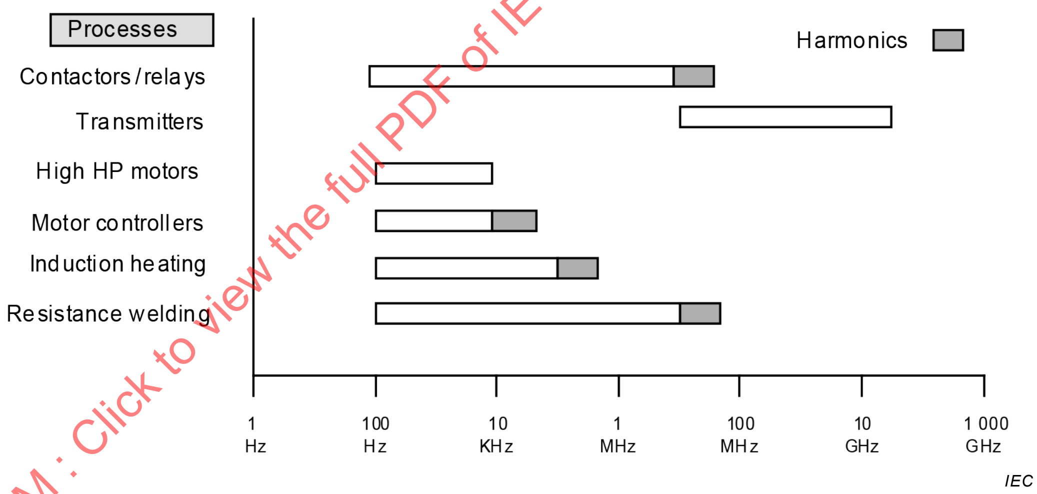


Figure B.6 – Frequency range of electromagnetic disturbance from common industrial devices

Table B.3 provides general guidance as to the electromagnetic level (E_1, E_2, E_3) for many common electromagnetic disturbance-generating devices. The level of the interfering electromagnetic disturbance is dependent on two factors: 1) distance from and 2) magnitude of the interfering device. Table B.3 is provided as a rough guide for determining the possible electromagnetic classification (E_1, E_2, E_3) based on separation.

Table B.3 – Relationship between electromagnetic disturbance-generating devices and "E" classification

Electromagnetic disturbance-generating device	Distance from cabling	"E" classification
Contactor relay	< 0,5 m	E_2
	> 0,5 m	E_1
Transmitters (< 1 W)	< 0,5 m	E_3
	> 0,5 m	E_1 or E_2
Transmitters (1 W to 3 W)	< 1,0 m	E_3
	≥ 1,0 m	E_1 or E_2
Transmitters (TV, radio, mobile, base station)	< ~~1~~ 3 km	E_3
	≥ ~~0,~~ 3 km	E_1 or E_2
High ~~HP~~ power motors	< 3 m	E_3
	> 3 m	E_1 or E_2
Motor controllers	< 0,5 m	E_3
	0,5 m to 3 m	E_2
	> 3 m	E_1
Induction heating < 8 MW	< 0,5 m	E_3
	0,5 m to 3 m	E_2
	> 3 m	E_1
Resistance heating	< 0,5 m	E_2
	> 0,5 m	E_1
Fluorescent lights	< 0,15 m	E_3
	> 0,15 m	E_1 or E_2
Thermostatic switches 110 V to 230 V	< 0,5 m	E_2 or E_3
	> 0,5 m	E_1

As examples of particularly critical magnetic fields that may be encountered, the following cases are worth mentioning.

- Fixed magnetic fields in the food processing applications designed to remove magnetic material from food. These magnets have the potential to saturate the cores of both Ethernet transformers and switching power supplies causing temporary disruption in performance. Levels as high as $38,5 \times 10^{-3}$ T is significant to saturate the core of a Ethernet isolation transformer.
- High magnetic fields in 4 kHz to 8 kHz used in induction heating processes. These machines consume 4 MW to 12 MW for induction heating of magnetic materials. The machines are used in steel forging processes.
- Magnetic fields generated by direct currents used in aluminium processes. The currents are in the thousands ampere range. Due to ripple currents, there is a significant AC magnetic field that is imposed on the fixed magnetic field. Both can be disruptive to transformer cores when exposed to the magnetic fields.

A solution to these high magnetic fields is proper mitigation either by separation or isolation (magnetic shielding).

Table B.4 provides information regarding the coupling mechanism for some interfering devices. Table B.4 will help to guide the designer, installer and troubleshooting personnel in mitigating or correcting for noise interference. For example, in an environment where a relay contactor is found to cause interference, the mechanism for noise ingress is coupling through adjacent lines (EFT) caused by the high d*U*/d*t*. To correct this situation, additional separation may be provided to reduce the magnitude of coupling.

Table B.4 – Coupling mechanism for some interfering devices

Type	Electromagnetic disturbance	Coupling mechanism
Electric motors	Surge and EFT	Local earth, conducted
Drive controllers	Conducted and surge	Local earth, conducted
Relays and contactors	EFT	Radiated, conducted
Welding	EFT, induction	Radiated magnetic
RF induction welding	Radio frequency	Radiated, conducted
Material handling paper/textile	ESD	Radiated
Heating	EFT	Local earth, conducted, radiated
Induction heating	EFT, magnetic	Local earth, conducted, radiated
Radio communications	Radio frequency	Radiated

The graph given in Figure B.7 provides separation versus EFT value guidance. Alternatively, isolation through shields can be used to reduce the effects of electromagnetic transients by providing additional shielding attenuation.

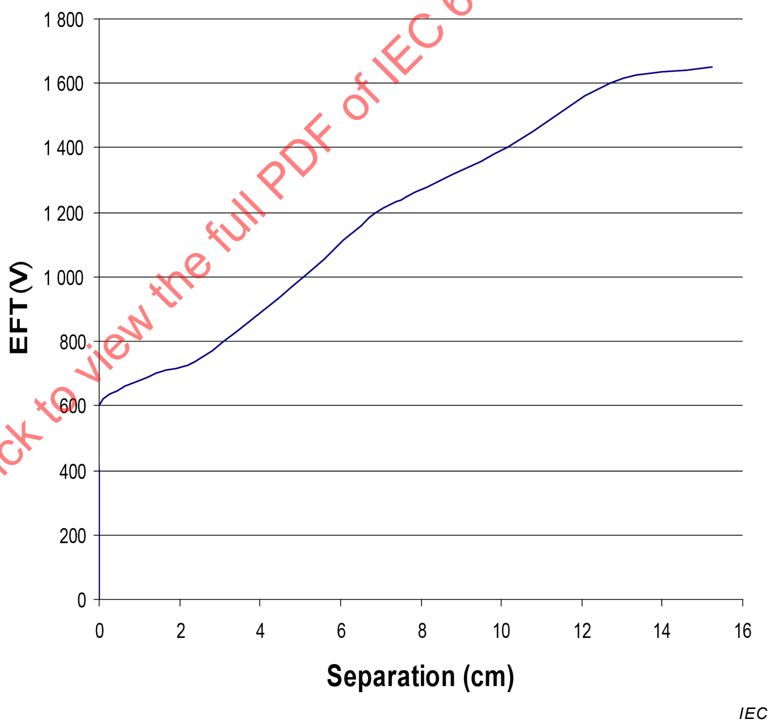


Figure B.7 – Example of a general guidance for separation versus EFT value

The graph in Figure B.7 represents the recommended separation of communication cables from conductors carrying electromagnetic transients. The separation assumes that cables meet the minimum requirements in ISO/IEC 11801 for balance and crosstalk.

NOTE ISO/IEC 11801-3 also contains information in support of non-generic cabling structures that can support the implementations of specific CPF.

B.5 The MICE table

Table B.5 is copied from ISO/IEC 11801-1. It is copied here to provide understanding of the informative description provided in this Annex B. Of course, for the specification of the MICE classifications of an industrial premises, the values specified in the most recent version of ISO/IEC 11801-1 apply.

Table B.5 – MICE definition

Mechanical	**M_1**	**M_2**	**M_3**
Shock/bump (see [a])			
Peak acceleration	40 ms^{-2}	100 ms^{-2}	250 ms^{-2}
Vibration			
Displacement amplitude (2 Hz to 9 Hz)	1,5 mm	7,0 mm	15,0 mm
Acceleration amplitude (9 Hz to 500 Hz)	5 ms^{-2}	20 ms^{-2}	50 ms^{-2}
Tensile force	See [b]	See [b]	See [b]
Crush	45 N over 25 mm (linear) min.	1 100 N over 150 mm (linear) min.	2 200 N over 150 mm (linear) min.
Impact	1 J	10 J	30 J
Bending, flexing and torsion	See [b]	See [b]	See [b]
Ingress	**I_1**	**I_2**	**I_3**
Particulate ingress (diameter max.)	12,5 mm	50 µm	50 µm
Immersion	None	Intermittent liquid jet ≤ 12,5 l/min ≥ 6,3 mm jet > 2,5 m distance	Intermittent liquid jet ≤ 12,5 l/min ≥ 6,3 mm jet > 2,5 m distance and immersion (≤1 m for ≤30 min)
Climatic and chemical	**C_1**	**C_2**	**C_3**
Ambient temperature	–10 °C to +60 °C	–25 °C to +70 °C	–40 °C to +70 °C
Rate of change of temperature	0,1 °C per minute	1,0 °C per minute	3,0 °C per minute
Humidity	5 % to 85 % (non-condensing)	5 % to 95 % (condensing)	5 % to 95 % (condensing)
Solar radiation	700 W m^{-2}	1 120 W m^{-2}	1 120 W m^{-2}
Liquid pollution (see [c]) Contaminants	Concentration × 10^{-6}	Concentration × 10^{-6}	Concentration × 10^{-6}
Sodium chloride (salt/sea water)	0	<0,3	<0,3
Oil (dry-air concentration) (for oil types, (see [b])	0	<0,005	<0,5
Sodium stearate (soap)	None	>5 × 10^4 aqueous non-gelling	>5 × 10^4 aqueous gelling
Detergent	None	ffs	ffs
Conductive materials	None	Temporary	Present
Gaseous pollution (see [c]) Contaminants	Mean/Peak (Concentration × 10^{-6})	Mean/Peak (Concentration × 10^{-6})	Mean/Peak (Concentration × 10^{-6})
Hydrogen sulphide	<0,003 / <0,01	<0,05 / <0,5	<10 / <50
Sulphur dioxide	<0,01 / <0,03	<0,1 / <0,3	<5 / <15

Mechanical	**M$_1$**	**M$_2$**	**M$_3$**
Sulphur trioxide (ffs)	<0,01 / <0,03	<0,1 / <0,3	<5 / <15
Chlorine wet (>50 % humidity)	<0,000 5 / <0,001	<0,005 / <0,03	<0,05 / <0,3
Chlorine dry (<50 % humidity)	<0,002 / <0,01	<0,02 / <0,1	<0,2 / <1,0
Hydrogen chloride	- / < 0,06	<0,06 / <0,3	<0,6 / 3,0
Hydrogen fluoride	<0,001 / <0,005	<0,01 / <0,05	<0,1 / <1,0
Ammonia	<1 / <5	<10 / <50	<50 / <250
Oxides of Nitrogen	<0,05 / <0,1	<0,5 / <1	<5 / <10
Ozone	<0,002 / <0,005	<0,025 / <0,05	<0,1 / <1
Electromagnetic	**E$_1$**	**E$_2$**	**E$_3$**
Electrostatic discharge – Contact (0,667 µC)	4 kV	4 kV	4 kV
Electrostatic discharge – Air (0,132 µC)	8 kV	8 kV	8 kV
Radiated RF – AM	3 V/m at (80 MHz to 1 000 MHz) 3 V/m at (1 400 MHz to 2 000 MHz) 1 V/m at (2 000 MHz to 2 700 MHz)	3 V/m at (80 MHz to 1 000 MHz) 3 V/m at (1 400 MHz to 2 000 MHz) 1 V/m at (2 000 MHz to 2 700 MHz)	10 V/m at (80 MHz to 1 000 MHz) 3 V/m at (1 400 MHz to 2 000 MHz) 1 V/m at (2 000 MHz to 2 700 MHz)
Conducted RF	3 V at (150 kHz to 80 MHz)	3 V at (150 kHz to 80 MHz)	10 V at (150 kHz to 80 MHz)
EFT/B (comms)	500 V	500 V	1 000 V
Surge (transient ground potential difference) – signal, line to earth	500 V	1 000 V	1 000 V
Magnetic field (50/60 Hz)	1 Am^{-1}	3 Am^{-1}	30 Am^{-1}
Magnetic field (60 Hz to 20 000 Hz)	ffs	ffs	ffs

[a] Bump: the repetitive nature of the shock experienced by the channel shall be taken into account.

[b] This aspect of environmental classification is installation-specific and should be considered in association with IEC 61918 and the appropriate component specification.

[c] A single dimensional characteristic, i.e. Concentration × 10^{-6}, was chosen to unify limits from different standards.

B.6 Communication devices and cabling considerations

B.6.1 General

The planner should consult the device and cabling manufacturer regarding correct selection of the device and cabling for the application under consideration.

The impact of industrial environment EMI on the communication network could result in incorrect reconstruction of the signal at the receiver.

The requirements specified in Clause 4, Clause 5 and Clause 6 fully clarify the mitigation measures to be used for the cabling. In this Annex B, some additional clarifications are provided in regard to the selection of the proper communication devices and cabling.

Communication devices are available with different constructions in order to serve a large range of different applications. The most critical impact of the industrial environment EMI on the devices is the saturation of the device physical layer interface with the cabling, which happens when the common mode (CM) voltage tolerance of the devices is less than the impact of the conducted disturbances.

Typically, the level of the CM voltage tolerance of a device depends on the performance of the device interface with the cabling.

B.6.2 Device types

From the point of view of the enhanced device interface immunity, the communication devices may be grouped in two types.

a) Devices type 1

Figure B.8 and Figure B.9 show the structures of the device type 1 interfaces.

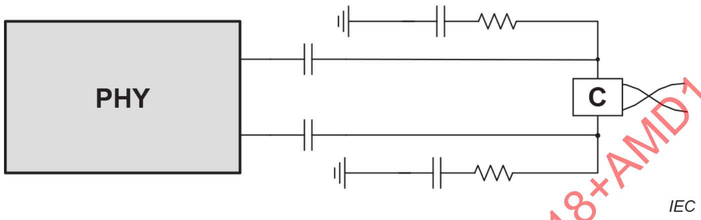


Figure B.8 – Communication device interface with limited EMI immunity

All the devices having type 1 interface, if associated with shielded cabling whose CA is at least 60 dB, can provide a compatibility with electromagnetic interferences up to the E3.

The use of unshielded cabling is not recommended in combination with devices type 1 for environments E2 and E3. In fact, these resulting combinations would require the use of costly and complex additional mitigation measures (see Clause 4 and Clause 5).

NOTE 1 All communication device interface figures only show the interface of the master device. The same interface is used at the field device, to prevent the saturation effect also on this side.

NOTE 2 It is possible to assess coupling attenuation by laboratory measurements of representative samples of channels assembled using their component and connector practices.

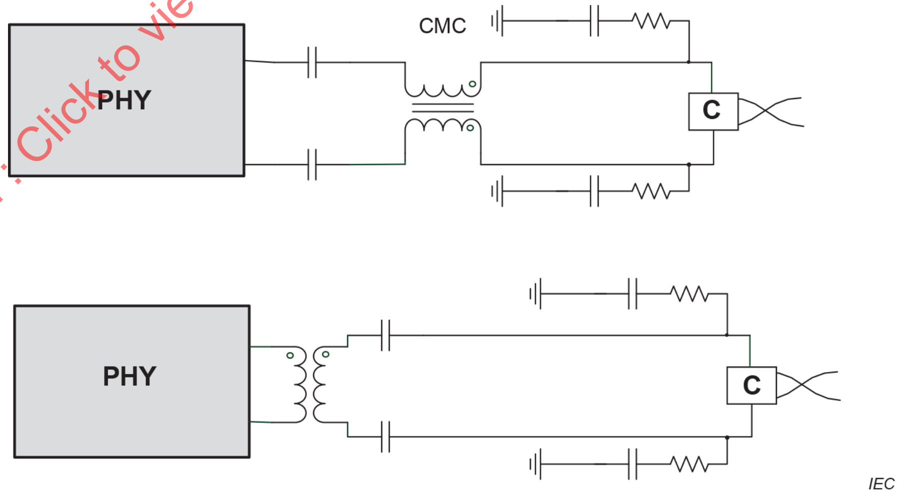


Figure B.9 – Communication device interfaces with medium EMI immunity

Figure B.9 shows the structure of two equivalent interfaces of the device type 1, with improved CM voltage tolerance at their interface. The interface that includes CM chokes may serve for intrinsic safety applications, where transformers cannot be used.

b) **Device type 2**

Figure B.10 shows the structure of the device type 2 interfaces, where a more complete set of mitigation elements is added at the device interface, as CM chokes and isolation transformers.

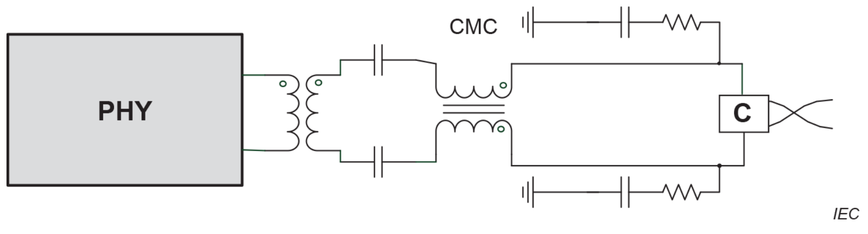


Figure B.10 – Communication device interface with the highest EMI immunity (type 2)

Type 2 interfaces, if combined with shielded cabling whose CA is at least 60 dB, can provide an improved CM voltage tolerance, which makes them suitable for the most aggressive interferences (even more than E3). This also means that type 2 devices could be used irrespective of the level of the electromagnetic interference, with the advantages for both the manufacturer and the user, which derive from managing just one type.

Devices type 2 may also be used with unshielded cabling, provided that the cabling has TCL and ELTCL = 80 − 20log(*f*), 46 dB maximum.

B.6.3 EMI resistance needed for E3 industrial applications

Table B.6 shows device and cabling requirements when E3 resistance is required.

Table B.6 – EMI resistance of industrial applications

Test procedure		Value (kV)
IEC 61000-4-4	Electrical fast transient/burst immunity test	2
IEC 61000-4-5	Surge immunity test	2

Annex C
(informative)

Network topologies

C.1 Common description

Each network topology provides a different set of features and benefits. This Annex C covers items for consideration by network designers and planners.

C.2 Total cable demand

The total amount of cable required for an installation will depend on the site geographical placing of devices and the topological layout used to connect them. In most cases, star and ring structures need more cable than other structures.

C.3 Maximum cable segment length

The maximum cable length for a segment between two nodes is set by the fieldbus type category for that part of the network. So this constraint should be checked.

C.4 Maximum network length

Repeaters can usually extend the network length over greater geographical distances because the communication signals are regenerated by each repeater. However, in some cases the regeneration process may introduce unacceptable transmission delays.

C.5 Fault tolerance

C.5.1 General

Consideration of all network designs should include an evaluation of potential failures and their impact on performance.

Failure of cabling, nodes and power supplies should be evaluated for the effect on the network performance. In a passive topology, this type of fault normally results in loss of communication with one node. In an active topology, this type of fault normally results in loss of communication for multiple nodes.

NOTE The central location of a star topology represents a single point for failures which can stop all communications as a result of faults in a non-redundant repeater/switch or environmental problems in and around the central location.

C.5.2 Use of redundancy

Network fault tolerance may be improved by using combinations of redundancy at active propagation points and/or by providing alternative/backup communication paths.

Ring-based technologies normally provide fault detection and automatic reconfiguration to work around at least one fault.

C.5.3 Failure analysis for networks with redundancy

The effects of failure on networks including redundancy should be considered in three stages including an evaluation of the time required for the following actions.

a) Initial fault detection and any needed reconfiguration to restore communication.

NOTE 1 After fault detection and reconfiguration, the network is operating normally, but in a 'backup mode' using some of the redundancy elements, so it has reduced fault resilience, and could not be able to recover from a second fault.

NOTE 2 Some network topologies and design approaches can support detection and reconfiguration without loss of time or communications. In ring-based networks, fault detection and reconfiguration can take from 0,3 s to several minutes.

b) Repair/replacement of the faulty function.

NOTE 3 This phase considers the communication impact of repair activities; for example, a network outage can be required to replace a multi-port switch with several good ports and one faulty port.

NOTE 4 During and after repair, the network can operate in its backup mode of operation.

c) Reinstatement of the network to its original operational state.

Any operational impact of the re-instatement process should be evaluated.

NOTE 5 As part of the reconfiguration and backup process, the active 'network manager' and active 'source of network time' can be transferred to other nodes on the network; however for normal operation these entities can need to be re-instated to their original design location such as a protected node in the main control room.

The number of fault impact elements will vary for different technologies, topologies, and fault cases. The above analysis should include an evaluation of the time required and the number of lost and delayed messages for various faults, including failure of an active network manager function and failure of an active source of network time, followed by repair and reinstatement.

C.6 Network access for diagnosis convenience

The central point of a star structure is a convenient single location for network diagnosis, network re-configuration and administration.

C.7 Maintainability and on-line additions

Many fieldbus technologies provide facilities for adding and removing devices in an operational fieldbus network.

If an application requires device changes during normal operation, then the supplier recommended procedures for on-line connection and disconnection should be evaluated with respect to

- time taken and communication impact of making/unmaking a device physical and logical connection;
- time taken and communication impact of including/excluding a device for the running application.

Typically, when devices are connected to a spur or a tap on a bus or to a switch port, they may be added and removed without loss of traffic among other devices.

Typically, when devices are part of a ring structure or a linear trunk structure, the addition and removal of devices will involve re-configuration and loss of traffic among other devices.

Annex D
(informative)

Connector tables

The connector tables provided in Annex D show the connectors used for copper cabling in the CPs. These tables are intended for use by installers and trouble-shooters of communication networks in industrial sites.

Table D.1 provides conventions for colours, as specified in IEC 60757. These conventions are used in the connector tables. Combinations of colour codes are written according to the following example: colour code 1/colour code 2. Dominating colour is written first.

Table D.1 – Conventions for colour code used in the connector table

Colours	Code
Black	BK
Blue	BU
Brown	BN
Green	GN
Grey	GY
Orange	OG
Pink	PK
Red	RD
Turquoise	TQ
Violet	VT
White	WH
Yellow	YE

Table D.3 to ~~Table D.13~~ Table D.15 provide the pin and wire colour code assignment for a number of connectors as defined by the consortia for their CPs.

Additional conventions are:

a) not used pins are identified with symbol ~~“ – “~~ " - ";

b) drain wire or shield is represented as “Drain”.

In most cases of construction for balanced cables, the wires are arranged in 2 or 4 pairs. When arranged in pairs, the two conductors of each pair are twisted together. The pairs are then twisted together to form a finished cable. It is noted that a quad is constructed without pairing by twisting the 4 wires in a specific order. When the pairs are twisted, they are usually numbered for identification purposes. The pair numbers are then assigned a colour scheme. For example, Table D.2 relates the pair number to the colour scheme.

With respect to the cables with 2 and 4 pairs, there are two common wiring methods that are recognized. These two wiring methods are identified by T568A and T568B. The different wiring designations were created to distinguish the two different wiring systems and for compatibility purposes. Figure H.1 and Figure H.2 show the relationship between the pair positions within a connector, for four pair systems and two pair systems respectively. In most cases, the pair transmission and electrical characteristics of the pairs are identical and therefore pin placement is not important. The two wiring systems reverse the positions of pairs 2 and 3 within the connector. The wiring method for a particular cord is typically identified by T568A or T568B marked on the cable jacket.

For the purposes of this document, these designations are adopted in the following tables. These designations only apply to straight through cables.

The CPs treated in the connector tables are listed hereafter, complete with their trade names (see Annex M for the complete list).

- **CPF 1** (FOUNDATION fieldbus): CP 1/1 (FOUNDATION H1) and CP 1/2 (FOUNDATION HSE).
- **CPF 2** (CIP™): CP 2/1 (ControlNet™), CP 2/2 (EtherNet/IP™) and CP 2/3 (DeviceNet™).
- **CPF 3** (PROFIBUS & PROFINET): CP 3/1 and CP 3/2 (PROFIBUS), CP 3/3, CP3/4, CP3/5, and CP3/6 (PROFINET).
- **CPF 4** (P-NET®): CP 4/1 (P-NET with physical layer according to RS 485) and CP 4/3 (P-NET on IP).
- **CPF 6** (INTERBUS®): one common installation profile for CPF 6 Type 8 networks (CP 6/1 etc.) and CP 6/2 over Ethernet.
- **CPF 8** (CC-Link & CC-Link IE): CP 8/1 and CP 8/2 (CC-Link/V1 and CC-Link/V2), CP 8/3 (CC-Link/LT), CP 8/4 (CC-Link IE Controller Network and CP 8/5 (CC-Link IE Field Network) and CP 8/6 (CC-Link IE TSN).
- **CPF 10** (Vnet/IP): CP 10/1(Vnet/IP).
- **CPF 11**(TCnet): CP 11/1 (TCnet-star), CP 11/2 (TCnet-loop 100) and CP 11/3 (TCnet-loop 1G).
- **CPF 12** (EtherCAT™): CP 12/1 and CP 12/2 (EtherCAT).
- **CPF 13** (Ethernet POWERLINK): CP 13/1 (Ethernet POWERLINK).
- **CPF 14** (EPA™): CP 14/1 (EPA-NRT), CP 14/2 (EPA-RT) and CP 14/3 (EPA-FRT).
- **CPF 15** (MODBUS®-RTPS): CP 15/1 (MODBUS) and CP 15/2 (RTPS).
- **CPF 16** (SERCOS): CP 16/1 (SERCOS I), CP 16/2 (SERCOS II) and CP 16/3 (SERCOS III).
- **CPF 17** (RAPIEnet): CP 17/1 (RAPIEnet)
- **CPF 18** (SafetyNET p): CP 18/1 (SafetyNET p RTFL) and CP 18/2 (SafetyNET p RTFN).
- **CPF 19** (MECHATROLINK): CP 19/1 (MECHATROLINK-II) and CP 19/2 (MECHATROLINK-III), CP 19/3 (Σ-LINK II) and CP 19/4 (MECHATROLINK-4).
- **CPF 20** (ADS-net): CP 20/1 (ADS-net/μΣNETWORK-1000) and CP 20/2 (ADS-net/NX).
- **CPF 21** (FL-net): CP 21/1 (FL-net).
- **CPF 22** (AUTBUS): CP 22/1 (AUTBUS).

Table D.2 – Pin/pair assignment and colour scheme

T568A			T568B		
Pair	**Pin**	**Colour**	**Pair**	**Pin**	**Colour**
3	1	WH/GN	2	1	WH/OG
	2	GN		2	OG
2	3	WH/OG	3	3	WH/GN
	6	OG		6	GN
1	5	WH/BU	1	5	WH/BU
	4	BU		4	BU
4	7	WH/BN	4	7	WH/BN
	8	BN		8	BN

Table D.3 – 8-way modular connector

CP	Pin								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Housing**
CP 1/1	-	-	-	-	-	-	-	-	-
CP 1/2	T568A or T568B								Drain
CP 2/1	-	-	-	-	-	-	-	-	-
CP 2/2	T568A or T568B								Drain
CP 2/3	-	-	-	-	-	-	-	-	-
CP 3/1	-	-	-	-	-	-	-	-	-
CP 3/2	-	-	-	-	-	-	-	-	-
CP 3/3 [a] CP 3/4 [a] CP 3/5 [a] CP 3/6 [a]	YE	OG	WH	-	-	BU	-	-	Drain
CP 4/1	-	-	-	-	-	-	-	-	-
CP 4/3	T568A or T568B								Drain
CP 6/1 CP 6/3	-	-	-	-	-	-	-	-	-
CP 6/2	T568B								Drain
CP 8/1 CP 8/2	-								-
CP 8/3	-								-
CP 8/4	T568B								Drain
CP 8/5									Drain
CP 8/6									
CP 10/1	T568B								Drain
CP 11/1 CP 11/2	T568B								Drain
CP 11/3	-	-	-	-	-	-	-	-	-
CP 12/1 [b]	YE	OG	WH	-	-	BU	-	-	Drain
CP 12/2 [b]	YE	OG	WH	-	-	BU	-	-	Drain
CP 13/1	T568B								Drain
CP 14/1	T568B								Drain
CP 14/2	T568B								Drain
CP 14/3	-	-	-	-	-	-	-	-	-

CP	**Pin**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Housing**
CP 15/1	T568A or T568B								Drain
CP 15/2	T568A or T568B								Drain
CP 16/1	-								-
CP 16/2	-								-
CP 16/3	YE	OG	WH	-	-	BU	-	-	Drain
CP 17/1	T568B								Drain
CP 18/1 CP 18/2	YE	OG	WH	-	-	BU	-	-	Drain
CP 19/1	-	-	-	-	-	-	-	-	-
CP 19/2 [c]	~~YE~~ BU	~~OG~~ WH	~~WH~~ OG	-	-	~~BU~~ YE	-	-	Drain
CP 19/3	-	-	-	-	-	-	-	-	-
CP 19/4	BU	WH	OG	-	-	YE	-	-	Drain
CP 20/1	T568A or T568B								Drain
CP 20/2	T568A or T568B								Drain
CP 21/1	T568A or T568B								Drain
CP 22/1	-								

[a] With 4 pair cabling, use T568A or T568B

[b] With four pair cabling, use T568B

[c] With crossover pairing pins: 1-3, 2-6, 3-1, 6-2.

Table D.4 – M12-4 A-coding connector

CP	Pin				
	1	**2**	**1**	**4**	**1**
CP 1/1	-	-	-	-	-
CP 1/2	-	-	-	-	-
CP 2/1	-	-	-	-	-
CP 2/2	-	-	-	-	-
CP 2/3	-	-	-	-	-
CP 3/1	-	-	-	-	-
CP 3/2	GN	-	RD	-	Drain
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-	-	-	-
CP 4/1	-	-	-	-	-
CP 4/3	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-
CP 6/2	-	-	-	-	-
CP 8/1 CP 8/2	Drain	WH	YE	BU	-
CP 8/3	-	-	-	-	-
CP 8/4	-	-	-	-	-
CP 8/5	-	-	-	-	-
CP 8/6	-	-	-	-	-
CP 10/1	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-
CP 12/1	-	-	-	-	-
CP 12/2	-	-	-	-	-
CP 13/1	-	-	-	-	-
CP 14/1	-	-	-	-	-
CP 14/2	-	-	-	-	-
CP 14/3	-	-	-	-	-
CP 15/1	-	-	-	-	-
CP 15/2	-	-	-	-	-
CP 16/1	-	-	-	-	-
CP 16/2	-	-	-	-	-
CP 16/3	-	-	-	-	-
CP 17/1	-	-	-	-	-
CP 18/1	-	-	-	-	-
CP 18/2	-	-	-	-	-
CP 19/1	-	-	-	-	-
CP 19/2	-	-	-	-	-
CP 19/3	-	-	-	-	-
CP 19/4	-	-	-	-	-
CP 20/1	-	-	-	-	-
CP 20/2	-	-	-	-	-

CP 21/1	-	-	-	-	-
CP 22/1	-	-	-	-	-

Table D.5 – M12-4 D-coding connector

CP	Pin				
	1	**2**	**3**	**4**	**Housing**
CP 1/1	-	-	-	-	-
CP 1/2	-	-	-	-	-
CP 2/1	-	-	-	-	-
CP 2/2	WH/OG	OG	WH/GN	GN	Drain
CP 2/3	-	-	-	-	-
CP 3/1	-	-	-	-	-
CP 3/2	-	-	-	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	YE	WH	OG	BU	Drain
CP 4/1	-	-	-	-	-
CP 4/3	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-
CP 6/2	WH/OG	OG	WH/GN	GN	Drain
CP 8/1 CP 8/2	-	-	-	-	-
CP 8/3	-	-	-	-	-
CP 8/4	-	-	-	-	-
CP 8/5	-	-	-	-	-
CP 8/6	WH/OG	WH/GN	OG	GN	Drain
CP 10/1	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-
CP 12/1 CP 12/2	YE	WH	OG	BU	Drain
CP 13/1	YE	WH	OG	BU	Drain
CP 14/1 CP 14/2	WH/OG	OG	WH/GN	GN	Drain
CP 14/3	-	-	-	-	-
CP 15/1 CP 15/2	WH/OG	OG	WH/GN	GN	Drain
CP 16/1	-	-	-	-	-
CP 16/2	-	-	-	-	-
CP 16/3	YE	WH	OG	BU	Drain
CP 17/1	-	-	-	-	-
CP 18/1 CP 18/2	YE	WH	OG	BU	Drain
CP 19/1	-	-	-	-	-
CP 19/2 [a]	-BU	-OG	-WH	-YE	-Drain
CP 19/3	-	-	-	-	-
CP 19/4	BU	OG	WH	YE	Drain
CP 20/1	-	-	-	-	-
CP 20/2	-	-	-	-	-

CP	Pin				
	1	2	3	4	Housing
CP 21/1	-	-	-	-	-
CP 22/1	-	-	-	-	-
[a] With crossover pairing pins: 1-2, 2-1, 3-4, 4-3.					

Table D.6 – M12-5 A-coding connector

CP	Pin					
	1	2	3	4	5	Housing
CP 1/1	a	b	Drain	-	-	-
CP 1/2	-	-	-	-	-	-
CP 2/1	-	-	-	-	-	-
CP 2/2	-	-	-	-	-	-
CP 2/3	Drain	RD	BK	WH	BU	Drain
CP 3/1	-	-	-	-	-	-
CP 3/2	-	-	-	-	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-	-	-	-	-
CP 4/1	-	-	-	-	-	-
CP 4/3	-	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-	-
CP 6/2	-	-	-	-	-	-
CP 8/1 CP 8/2	-	-	-	-	-	-
CP 8/3	-	-	-	-	-	-
CP 8/4	-	-	-	-	-	-
CP 8/5	-	-	-	-	-	-
CP 8/6	-	-	-	-	-	-
CP 10/1	-	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-	-
CP 12/1	-	-	-	-	-	-
CP 12/2	-	-	-	-	-	-
CP 13/1	-	-	-	-	-	-
CP 14/1	-	-	-	-	-	-
CP 14/2	-	-	-	-	-	-
CP 14/3	-	-	-	-	-	-
CP 15/1	-	-	-	-	-	-
CP 15/2	-	-	-	-	-	-
CP 16/1	-	-	-	-	-	-
CP 16/2	-	-	-	-	-	-
CP 16/3	-	-	-	-	-	-
CP 17/1	-	-	-	-	-	-
CP 18/1	-	-	-	-	-	-
CP 18/2	-	-	-	-	-	-
CP 19/1	-	-	-	-	-	-
CP 19/2	-	-	-	-	-	-
CP 19/3	-	-	-	-	-	-
CP 19/4	-	-	-	-	-	-
CP 20/1	-	-	-	-	-	-
CP 20/2	-	-	-	-	-	-
CP 21/1	-	-	-	-	-	-
CP 22/1	-	-	-	-	-	-

CP	Pin					
	1	2	3	4	5	Housing

[a] This wire is for "+ Data" with no colour specified.

[b] This wire is for "- Data" with no colour specified.

Table D.7 – M12-5 B-coding connector

CP	Pin					
	1	2	3	4	5	Housing
CP 1/1	-	-	-	-	-	-
CP 1/2	-	-	-	-	-	-
CP 2/1	-	-	-	-	-	-
CP 2/2	-	-	-	-	-	-
CP 2/3	-	-	-	-	-	-
CP 3/1	-	GN	-	RD	-	Drain
CP 3/2	-	-	-	-	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-	-	-	-	-
CP 4/1	-	-	-	-	-	-
CP 4/3	-	-	-	-	-	-
CP 6/1 CP 6/3	YE	GN	GY	PK	BN	Drain
CP 6/2	-	-	-	-	-	-
CP 8/1 CP 8/2	-	-	-	-	-	-
CP 8/3	-	-	-	-	-	-
CP 8/4	-	-	-	-	-	-
CP 8/5	-	-	-	-	-	-
CP 8/6	-	-	-	-	-	-
CP 10/1	-	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-	-
CP 12/1	-	-	-	-	-	-
CP 12/2	-	-	-	-	-	-
CP 13/1	-	-	-	-	-	-
CP 14/1	-	-	-	-	-	-
CP 14/2	-	-	-	-	-	-
CP 14/3	-	-	-	-	-	-
CP 15/1	-	-	-	-	-	-
CP 15/2	-	-	-	-	-	-
CP 16/1	-	-	-	-	-	-
CP 16/2	-	-	-	-	-	-
CP 16/3	-	-	-	-	-	-
CP 17/1	-	-	-	-	-	-
CP 18/1	-	-	-	-	-	-
CP 18/2	-	-	-	-	-	-
CP 19/1	-	-	-	-	-	-
CP 19/2	-	-	-	-	-	-
CP 19/3	-	-	-	-	-	-
CP 19/4	-	-	-	-	-	-
CP 20/1	-	-	-	-	-	-
CP 20/2	-	-	-	-	-	-
CP 21/1	-	-	-	-	-	-
CP 22/1	-	-	-	-	-	-

Table D.8 – SubD connector

CP	Pin									
	1	2	3	4	5	6	7	8	9	Housing
CP 1/1	-	-	-	-	-	a	b	-	-	-
CP 1/2	-	-	-	-	-	-	-	-	-	-
CP 2/1	-	-	-	-	-	-	-	-	-	-
CP 2/2	-	-	-	-	-	-	-	-	-	-
CP 2/3	-	-	-	-	-	-	-	-	-	-
CP 3/1	-	-	RD	-	-	-	-	GN	-	Drain
CP 3/2	-	-	-	-	-	-	-	-	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-	-	-	-	-	-	-	-	-
CP 4/1	WH	-	Drain	-	BN	-	-	-	-	Drain
CP 4/3	-	-	-	-	-	-	-	-	-	-
CP 6/1 CP 6/3	YE	GY	BN	-	-	GN	PK	-	-	Drain
CP 6/2	-	-	-	-	-	-	-	-	-	-
CP 8/1 CP 8/2	-	-	-	-	-	-	-	-	-	-
CP 8/3	-	-	-	-	-	-	-	-	-	-
CP 8/4	-	-	-	-	-	-	-	-	-	-
CP 8/5	-	-	-	-	-	-	-	-	-	-
CP 8/6	-	-	-	-	-	-	-	-	-	-
CP 10/1	-	-	-	-	-	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-	-	-	-	-	-
CP 12/1	-	-	-	-	-	-	-	-	-	-
CP 12/2	-	-	-	-	-	-	-	-	-	-
CP 13/1	-	-	-	-	-	-	-	-	-	-
CP 14/1 CP 14/2	WH/OG	OG	WH/GN	BU	WH/BU	WH/BN	GN	BN	-	Drain
CP 14/3	-	-	-	-	-	-	-	-	-	
CP 15/1	-	-	-	-	-	-	-	-	-	-
CP 15/2	-	-	-	-	-	-	-	-	-	-
CP 16/1	-	-	-	-	-	-	-	-	-	-
CP 16/2	-	-	-	-	-	-	-	-	-	-
CP 16/3	-	-	-	-	-	-	-	-	-	-
CP 17/1	-	-	-	-	-	-	-	-	-	-
CP 18/1	-	-	-	-	-	-	-	-	-	-
CP 18/2	-	-	-	-	-	-	-	-	-	-
CP 19/1	-	-	-	-	-	-	-	-	-	-
CP 19/2	-	-	-	-	-	-	-	-	-	-
CP 19/3	-	-	-	-	-	-	-	-	-	-
CP 19/4	-	-	-	-	-	-	-	-	-	-
CP 20/1	-	-	-	-	-	-	-	-	-	-
CP 20/2	-	-	-	-	-	-	-	-	-	-
CP 21/1	-	-	-	-	-	-	-	-	-	-
CP 22/1	-	-	-	-	-	-	-	-	-	-

CP	Pin									
	1	2	3	4	5	6	7	8	9	Housing

[a] This wire is for "+ Data" with no colour specified.

[b] This wire is for "- Data" with no colour specified.

Table D.9 – 7/8-16 UN-2B THD / M18 connector

CP	Pin				
	1	2	3	4	5
CP 1/1	-	-	-	-	-
CP 1/2	-	-	-	-	-
CP 2/1	-	-	-	-	-
CP 2/2	-	-	-	-	-
CP 2/3	Drain	RD	BK	WH	BU
CP 3/1	-	-	-	-	-
CP 3/2	-	-	-	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-	-	-	-
CP 4/1	-	-	-	-	-
CP 4/3	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-
CP 6/2	-	-	-	-	-
CP 8/1 CP 8/2	-	-	-	-	-
CP 8/3	-	-	-	-	-
CP 8/4	-	-	-	-	-
CP 8/5	-	-	-	-	-
CP 8/6	-	-	-	-	-
CP 10/1	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-
CP 12/1	-	-	-	-	-
CP 12/2	-	-	-	-	-
CP 13/1	-	-	-	-	-
CP 14/1	-	-	-	-	-
CP 14/2	-	-	-	-	-
CP 14/3	-	-	-	-	-
CP 15/1	-	-	-	-	-
CP 15/2	-	-	-	-	-
CP 16/1	-	-	-	-	-
CP 16/2	-	-	-	-	-
CP 16/3	-	-	-	-	-
CP 17/1	-	-	-	-	-
CP 18/1	-	-	-	-	-
CP 18/2	-	-	-	-	-
CP 19/1	-	-	-	-	-
CP 19/2	-	-	-	-	-
CP 19/3	-	-	-	-	-
CP 19/4	-	-	-	-	-
CP 20/1	-	-	-	-	-
CP 20/2	-	-	-	-	-
CP 21/1	-	-	-	-	-
CP 22/1	-	-	-	-	-

Table D.10 – Open style connector

CP	Pin								
	1	2	3	4	5	6	7	8	Device housing
CP 1/1	-	-	-	-	-	-	-	-	-
CP 1/2	-	-	-	-	-	-	-	-	-
CP 2/1	-	-	-	-	-	-	-	-	-
CP 2/2	-	-	-	-	-	-	-	-	-
CP 2/3	BK	BU	Drain	WH	RD	-	-	-	-
CP 3/1	-	-	-	-	-	-	-	-	-
CP 3/2	-	-	-	-	-	-	-	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-	-	-	-	-	-	-	-
CP 4/1	-	-	-	-	-	-	-	-	-
CP 4/3	-	-	-	-	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-	-	-	-	-
CP 6/2	-	-	-	-	-	-	-	-	-
CP 8/1 CP 8/2	-BU	-WH	-YE	-	-Drain	-	-	-	-
CP 8/3	-	-	-	-	-	-	-	-	-
CP 8/4	-	-	-	-	-	-	-	-	-
CP 8/5	-	-	-	-	-	-	-	-	-
CP 8/6	-	-	-	-	-	-	-	-	-
CP 10/1	-	-	-	-	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-	-	-	-	-
CP 12/1	-	-	-	-	-	-	-	-	-
CP 12/2	-	-	-	-	-	-	-	-	-
CP 13/1	-	-	-	-	-	-	-	-	-
CP 14/1 [a]	WH/OG	OG	WH/GN	GN	-	-	-	-	Drain
CP 14/2 [a]	WH/OG	OG	WH/GN	GN	-	-	-	-	Drain
CP 14/1 [b]	WH/OG	OG	WH/GN	GN	BU	BN	-	-	Drain
CP 14/2 [b]	WH/OG	OG	WH/GN	GN	BU	BN	-	-	Drain
CP 14/1 [c]	WH/OG	OG	WH/GN	BU	WH/BU	GN	WH/BN	BN	Drain
CP 14/2 [c]	WH/OG	OG	WH/GN	BU	WH/BU	GN	WH/BN	BN	Drain
CP 14/3	-	-	-	-	-	-	-	-	-
CP 15/1	-	-	-	-	-	-	-	-	-
CP 15/2	-	-	-	-	-	-	-	-	-
CP 16/1	-	-	-	-	-	-	-	-	-
CP 16/2	-	-	-	-	-	-	-	-	-
CP 16/3	-	-	-	-	-	-	-	-	-
CP 17/1	-	-	-	-	-	-	-	-	-
CP 18/1	-	-	-	-	-	-	-	-	-
CP 18/2	-	-	-	-	-	-	-	-	-
CP 19/1	-	-	-	-	-	-	-	-	-
CP 19/2	-	-	-	-	-	-	-	-	-
CP 19/3 [b]	OG	BK	BN	GY	RD	BU	-	-	Drain
CP 19/3 [c]	OG	BK	BN	GY	RD	BU	YE	WH	Drain
CP 19/4	-	-	-	-	-	-	-	-	-
CP 20/1	-	-	-	-	-	-	-	-	-
CP 20/2	-	-	-	-	-	-	-	-	-
CP 21/1	-	-	-	-	-	-	-	-	-
CP 22/1	WH	-	RD	-	-	-	-	-	-

CP	Pin								
	1	2	3	4	5	6	7	8	Device housing
[a] Using open style 4 pins. [b] Using open style 6 pins. [c] Using open style 8 pins.									

Table D.11 – M12-8 X-coding connector and A-coding connector

CP	Pin								
	1	2	3	4	5	6	7	8	Housing
CP 1/1	-	-	-	-	-	-	-	-	-
CP 1/2	-	-	-	-	-	-	-	-	-
CP 2/1	-	-	-	-	-	-	-	-	-
CP 2/2	WH/GN	GN	WH/OG	OG	WH/BN	BN	WH/BU	BU	Drain
CP 2/3	-	-	-	-	-	-	-	-	-
CP 3/1	-	-	-	-	-	-	-	-	-
CP 3/2	-	-	-	-	-	-	-	-	-
CP 3/3	WH/GN	GN	WH/OG	OG	WH/BN	BN	WH/BU	BU	Drain
CP 3/4 CP 3/5 CP 3/6	or								
	WH/OG	OG	WH/GN	GN	WH/BN	BN	WH/BU	BU	Drain
CP 4/1	-	-	-	-	-	-	-	-	-
CP 4/3	-	-	-	-	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-	-	-	-	-
CP 6/2	WH/GN	GN	WH/OG	OG	WH/BN	BN	WH/BU	BU	Drain
CP 8/1 CP 8/2	-	-	-	-	-	-	-	-	-
CP 8/3	-	-	-	-	-	-	-	-	-
CP 8/4 CP 8/5	WH/GN	GN	WH/OG	OG	WH/BN	BN	WH/BU	BU	Drain
CP 10/1	-	-	-	-	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-	-	-	-	-
CP 12/1 CP 12/2	- WH/OG	- OG	- WH/GN	- GN	- WH/BN	- BN	- WH/BU	- BU	- Drain
CP 13/1	-	-	-	-	-	-	-	-	-
CP 14/1	-	-	-	-	-	-	-	-	-
CP 14/2	-	-	-	-	-	-	-	-	-
CP 14/3	-	-	-	-	-	-	-	-	-
CP 15/1	-	-	-	-	-	-	-	-	-
CP 15/2	-	-	-	-	-	-	-	-	-
CP 16/1	-	-	-	-	-	-	-	-	-
CP 16/2	-	-	-	-	-	-	-	-	-
CP 16/3	-	-	-	-	-	-	-	-	-
CP 17/1	-	-	-	-	-	-	-	-	-
CP 18/1	-	-	-	-	-	-	-	-	-
CP 18/2	WH/GN	GN	WH/OG	OG	WH/BN	BN	WH/BU	BU	Drain
CP 19/1	-	-	-	-	-	-	-	-	-
CP 19/2	-	-	-	-	-	-	-	-	-
CP 19/3 [a]	OG	BK	BN	GY	RD	BU	YE	WH	Drain
CP 19/4	OR/WH	OG	GR/WH	GR	BU	BU/WH	BR/WH	BR	Drain
CP 20/1	-	-	-	-	-	-	-	-	-
CP 20/2	-	-	-	-	-	-	-	-	-
CP 21/1	-	-	-	-	-	-	-	-	-
CP 22/1	-	-	-	-	-	-	-	-	-

[a] This connector is A-coding. All the others are X-coding

Table D.12 – BNC connector

CP	Connections	
	Centre	Outer part
CP 1/1	-	-
CP 1/2	-	-
CP 2/1	wire	shield
CP 2/2	-	-
CP 2/3	-	-
CP 3/1	-	-
CP 3/2	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-
CP 4/1	-	-
CP 4/3	-	-
CP 6/1 CP 6/3	-	-
CP 6/2	-	-
CP 8/1 CP 8/2	-	-
CP 8/3	-	-
CP 8/4	-	-
CP 8/5	-	-
CP 8/6	-	-
CP 10/1	-	-
CP 11/1 CP 11/2 CP 11/3	-	-
CP 12/1	-	-
CP 12/2	-	-
CP 13/1	-	-
CP 14/1	-	-
CP 14/2	-	-
CP 14/3	-	-
CP 15/1	-	-
CP 15/2	-	-
CP 16/1	-	-
CP 16/2	-	-
CP 16/3	-	-
CP 17/1	-	-
CP 18/1	-	-
CP 18/2	-	-
CP 19/1	-	-
CP 19/2	-	-
CP 20/1	-	-
CP 20/2	-	-
CP 21/1	-	-
CP 22/1	wire	shield

Table D.13 – TNC connector

CP	Connections	
	Centre	**Outer part**
CP 1/1		
CP 1/2	-	-
CP 2/1	wire	shield
CP 2/2	-	-
CP 2/3	-	-
CP 3/1	-	-
CP 3/2	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-
CP 4/1	-	-
CP 4/3	-	-
CP 6/1 CP 6/3	-	-
CP 6/2	-	-
CP 8/1 CP 8/2	-	-
CP 8/3	-	-
CP 8/4	-	-
CP 8/5	-	-
CP 8/6	-	-
CP 10/1	-	-
CP 11/1 CP 11/2 CP 11/3	-	-
CP 12/1	-	-
CP 12/2	-	-
CP 13/1	-	-
CP 14/1	-	-
CP 14/2	-	-
CP 14/3	-	-
CP 15/1	-	-
CP 15/2	-	-
CP 16/1	-	-
CP 16/2	-	-
CP 16/3	-	-
CP 17/1	-	-
CP 18/1	-	-
CP 18/2	-	-
CP 19/1	-	-
CP 19/2	-	-
CP 19/3	-	-
CP 19/4	-	-
CP 20/1	-	-
CP 20/2	-	-
CP 21/1	-	-
CP 22/1	-	-

Table D.14 – Rectangular 8-way/10-way modular connectors

CP	Pin								
	1	2	3	4	5	6	7	8	Device housing
CP 1/1	-	-	-	-	-	-	-	-	-
CP 1/2	-	-	-	-	-	-	-	-	-
CP 2/1	-	-	-	-	-	-	-	-	-
CP 2/2	-	-	-	-	-	-	-	-	-
CP 2/3	-	-	-	-	-	-	-	-	-
CP 3/1	-	-	-	-	-	-	-	-	-
CP 3/2[b]	BU	WH	OG	YE	-	-	-	-	Drain
CP 3/2[c]	BU	WH	OG	YE	-	-	-	-	Drain
CP 3/3 CP 3/4 CP 3/5 CP 3/6	-	-	-	-	-	-	-	-	-
CP 4/1	-	-	-	-	-	-	-	-	-
CP 4/3	-	-	-	-	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-	-	-	-	-
CP 6/2	-	-	-	-	-	-	-	-	-
CP 8/1 CP 8/2	-	-	-	-	-	-	-	-	-
CP 8/3	-	-	-	-	-	-	-	-	-
CP 8/4	-	-	-	-	-	-	-	-	-
CP 8/5	-	-	-	-	-	-	-	-	-
CP 8/6	-	-	-	-	-	-	-	-	-
CP 10/1	-	-	-	-	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-	-	-	-	-
CP 12/1	-	-	-	-	-	-	-	-	-
CP 12/2	-	-	-	-	-	-	-	-	-
CP 13/1	-	-	-	-	-	-	-	-	-
CP 14/1	-	-	-	-	-	-	-	-	-
CP 14/2	-	-	-	-	-	-	-	-	-
CP 14/1	-	-	-	-	-	-	-	-	-
CP 14/2	-	-	-	-	-	-	-	-	-
CP 14/1	-	-	-	-	-	-	-	-	-
CP 14/2	-	-	-	-	-	-	-	-	-
CP 14/3	-	-	-	-	-	-	-	-	-
CP 15/1	-	-	-	-	-	-	-	-	-
CP 15/2	-	-	-	-	-	-	-	-	-
CP 16/1	-	-	-	-	-	-	-	-	-
CP 16/2	-	-	-	-	-	-	-	-	-
CP 16/3	-	-	-	-	-	-	-	-	-
CP 17/1	-	-	-	-	-	-	-	-	-
CP 18/1	-	-	-	-	-	-	-	-	-
CP 18/2	-	-	-	-	-	-	-	-	-
CP 19/1	-	-	-	-	-	-	-	-	-
CP 19/2 [a,b]	BU	WH	OG	-	-	YE	-	-	Drain
CP 19/3	-	-	-	-	-	-	-	-	-
CP 19/4 [b]	BU	WH	OG	-	-	YE	-	-	Drain
CP 20/1	-	-	-	-	-	-	-	-	-
CP 20/2	-	-	-	-	-	-	-	-	-
CP 21/1	-	-	-	-	-	-	-	-	-
CP 22/1	-	-	-	-	-	-	-	-	-

NOTE Rectangular connectors are specified in IEC 61076-3-122 (8-way) and IEC 61076-3-124 (10-way).

[a] With crossover pairing: pins: 1-OG, 2-YE, 3-BU, 6-WH

[b] 8-way

[c] 10-way

Table D.15 – M8-4 A-coding, D-coding, P-coding, X-coding connectors

CP	Pin				
	1	2	3	4	Housing
CP 1/1	-	-	-	-	-
CP 1/2	-	-	-	-	-
CP 2/1	-	-	-	-	-
CP 2/2	-	-	-	-	-
CP 2/3	-	-	-	-	-
CP 3/1	-	-	-	-	-
CP 3/2	-	-	-	-	-
CP 3/3 CP 3/4 CP 3/5 CP 3/6	YE	WH	OG	BU	Drain
CP 4/1	-	-	-	-	-
CP 4/3	-	-	-	-	-
CP 6/1 CP 6/3	-	-	-	-	-
CP 6/2 [d]	-	-	-	-	Drain
CP 8/1 CP 8/2	-	-	-	-	-
CP 8/3	-	-	-	-	-
CP 8/4	-	-	-	-	-
CP 8/5	-	-	-	-	-
CP 10/1	-	-	-	-	-
CP 11/1 CP 11/2 CP 11/3	-	-	-	-	-
CP 12/1 [a p] CP 12/2 [a p]	YE	WH	BU	OG	Drain
CP 13/1	-	-	-	-	-
CP 14/1 CP 14/2	-	-	-	-	-
CP 14/3	-	-	-	-	-
CP 15/1 CP 15/2	-	-	-	-	-
CP 16/1	-	-	-	-	-
CP 16/2	-	-	-	-	-
CP 16/3	-	-	-	-	-
CP 17/1	-	-	-	-	-
CP 18/1 CP 18/2	-	-	-	-	-
CP 19/1	-	-	-	-	-
CP 19/2	-	-	-	-	-
CP 20/1	-	-	-	-	-
CP 20/2	-	-	-	-	-
CP 21/1	-	-	-	-	-
CP 22/1 [x]	WH	-	RD	-	Drain

[a] A-coding specified in IEC 61076-2-104

[d] D-coding specified in IEC 61076-2-114

[p] P-coding specified in IEC 61076-2-114

[x] X-coding specified in IEC 61076-2-101, IEC 63171-2 and IEC 63171-5

Annex E
(informative)

Power networks with respect to electromagnetic interference – TN-C and TN-S approaches

A major source of electromagnetic interference is based on the wiring of power lines between decentralized automation systems communicating via fieldbus. So far it was common practice and permitted by standards to use a combined PE (protective earth) and N (neutral lead) wire between main racks and sub-racks. This kind of wiring is also called a TN-C power network. This method is acceptable if no extended fieldbus networks are involved and the currents within the power lines L1, L2, L3 are balanced out (Figure E.1).

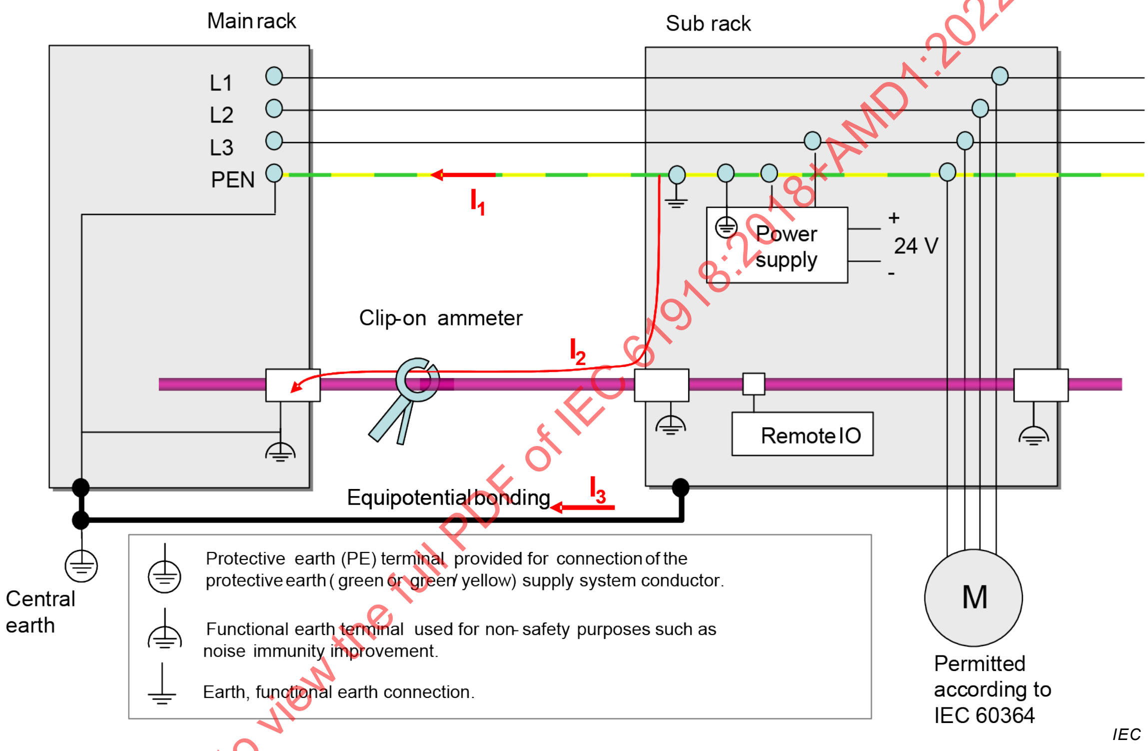


Figure E.1 – Four-wire power network (TN-C)

The functional earth of fieldbus devices is connected to the functional earth bus bar that is bonded to protective earth at the source of supply in accordance with national/local electrical regulation requirements.

Modern drive electronics and power supplies are using high frequency switching technology, which causes unbalanced (high frequency) currents flowing through the combined PEN wire of the system. The low impedance shielding of a fieldbus cable in parallel to the PEN wire will take over these high frequency currents and thus perturb the transmission of messages.

It is highly recommended to use separate PE and N wires ("5 wires") in accordance with IEC 60364-4-44 in order to avoid fieldbus communication errors and possible retries, which will affect the efficiency and probably the availability of the whole system (see Figure E.2). The corresponding types of power networks are called TN-S.

More complete information about the design of power networks in respect to electromagnetic interference can be retrieved from IEC 60364-4-44.

More complete information about the design of power networks in respect to safety can be retrieved from 312.2.1 of IEC 60364-1:2005, TN Systems.

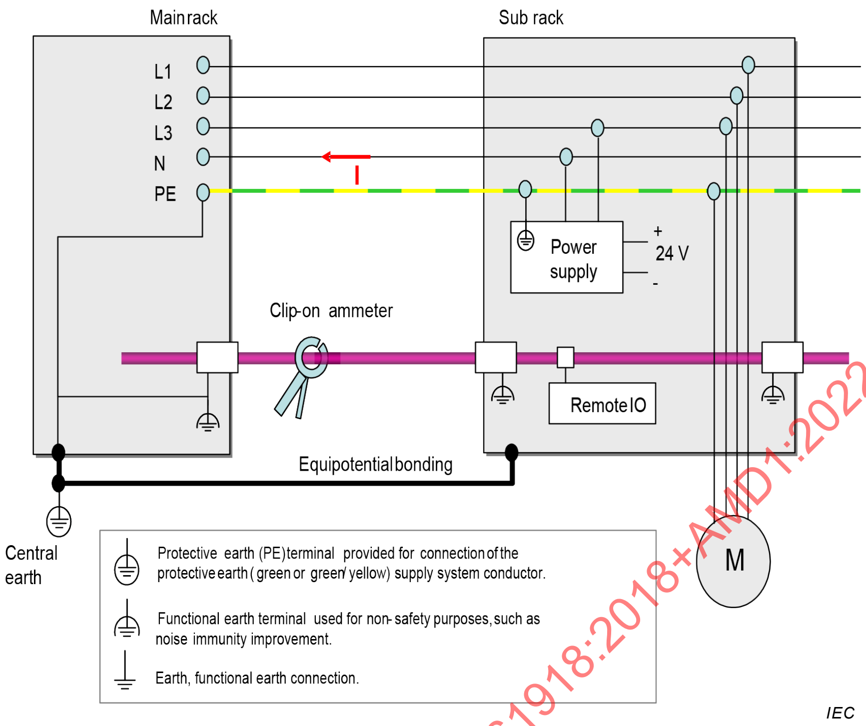


Figure E.2 – Five wire power network (TN-S)

Also in this case, the functional earth terminals and the functional earth connections are bonded as described above.

Annex F
(informative)

Conductor sizes in electrical cables

International standard manufacturing sizes for conductors in electrical cables are defined in IEC 60228. Conductors described in IEC 60228 are specified in metric sizes. North America (USA and CANADA) at present uses conductor sizes and characteristics according to the American Wire Gauge (AWG) system and kcmil for larger sizes. IEC cable product standards do not prescribe cables with AWG/kcmil conductors. Table F.1 gives data of nominal cross-sectional area (mm^2) corresponding to the conductor size expressed in AWG and kcmil.

Conductor sizes listed in IEC 60228 for both solid conductors for single-core and multicore cables and stranded conductors for single-core and multi-core cables have the following nominal cross-sectional areas (mm^2):

0,5 – 0,75 – 1 – 1,5 – 2,5 – 4 – 6 – 10 – 16 – 25 – 35 – 50 – 70 – 95 – 120 – 150 – 185 – 240 – 300.

These areas are different from those of the AWG system and there is not a direct correspondence between the two systems.

Table F.1 – American wire gauge system and kcmil

AWG				kcmil			
Conductor size	**Nominal cross-sectional area** mm^2	**Conductor size**	**Nominal cross-sectional area** mm^2	**Conductor size**	**Nominal cross-sectional area** mm^2	**Conductor size**	**Nominal cross-sectional area** mm^2
30	0,0509	13	2,62	250	127	750	380
29	0,0642	12	3,31	300	152	800	405
28	0,081	11	4,17	350	177	900	456
27	0,102	10	5,26	400	203	1 000	507
26	0,129	9	6,63	450	228	1 200	608
25	0,162	8	8,36	500	253	1 250	633
24	0,205	7	10,5	550	279	1 500	760
23	0,258	6	13,3	600	304	1 750	887
22	0,326	5	16,8	650	329	2 000	1 010
21	0,41	4	21,1	700	355		
20	0,518	3	26,7				
19	0,653	2	33,6				
18	0,823	1	42,4				
17	1,04	1/0	53,5				
16	1,31	2/0	67,4				
15	1,65	3/0	85				
14	2,08	4/0	107				

To convert to AWG a conductor size specified in mm^2, obtain from Table F.1 the AWG conductor size expressed in mm^2 and specify the next larger size as the equivalent mm^2 size.

EXAMPLE The AWG value for a conductor size 1 mm^2 is AWG 17 because the corresponding nominal cross-sectional area is 1,04 mm^2 that is the next larger size than 1 mm^2.

Annex G
(informative)

Installed cabling verification checklists

G.1 General

Annex G provides the checklists for installed cabling verification.

The verifier should confirm that all the items listed in the checklists are in accordance with the cabling planning documentation completed with recorded deviations and additions and the appropriate installation profile of IEC 61784-5 (all parts).

G.2 Copper cabling verification checklist

Table G.1 provides the copper cabling verification checklist.

Table G.1 – Copper cabling verification checklist

System			Segment name	
			Transmission speed	
Assembly acceptance performed by				
Comments				
Installed copper cabling visual inspection, verification				
OK	**Not OK**	**A.I. No.**	**Action item**	**Notes**
General checks for all CPs				
		1	Use of proper cable(s) and connectors; no damaged cable jacket	
		2	Placement of cabling components	
		3	Pathways	
		4	Routing of cabling for EMC purposes	
		5	Separation from other circuits. Minimum spacing between cabling has been complied with, or metal partitions have been inserted	
		6	Cable crossings executed at right angles	
		7	Protection from damage. Safeguards against mechanical damage present at hazard points	
		8	Sharp edges have been covered or removed	
		9	No kinks in the cable	
		10	Bending radii specification observed	
		11	Max. length of segment/branch lines not exceeded	
		12	Max. number of connections within a channel not exceeded	
		13	Proper cable lead-in into cabinets and/or buildings	
		14	Wire glands in place and properly installed; strain relief fixtures attached	
		15	Wire map	
		16	Miswiring, correct pairing and pinning and no shorts or opens	
		17	Protective caps for connectors	
		18	Earthing	
		19	Cable shield earthing	
		20	Cable trays earthed	
		21	All equipotential bonding points available	
		22	Shielding on the cabinet entrance is connected with the equipotential bonding	
		23	Shielding is applied to the devices and connected to the equipotential bonding	
		24	Channels not required are switched according to manufacturer's description	
		25	Physical topology	
		26	Labelling and marking	
		27	At least one plug/jack is reserved for programming/maintenance device connection	

System			Segment name	
			Transmission speed	
Assembly acceptance performed by				
Comments				
Installed copper cabling visual inspection, verification				
OK	**Not OK**	**A.I. No.**	**Action item**	**Notes**
General checks for all CPs				
		28	Subassemblies used in accordance with the structure plan (24 V/230 V subassemblies not reversed)	

Table G.2 provides the earthing and bonding measurements checklist.

Table G.2 – Earthing and bonding measurements checklist

Measurements on earthing and bonding							**Max. allowed values**	
OK	**Not OK**	**No.**	**Measurement**	**Measured value**				
		1	Resistance to earth[a]		mΩ		0,005	Ω
		2	Resistance offset[b]		Ω		0,6	Ω
		3	Voltage offset[c]		V		1	V

[a] Measured between connections and surfaces bonded to earth and dedicated earthing points.

[b] Measured between any newly installed earthing and bonding connection and one pre-existing earthing and bonding point.

[c] Measured between any newly installed earthing and bonding connection and one pre-existing earthing and bonding point. This measurement should be repeated when the system is fully operational.

Table G.3 provides place for the installer's and commissioning personnel's signature.

Table G.3 – Signatures for Table G.1 and Table G.2 checklists

Date	**Installer's signature**	**Commissioning personnel's signature**

Table G.4 provides the checklist for special checks for non-Ethernet base CPs.

Table G.4 – Checklist for special checks for non-Ethernet base CPs

Special checks for non-Ethernet base CPs				
OK	**Not OK**	**A.I. No.**	**Action item**	**Notes**
		1	Transmission speed and fieldbus dependant device-address	
		2	Correct number of terminators present, with correct values in the correct positions	
		3	Guaranteed power supply for terminating resistors (even in case of emergency stop)	
		4	Cable ends for unterminated cables	
Additional checks in case of IS-segments (Ex i environment)				
		IS 1	Fieldbus-isolating repeaters are used to isolate the Ex i Trunk from the NON Ex i Trunk	
		IS 2	Limited transmission rate ensured	
		IS 3	Only connectors according to RS 485-IS specification are used, such as no discrete inductor, special terminator resistor	
		IS 4	All devices in use are Ex i certified	
		IS 5	The max. safety values of all bus participants (field devices, fieldbus isolating repeaters, etc.) are within the specification	
		IS 6	Check if the interconnection of all bus participants (field devices, fieldbus isolating repeaters, etc.) is intrinsically safe	
		IS 7	Check if the national rules for installation in the hazardous area are observed and followed, such as IEC 60079-14	

Table G.5 provides place for the installer's and commissioning personnel's signature.

Table G.5 – Signatures for Table G.4 checklist

Date	Installer's signature	Commissioning personnel's signature

G.3 Optical fibre cabling verification checklist

Table G.6 provides the optical fibre cabling verification checklist.

Table G.6 – Optical fibre cabling verification checklist

System			Segment name	
			Transmission speed	
Assembly acceptance performed by				
Comments				
Optical fibre cabling visual inspection, verification				
OK	**Not OK**	**A.I. Nos.**	**Action item**	**Notes**
		1	Use of proper cable(s) and connectors; no damaged cable jacket	
		2	Placement of cabling components	
		3	Pathways	
		4	Separation from other circuits. Optical fibre cables on top in a tray	
		5	Protection from damage. Safeguards against mechanical damage present at hazard points	
		6	Sharp edges have been covered or removed	
		7	No kinks in the cable	
		8	Bending radii specification observed	
		9	Min./max. length of segment/branch lines not exceeded	
		10	Proper cable lead-in into cabinets and/or buildings	
		11	Tensile strength not exceeded	
		12	Wire glands in place and properly installed; strain relief fixtures attached	
		13	Wire map	
		14	Proper optical fibre polarity	
		15	Protective caps for connectors	
		16	Connectors protected against contamination	
		17	Range of temperature for operation and storage	
		18	Physical topology	
		19	Labelling and marking	

Table G.7 provides place for the installer's and commissioning personnel's signature.

Table G.7 – Signatures for Table G.6 checklist

Date	**Installer signature**	**Commissioning personnel signature**

Annex H
(normative)

Cord sets

H.1 General

For the purposes of this document, the term cord includes cords constructed of two plugs or one plug and one jack connected by cable. Annex H is intended for shielded and unshielded cord sets for Ethernet-based networks. Annex H provides tables with connector pin outs to help in the construction and verification of cord sets. Cord sets can either be factory-assembled or field-assembled. Cord sets shall conform to the channel de-rating based on the cable type and environmental conditions. Cord sets shall be fitted with a plug at each end of the cable. Extension cord sets may be fitted with a plug and jack to minimize the number of connections in the channel. Due to crossover cable function and the optional T568A and T568B wiring, the pairs and colours may be swapped at one or more ends of the cord set. For the T568A and T568B wiring and the associations between pair numbers and colours, read Annex D.

H.2 Constructing cord sets

H.2.1 Straight through cord sets with M12-4 D-coding connectors

Straight through M12-4 D-coding cord sets can be factory-supplied or field-constructed. If field-constructed, there are several connector assembling methods. Among the most popular solutions that do not require tools to assemble there is the insulation displacement connection IDC type connector and the method for assembling a cable thereto that require no tools to assemble. Others may provide cage cramps, screw terminals or solder cups for wire attachment. If field-assembled, the correct connector shall be selected to meet the relevant international protection (IP) code for the environment. Incorrect assembly can cause loss of IP rating on the connector. The manufacturer's assembly instructions should be followed. The used cable shall be in accordance with the specific requirements defined in the specific installation profile. The cord set shall be wired as shown in Table H.1. See Figure H.1 for connector pin out.

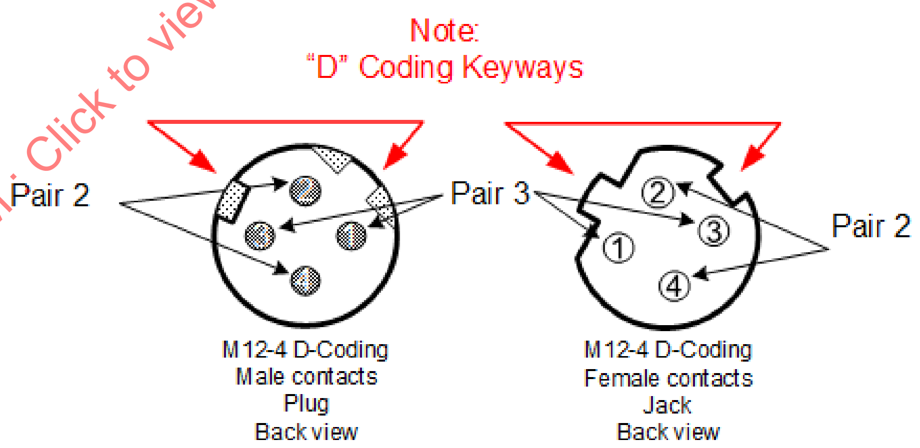


Figure H.1 – Straight through cord sets with M12-4 D-coding connectors

Table H.1 – M12-4 D-coding pin/pair assignment

Pin	Pair	Wire colour	Name	Signal
1	2	See Table D.5	Transmit data +	TXD+
3			Transmit data -	TXD-
2	3		Receive data +	RXD+
4			Receive data -	RXD-
Housing			Shield	Shield

H.2.2 Crossover cord sets with M12-4 D-coding connectors

Crossover M12-4 D-coding cord sets can be factory-supplied or field-constructed. If field-assembled, the correct connector shall be selected to meet the relevant international protection (IP) code for the environment. Incorrect assembly can cause loss of IP rating on the connector. The cord set shall be wired as shown in Table H.2. See Figure H.1 for connector pin out.

Table H.2 – M12-4 D-coding to M12-4 D-coding crossover pin/pair assignment

M12-4 pin	M12-4 pin	Wire colour	Name	Signal
2	1	See Table D.5	Transmit data +	TXD+
1	2		Receive data +	RXD+
4	3		Transmit data -	TXD-
3	4		Receive data -	RXD-
Housing	Housing		Shield	Shield

H.2.3 Straight through cord sets with 8-way modular connectors

8-way modular cord sets can be factory-supplied or field-constructed. If field-assembled, the correct connector shall be selected to meet the relevant international protection (IP) code for the environment. Incorrect assembly can cause loss of IP rating on the connector. The manufacturer's assembly instructions should be followed. The cord set shall be wired as shown in Table H.3. See Figure H.2 or Figure H.3 for connector pin out.

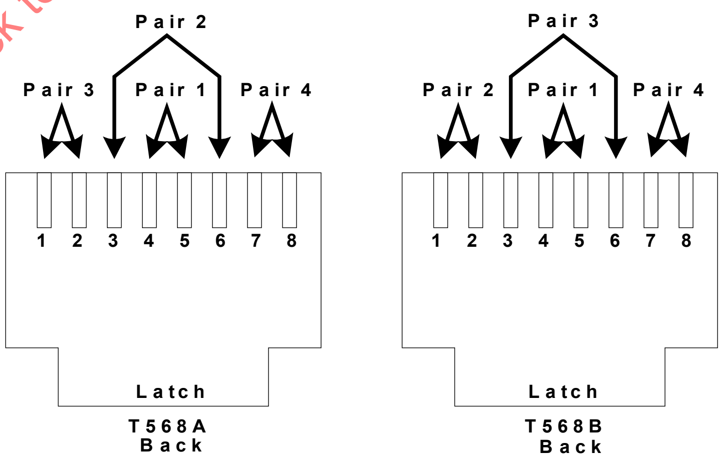


Figure H.2 – Straight through cord sets with 8-way modular connectors, 8 poles

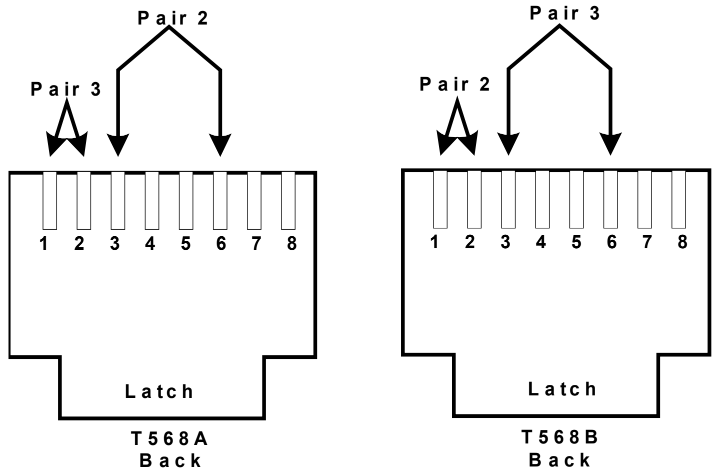


Figure H.3 – Straight through cord sets with 8-way modular connectors, 4 poles

Table H.3 – 8-way modular pin/pair assignment

Pin	Signal	T568A		T568B		CP
		Wire colour	**Pair**	**Wire colour**	**Pair**	**Wire colour**
1	TXD+		Pair 3		Pair 2	
2	TXD-					
3	RXD+		Pair 2		Pair 3	
4	-		Pair 1		Pair 1	
5	-	See Table D.2		See Table D.2		See Table D.3
6	RXD-		Pair 2		Pair 3	
7	-		Pair 4		Pair 4	
8	-					
SH [a]	Shield		–		–	

NOTE 1 Pairs 1 and 4 are not used for 10Base-TX and for 100Base-TX.

NOTE 2 CPs that do not use star quad do not assign pairs.

[a] SH is either a shield around the connector, metallic frame or protective housing.

H.2.4 Crossover cord sets with 8-way modular connectors

8-way modular crossover cord sets can be factory-supplied or field-constructed. If field-assembled, the correct connector shall be selected to meet the relevant international protection (IP) code for the environment. Incorrect assembly can cause loss of IP rating on the connector. The manufacturer's assembly instructions should be followed. The cord set shall be wired as shown in Table H.4. See Figure H.2 or Figure H.3 for connector pin out.

Table H.4 – 8-way modular crossover pin/pair assignment

Pin	Signal	CP wire colour	Pair	Route to pin
1	TXD+	See Table D.3	Pair 3	3
2	TXD-			6
3	RXD+		Pair 2	1
4	-		Pair 1	7
5	-			8
6	RXD-		Pair 2	2
7	-		Pair 4	4
8	-			5
SH [a]	Shield		Shield	SH [a]

NOTE 1 Pairs 1 and 4 are not used for 10Base-TX and for 100Base-TX.

NOTE 2 CPs that do not use star quad do not assign pairs.

[a] SH is either a shield around the connector, metallic frame or protective housing.

H.2.5 Straight conversion from one connector family to another

The following is the pin out information for a cord set (plug to plug) providing connectivity between an 8-way modular connector and a 4-pole M12 D-coding connector. The manufacturer's assembly instructions should be followed. The cord set shall be wired as shown in Table H.5. See Figure H.1 and Figure H.2 or Figure H.3 for connector pin out.

Table H.5 – Connectivity pin assignment

8-way modular pin	M12-4 pin	Wire colour	Name	Signal
1	1	See Table D.5	Transmit data +	TXD+
3	2		Receive data +	RXD+
2	3		Transmit data -	TXD-
6	4		Receive data -	RXD-
SH [a]	Housing		Shield	Shield

[a] SH is either a shield around the connector, metallic frame or protective housing.

H.2.6 Crossover conversion from one connector family to another

The following is the wiring schematic for a crossover conversion cable using an M12-4 D-coding connector to an 8-way modular connector. The manufacturer's assembly instructions should be followed. The cord set shall be wired as shown in Table H.6. See Figure H.1 and Figure H.2 or Figure H.3 for connector pin out.

Table H.6 – M12-4 to 8-way modular crossover pin pair assignment

8-way modular connector	M12-4 pin	CP Wire colour	Name	Signal
3	1	See Table D.5	Transmit data +	TXD+
1	2		Receive data +	RXD+
6	3		Transmit data -	TXD-
2	4		Receive data -	RXD-
SH [a]	Housing		Shield	Shield

[a] SH is either a shield around the connector, metallic frame or protective housing.

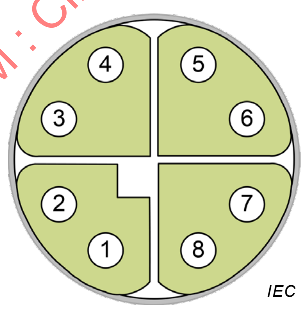
H.2.7 Assignment of PMA signal to MDI and MDI-X in outs

According to IEEE 802.3, the medium dependent interface (MDI), both physical and electrical, in a computer network is the interface from a physical layer implementation to the physical medium used to carry the transmission. IEEE 802.3 also defines a medium dependent crossover interface (MDI-X). Table H.7 is a copy of the Table 40-12 of IEEE 802.3:2015 that illustrates the assignment of the physical medium attachment (PMA) signal to MDI and MDI-X pin outs.

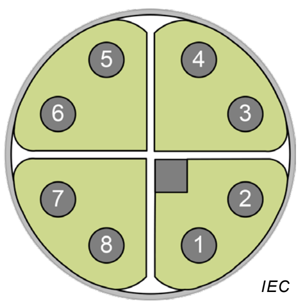
Table H.7 – Assignment of PMA signal to MDI and MDI-X pin outs

Pin	MDI	MDIX
1	BI_DA+	BI_DB+
2	BI_DA-	BI_DB-
3	BI_DB+	BI_DA+
6	BI_DB-	BI_DA-
5	BI_DC-	BI_DD-
4	BI_DC+	BI_DD+
7	BI_DD+	BI_DC+
8	BI_DD-	BI_DC-

Table H.8 shows the signal and pin/pair assignment for 8-way modular connector and an M12-8 X-coding connector (see Figure H.4) when used as an MDI in a T568B style wiring.



Female contacts



Male contacts

Figure H.4 –M12-8 X-coding connector

Table H.8 – Signal and pin/pair assignment for MDI and TIA 568B

IEEE 802.3 (MDI)	8-way IEC 60603-7 (T568B)			M12-8 X-Coding IEC 61076	
PMA signal	pin	pair	wire colour	pin	PMA signal
BI_DA+	1	2	See Table D.2	1	BI_DA+
BI_DA-	2			2	BI_DA-
BI_DB+	3	3		3	BI_DB+
BI_DB-	6			4	BI_DB-
BI_DC-	5	1		7	BI_DC-
BI_DC+	4			8	BI_DC+
BI_DD+	7	4		5	BI_DD+
BI_DD-	8			6	BI_DD-

H.2.8 Signal and pin assignment for MDI and TIA568A

Table H.9 shows the signal and pin/pair assignment for 8-way modular connector and an M12-8 X-coding connector when used as an MDI in a T568A style wiring.

Table H.9 – Signal and pin/pair assignment for MDI and T568A

IEEE 802.3 (MDI)	8-way IEC 60603-7 (T568A)			M12-8 X-Coding IEC 61076	
PMA signal	pin	pair	wire colour	pin	PMA signal
BI_DA+	1	3	See Table D.2	1	BI_DA+
BI_DA-	2			2	BI_DA-
BI_DB+	3	2		3	BI_DB+
BI_DB-	6			4	BI_DB-
BI_DC-	5	1		7	BI_DC-
BI_DC+	4			8	BI_DC+
BI_DD+	7	4		5	BI_DD+
BI_DD-	8			6	BI_DD-

H.2.9 Signal and pin assignment for MDIX and TIA568B

Table H.10 shows the signal and pin assignment for 8-way modular connector and an M12-8 X-coding connector when used as an MDIX in a T568B style wiring.

Table H.10 – Signal and pin/pair assignment for MDIX and T568B

IEEE 802.3 (MDIX)	8-way IEC 60603-7 (T568B)			M12-8 X-Coding IEC 61076	
PMA signal	pin	pair	wire colour	pin	PMA signal
BI_DB+	1	2	See Table D.2	1	BI_DB+
BI_DB-	2			2	BI_DB-
BI_DA+	3	3		3	BI_DA+
BI_DA-	6			4	BI_DA-
BI_DD-	5	1		7	BI_DD-
BI_DD+	4			8	BI_DD+
BI_DC+	7	4		5	BI_DC+
BI_DC-	8			6	BI_DC-

H.2.10 Signal and pin assignment for MDIX and TIA568A

Table H.11 shows the signal and pin assignment for 8-way modular connector and an M12-8 X-coding connector when used as an MDIX in a T568A style wiring.

Table H.11 – Signal and pin/pair assignment for MDIX and T568A

IEEE 802.3 (MDIX)	8-way IEC 60603-7 (T568A)			M12-8 X-Coding IEC 61076	
PMA signal	pin	pair	wire colour	pin	PMA signal
BI_DB+	1	3	See Table D.2	1	BI_DB+
BI_DB-	2			2	BI_DB-
BI_DA+	3	2		3	BI_DA+
BI_DA-	6			4	BI_DA-
BI_DD-	5	1		7	BI_DD-
BI_DD+	4			8	BI_DD+
BI_DC+	7	4		5	BI_DC+
BI_DC-	8			6	BI_DC-

H.2.11 Straight through cord set with IEC 63171-6 connectors

Signal and pin assignment are specified in Q.2.4.

Annex I
(informative)

Guidance for terminating cable ends

I.1 General

As examples of good practice for terminating cable ends, the following guidance is given here in addition to the rules provided in 5.3.

The following tools are needed to terminate the ends of the cable:

- cable cutting and preparation tool;
- cable jacket stripper;
- crimp tool.

I.2 Guidance for terminating shielded twisted pair cable ends for 8-way modular plugs

There are several variants of shielded twisted pair cables available offering different levels of shielding effectiveness. In general, they are all terminated in the same way. The following description refers to all these shielded variants as STP cables.

Depending on the type of shielding used on the cable, the process of preparing and terminating the cable may be different from cable to cable and from connector to connector. Refer to cable and/or connector manufacturer's recommendations for proper termination methods.

Basic steps to be followed for terminating shielded twisted pair cable ends are as follows.

a) Measure the cable and trim it to the proper length using the cable cutter. Cut the cable about 75 mm (3 in) longer than the final cable length.
b) Refer to Figure I.1 and strip back about 25 mm (1 in) of jacket, using the jacket strip tool.

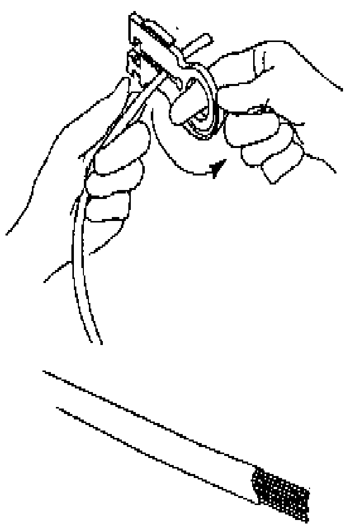


Figure I.1 – Stripping the cable jacket

c) Prepare the shield to provide a 360° coverage over the conductors. Care should be taken not to cut the shield, drain or insulation of the wires. If the shield, drain or insulation are damaged, cut off the end of the cable and start over.

d) Separate the individual wire pairs. Un-twist each conductor pair no further back than to the jacket edge, as shown in Figure I.2.

e) Fold the drain wire and/or shields back in line with the cable.

f) Align the wires into colour groups as shown in Figure I.2. Wire colour codes for the several CPs are given in Table D.3 (for example for CP 2/2).

   – If wiring to T568A, then the white/orange and orange pair is split across blue and white/blue.

   – If wiring to T568B, then the green/white and green pair is split across blue and white/blue.

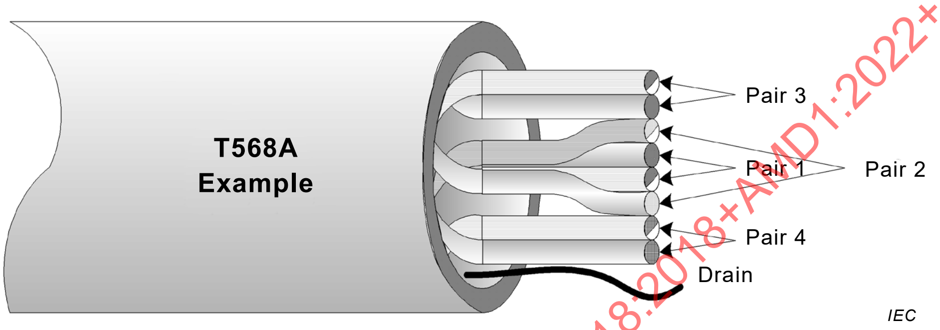


Figure I.2 – Example of wire preparation for type A cables

g) Check the following:

   – pair twists extend as far out as possible;

   – pair 2 (T568A) is evenly split;

   – ends of conductors trimmed evenly;

   – conductor trim length is dependent on connector manufacturers' instructions.

h) Hold the conductors in the proper orientation and trim off the excess length using a pair of sharp cutters. The finished length beyond the jacket should be less than 12 mm (0,5 in).

i) Confirm the correct orientation of the conductors. Apply the CP-specific wiring convention (provided in the relevant installation profile) and the connector pin out in Figure I.3. Insert the conductors into the connector body as shown in Figure I.4.

   NOTE Each wire has its own slot.

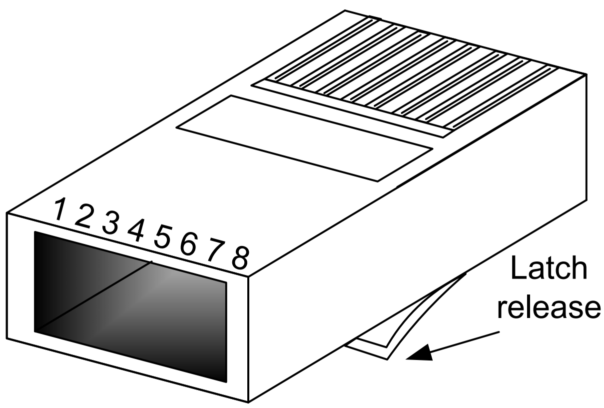


Figure I.3 – 8-way modular plug

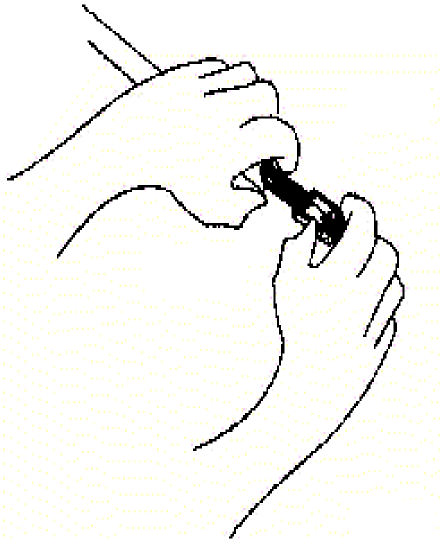


Figure I.4 – Inserting the cable into the connector body

j) Push the cable into the shielded connector body until all the wires touch the end of the connector body. The jacket should be inserted far enough into the connector body that the cable clamp will engage and hold the jacket.

k) Insert the connector into the crimp tool (Figure I.5) and crimp the connector. Confirm that the connector is fully seated into the crimp dies.

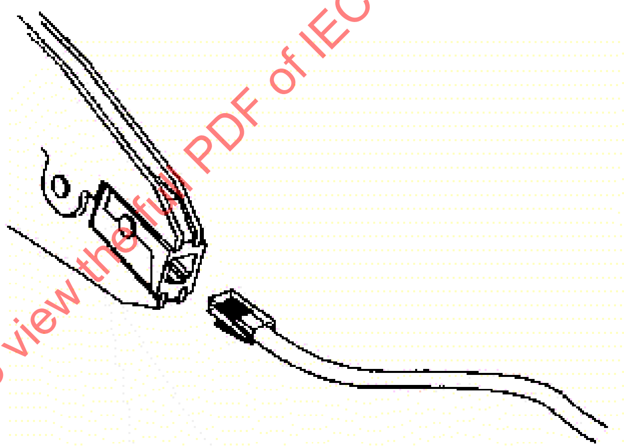


Figure I.5 – Crimping the connector

l) Squeeze the hand tool to complete the crimp. The tool will not release until the jaws are fully closed and crimped.

m) Check the crimp by pulling gently on the connector. If the jacket or conductors slide out, cut the connector off and start over.

n) Electrically test the connection using an appropriate test tool such as commercially available Ethernet test tool.

I.3 Guidance for terminating unshielded twisted pair cable ends for 8-way modular plugs

Terminate unshielded cable ends for 8-way modular plugs as follows.

a) Measure the cable and trim it to the proper length using the cable cutter. Cut the cable about 75 mm (3 in) longer than the final cable length.

b) Using a stripping tool similar to the one in Figure I.1, strip back 25 mm (1 in) of jacket. Be careful not to cut the insulation of the wire. If the wire insulation is damaged, cut off the end of the cable and start over.

c) Align the wires into colour groups as shown as shown in Figure I.6.

d) Separate the individual wire pairs. Wire colour codes for the several CPs are given in Table D.3. For example for CP 2/2.

- If wiring to T568A, then the white/orange and orange pair is split across blue and white/blue.
- If wiring to T568B, then the green/white and green pair is split across blue and white/blue.

e) Un-twist the conductors only back to the jacket edge (see Figure I.6).

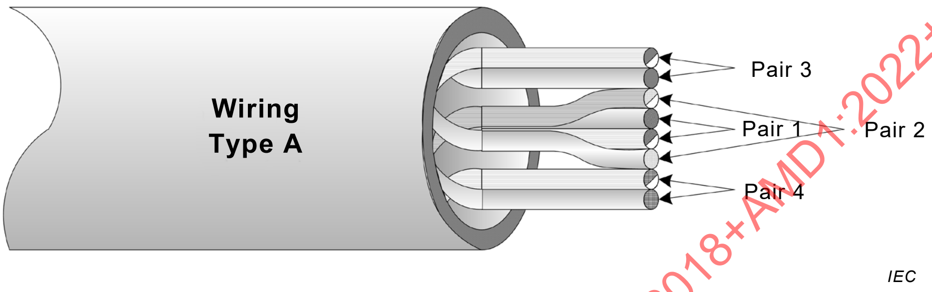


Figure I.6 – Example of a cable preparation for type A wiring

f) Check the following:

- pair twists extend as far out as possible;
- pair 2 (T568A) is evenly split;
- ends of conductors trimmed evenly;
- conductor trim length is dependent on connector manufacturers' instructions.

g) Hold the conductors in the proper orientation and trim off excess length using a pair of sharp cutters. The finished length beyond the jacket should be less than 12 mm (0,5 in). See connector manufacturer's instructions.

h) Confirm the correct orientation of the conductors and insert the conductors into the connector body (Figure I.4).

NOTE Each wire has its own slot in the connector body.

i) Push the cable into the connector body until all the wires touch the end of the connector body. The jacket should be inserted far enough into the connector body that the cable clamp will engage and hold the jacket.

j) Insert the connector into the crimp tool (Figure I.5) and crimp the connector. Confirm that the connector is fully seated into the crimp dies.

k) Squeeze the hand tool to complete the crimp. The tool will not release until the jaws are fully closed and crimped.

l) Check the crimp by pulling gently on the connector. If the jacket or conductors slide out, cut the connector off and start over.

m) Electrically test the connection using an appropriate tester such as a commercially available Ethernet test tool.

I.4 Guidance for M12~~-4 D-coding~~ connector installation

The following are example steps for installing a M12-4 D-coding connector on a 2 pair unshielded or shielded cable. This procedure is applicable to all M12 coded connectors, including the M12 X-coding, by applying the appropriate wiring map in step i) according to the corresponding wire map table in Annex D. The basic steps of this procedure are also applicable to type M12 and type M8 of IEC 63171-6 connector, specified in Q.2.4. This procedure can be used for both metal and plastic connector shell constructions. If a STP cable is used, there are additional steps that are required to prepare the shield.

a) Identify the connector components and separate the components (see Figure I.7).

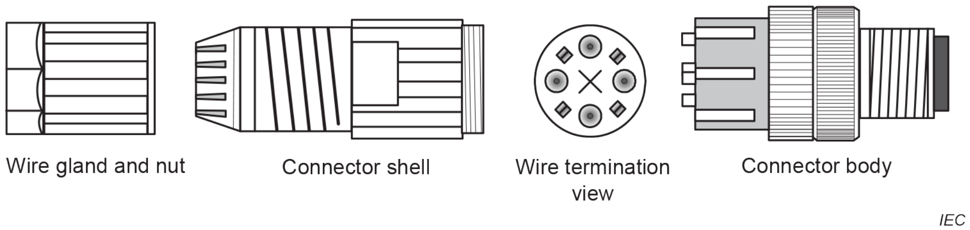


Figure I.7 – Connector components

b) Cut approximately 50 mm off the end of the cable and discard the cut off (see Figure I.8).

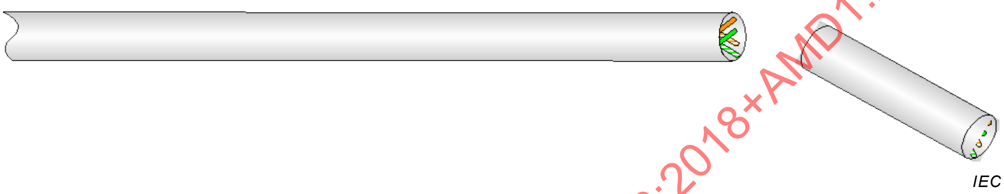


Figure I.8 – Cable preparation

c) Slide the wire gland, nut and connector shell on the cable (see Figure I.9).

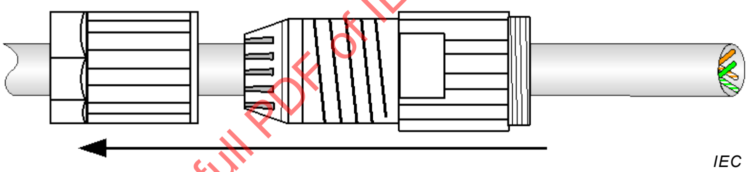


Figure I.9 – Connector wire gland, nut and shell on the cable

d) Score and strip approximately 2 cm of the cable jacket. Take care not to score or cut the conductors or shield if present. If the conductor insulation or shield is scored or cut, then start over by going back to step 2 (see Figure I.10).

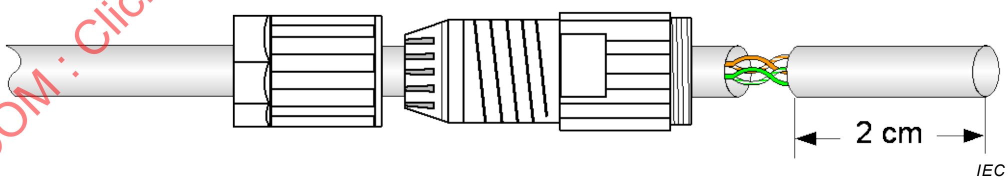


Figure I.10 – Conductors preparation

e) Remove and discard the jacket (see Figure I.11).

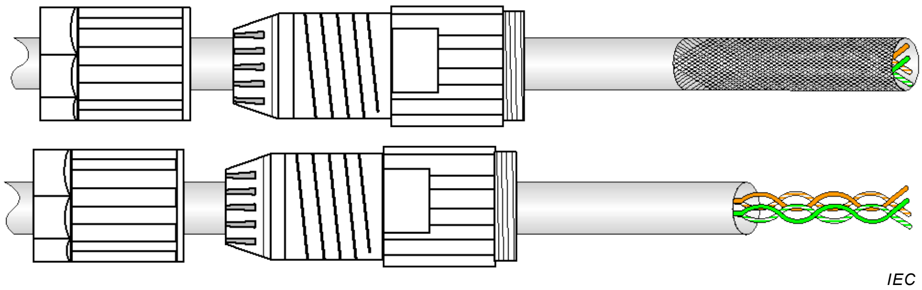


Figure I.11 – Jacket removal

f) If the cable is shielded, fold the shield back over the jacket and trim in accordance with the connector documentation, otherwise skip this step (see Figure I.12).

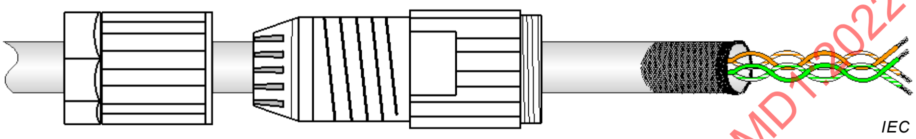


Figure I.12 – Shield preparation

g) Trim conductors to the necessary length. It is important to keep the untwisted length and exposed length as short as possible. Strip off 0,5 cm of the conductor insulation (see Figure I.13).

NOTE Some connectors use IDC contacts in place of screw terminals or cage clamps. Stripping of the insulation is not necessary for IDC contacts.

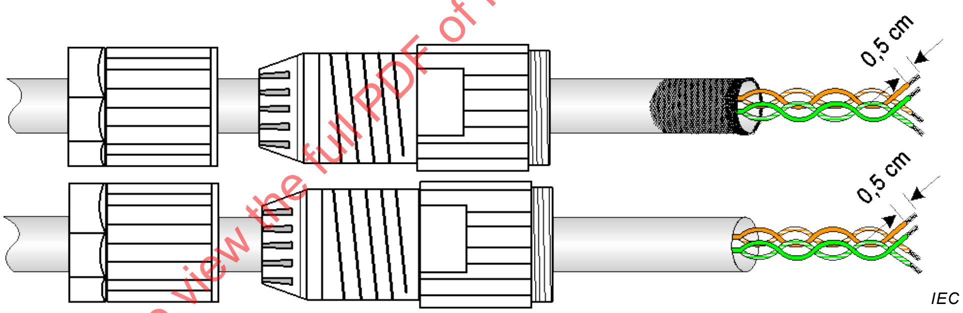


Figure I.13 – Conductors preparation

h) Prepare the conductors according to the wire map specified in the cabling planning documentation.

i) Insert the wires in to the backend of the connector body (see Figure I.14). Depending on the connector, the wires may be secured using screw terminals, cage clamps or IDC type contacts.

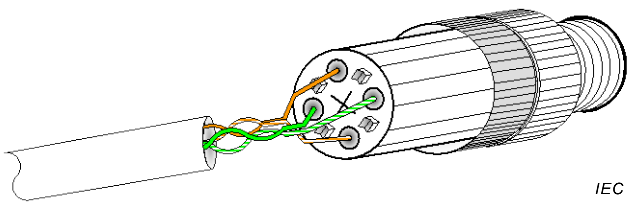


Figure I.14 – Installing conductors in connector

j) Check that the conductors are securely fastened to the connector contacts by gently pulling the wires.

k) Slide the connector shell over the connector back end and thread on in accordance with the connector documentation (see Figure I.15).

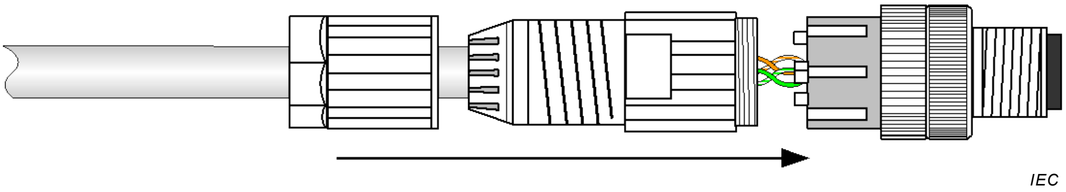


Figure I.15 – Assembling the body of the connector

l) Slide the wire gland over the connector shell and tighten using hand tools (see Figure I.16). Care should be taken not to over tighten the wire gland causing damage to the connector.

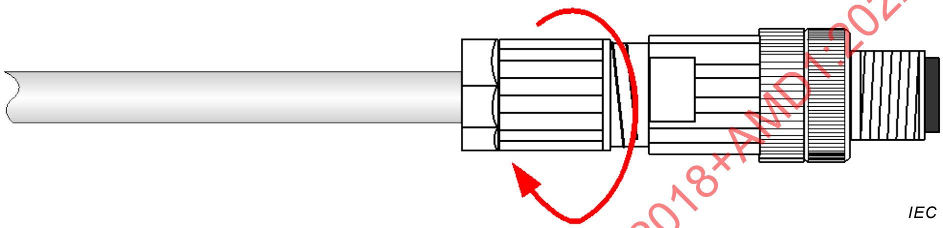


Figure I.16 – Final assembling

m) Test the cable when assembly is complete.

I.5 Guidance for terminating optical fibre cable ends

A number of optical fibre connectors exist for the several optical fibre cables. The ones to be used, out of those listed in Table 9, are listed in the CP installation profiles.

Optical fibres are thin glass or plastic filaments used for the transmission of information via light signals. For optical fibres, unlike copper wires, a mechanical connection is not sufficient. The light should come out of the fibre with minimal loss of signal and the optical fibre should be well aligned to the optical receiver to which the optical fibre cable is connected.

There are several methods for terminating optical fibre cable ends for both connectors attached with epoxy or without. The detailed description of each method depends on the particular characteristics of each connector and the connection method proposed by the manufacturer of the connectors.

To know the specific method to use for each connector type, use the relevant documentation provided by the manufacturer.

Particular attention should be paid to the final polishing of the connector and to the removal from the connector of any debris.

Then a test of the connection is indispensable to guarantee the required performance of the connection. The tool to use is an optical fibre microscope that allows one to see any cracks or imperfections. If cracks or imperfections are in the cladding, this is not a problem because the cladding does not carry a signal. If cracks or imperfections are in the core, it is a problem that should be solved by cutting the connector off and terminating the cable again, unless a repolishing of the fibre does not solve the problem.

Annex J
(informative)

Recommendations for bulkhead connection performance and channel performance with more than 4 connections in ~~the~~ a 4-pair channel

J.1 General

The following recommendation should be considered when using bulkhead connections with back-to-back connectors and when more than 4 connections are needed in a 4-pair channel.

J.2 Recommendations

The number of connections to be counted for one bulkhead connection depends on the electrical performance of the back-to-back connectors and the distance between the two connectors. If the distance between the two connectors is less than 10 cm, one connection should be counted. If the distance between the two connectors is >10 cm, two connections are counted.

Current studies show the following.

a) A plug-to-plug connection including a bulkhead connection can be considered as a single mated category 5 connection as defined in ISO/IEC 11801 1:2017, provided that each plug/jack interface exceeds the return loss given by formula (J.1) in both directions and each plug/jack interface meets minimum category 6 PSNEXT and PSFEXT performance.

$$RL\ (f) > 66 - 20\ \log(f) \qquad \text{(J.1)}$$

where

RL is the return loss (dB);

f is the frequency (MHz), with $f \leq 250$.

b) A channel topology can include up to 4 mated connections, where each mated connection meets minimum category 5 (ISO/IEC 11801 1:2017) performance.

c) A Class D channel topology can include up to 6-mated connections, where each mated connection meets a minimum category 6 performance.

d) Maximum distance between jack and jack of the bulkhead connection is 10 cm. If the distance is greater than 10 cm, each plug/jack interface is considered as a separate mated connection.

Channels with more than 4 connections should use higher performance connections in order to meet the requirements of the desired category. In order to maintain category 5 performance in the channel, category 6 connections are used. See Table J.1 for return loss and NEXT transmission requirements for construction of higher count channels.

Table J.1 – Transmission requirements for more than 4 connections in a channel

Desired channel class	Number of connections	Required minimum connecting hardware return loss dB	Required minimum connecting hardware NEXT dB	Cable category
D	5 or 6	66(TBD) – 20 log (f)	94(TBD) – 20 log (f)	CAT 5
E	5 or 6	70(TBD) – 20 log (f)	100(TBD) – 20 log (f)	CAT 6
NOTE Class E channel requiring five or six connections can be limited by the connector return loss and NEXT performance.				

Annex K
(informative)

Fieldbus data transfer testing

K.1 Background

Control systems for industrial automation require communication channels that provide 'deterministic' and 'repeatable' data transfer. These requirements implicitly set constraints on allowable errors due to cabling and interference.

Network total availability or up-time and the incidence of burst errors are also critical to many control applications.

K.2 Allowable error rates for control systems

K.2.1 Bit errors

Normal bit error events result in loss or rejection of the message frame containing the error. In most cases, the loss is followed by a recovery activity to resend the message frame at a later time.

This has the following effects on communication traffic:

- Control information in the affected message frame is either lost completely or not provided to a target receiver in a timely fashion.
- Channel response time is extended when resources are diverted for recovery events.
- Channel total transfer capacity is reduced.

These consequences are not acceptable to many control applications, which require predictable response times for control and deterministic worst case delivery times for critical alarm and control events.

To ensure acceptable communication channel performance, for a fieldbus application, the maximum allowable ratio of faulty data bits as a proportion of the total should be

- 1 in 10^6 for a fieldbus using a nominal data rate of 100 kbit/s;
- 1 in 10^{12} for a fieldbus using a nominal data rate of 100 Mbit/s.

K.2.2 Burst errors

Small numbers of random communication errors will always exist in a real communication channel. So control systems are normally designed to tolerate a few events when one data sample is lost in communication or fails to arrive on schedule.

Communication losses or delays affecting a sequence of two of more measurement samples for a control loop are generally not acceptable as they can de-stabilise the loop.

As a general rule, the longest burst error affecting communication of multiple samples should be shorter than the sample interval of the fastest control loop.

Typical values for fast control loop sampling intervals are the following:

- 100 ms is a fast sampling interval for process control;
- 10 ms is a fast sampling interval for factory automation;

- 1 ms and below are sampling intervals used by some robotic and motor speed control applications.

Based on these values, for a factory application, a burst error lasting 1 ms could cause the loss of 100 successive messages representing one sample for each of 100 control loops. This is normally not an unsafe situation, as each loop should tolerate loss of one sample.

However, a burst error lasting 20 ms would cause the loss of two successive samples for each loop running at 10 ms sampling interval. In the above example, all 100 loops would be de-stabilised with a high potential for an unsafe control situation.

For a specific control system application, the longest acceptable burst error event may be calculated from the shortest sampling interval used by the control system.

K.3 Testing channel performance

Installed communication channels should be tested to verify the required channel performance. The test methods to be used and channel performance limits depend on the cable type and the needs of applications to be supported by the cabling system.

Channel performance testing can be considered at the two following levels:

- cabling system level;
- application level.

K.4 Testing cable parameters

K.4.1 General

Cable parameter testing provides measurements of connectivity, resistance, bandwidth, reflections, cross-talk etc. over a frequency range applicable to the cable category/class.

Cable parameter performance measures report the installed characteristics of the cabling plus connecting hardware, including patch cords, cross connect wiring, etc. They relate only to the passive elements comprising the physical layer of the communication system. They do not normally report the presence of electrical or electro-magnetic interference and do not measure statistics related to data transfer errors.

NOTE 1 Validation to meet a set of cable parameters demonstrates only raw bandwidth capability of a channel, it does not measure the presence of interference factors or predict their impact on actual data transfer performance. Compliance with a particular transmission class gives no assurance of channel useful data transfer rate or values for expected bit error rates or burst errors arising from interference when the validated channel is used with a particular communication technology.

NOTE 2 When testing cable parameters in the presence of significant interference, the test equipment can report the interference as part of the test results, or the tester person can infer the presence of interference because tests take an abnormally long time.

K.4.2 Generic ~~cable~~ cabling testing

When generic cabling is installed in industrial premises, it should be tested in accordance with the methods specified in ISO/IEC 14763-2 against requirements of the relevant transmission performance class of ISO/IEC 11801-3.

NOTE The frequency range for Cat 5e/Class D is 1 MHz to 100 MHz, and for Cat 6/Class E is 1 MHz to 250 MHz.

K.4.3 Fieldbus ~~cable~~ cabling testing

Fieldbus cabling should be tested in accordance with methods specified in the relevant CP installation profiles. If the fieldbus system is using any portions of other cabling or generic cabling to control applications, then those portions should be included in the fieldbus application testing.

NOTE A wide variety of frequency ranges is applicable for different fieldbus types and profiles.

K.5 Testing fieldbus data rate performance

K.5.1 General

Fieldbus data rate testing provides statistical reports covering data transfer errors for an installed fieldbus technology profile, using its specific signal modulation and encoding methods.

These tests are normally part of the installed control system equipment. Most fieldbus-based measurement and control systems include management entities to count and report bad communication events. This information should be logged and used for fault finding and to track trends in cabling performance.

Additional tools may be available to send test messages and analyse detected error events to report the incidence of bit errors.

K.5.2 Fieldbus test

Fieldbus users are interested in reports from tests taken over a reasonable period (h/days) for a user specified environment and fieldbus type, to achieve statistical BER or acceptable error rate for the application.

Typical items of interest for fieldbus test reports are the following:

- message error rate for a particular level of fieldbus traffic;
- an analysis of lost message statistics, including burst errors and details for loss events that extend over multiple consecutive messages.

These reports enable users to decide if the expected error patterns can be tolerated by their control application.

K.5.3 Planning for fieldbus data rate testing

Many installations have time and climate related patterns of interference so, when resources allow, measurements of data transfer rate, and error statistics should be carried out over a suitable time period which includes the expected worst case levels of communication disturbance.

Items to consider when planning fieldbus performance testing include:

- design features of the installed fieldbus CP;
- extent or location of network parts to be tested;
- time of day and duration for test(s);
- message size(s) and message pattern(s) to be used.

In the absence of specific test parameters, the following default values are recommended:

- full network test covering all installed channels;
- test duration is 24 h;
- test repeated on 2 successive days;
- test at full system data rate;

- test message size to be the maximum for the fieldbus;
- test message rate to be the maximum for the fieldbus.

K.5.4 Fieldbus data rate test reporting template

Recommendations for test report include:

- details of the specific test plan;
- a time-based graph showing throughput achieved as fraction of possible throughput during the test period;
- a time-based graph showing detected message loss events and numbers of messages lost;
- a graphical report showing the number of multi-message loss events (burst errors) plotted against the duration of each event in appropriate time units.

K.5.5 Values for acceptable fieldbus performance

The values for acceptable performance should be calculated based on the application needs.

Annex L
(informative)

Communication network installation work responsibility

L.1 General

This document specifies requirements for the several phases of a communication network installation lifecycle (for example planning, installation implementation, verification, validation). For each phase, a specific body (person or organisation) is identified as responsible for meeting these requirements.

L.2 Installation work responsibility

One body (person or organisation) should be responsible for each phase of the installation lifecycle as defined in this document.

If part of the work for one defined phase is delegated or sub-contracted, then the body responsible for that phase should remain responsible for the compliance of the items delegated or sub-contracted. As an example, part of the work assigned to the installer could be done by others; in this case, the installer should still be required to assess the compliance of the work done by the others as required by Clause 5.

In addition, a responsible body should be identified for all items that are prerequisites for correct installation of the network (for example building earthing and plant earthing). If these tasks are not part of the network installation work, an identified responsible body is still necessary to provide information and documentation to correctly develop the network installation work.

L.3 Installation work responsibility table

For complex installation work, it is recommended to maintain a responsibility table to clearly state the responsibility for solving requirements defined in each subclause (or group of subclauses) of this document.

Annex M
(informative)

Trade names of communication profiles

Annex D lists CPF names that could be trade names. The trade names of all CPs defined in IEC 61784-1 and IEC 61784-2 are listed in Table M.1.

Table M.1 – Trade names of CPFs and CPs

Family CPF numbers	Technology name
1	FOUNDATION™ fieldbus [7]
2	CIP™[8]
CP 2/1	ControlNet™[~~6~~7]
CP 2/2	EtherNet/IP™[~~6~~7]
CP 2/3	DeviceNet™[~~6~~7]
3	PROFIBUS & PROFINET[9]
4	P-NET®[10]
5	WorldFIP®[11]
6	INTERBUS®[12]
8	CC-Link & CC-Link IE[13]
9	HART[14]

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7 FOUNDATION™ fieldbus is the trade name of the non-profit consortium Fieldbus Foundation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

8 CIP™, ControlNet™, EtherNet/IP™ and DeviceNet™ are trade names of ODVA, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade names. Use of the trade names requires permission of the trade name holder.

9 PROFIBUS and PROFINET are the trade names of the non-profit organization PROFIBUS Nutzerorganisation e.V. (PNO). This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade names holder or any of its products. Compliance does not require use of the registered trade name. Use of the trade names requires permission of the trade name holder.

10 P-NET is the trade name of International P-NET User Organisation ApS (IPUO). This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

11 WorldFIP is the trade name of the WorldFIP organization. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

12 INTERBUS is the trade name of Phoenix Contact GmbH & Co. KG., control of trade name use is given to the non-profit organisation INTERBUS Club. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

13 CC-Link, CC-Link/LT and CC-Link IE are trade names of Mitsubishi Electric Co., control of trade name use is given to CC-Link Partner Association. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

14 HART is a trade name of the HART Communications Foundation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

Family CPF numbers	Technology name
10	Vnet/IP[15]
11	TCnet[16]
12	EtherCAT™[17]
13	Ethernet POWERLINK[18]
14	EPA[19]
15	MODBUS®-RTPS[20]
16	SERCOS[21]
17	RAPIEnet[22]
18	SafetyNET p[23]
19	MECHATROLINK [24]
CP 20/1	ADS-net/μΣNETWORK-1000[25]

15 Vnet/IP is a trade name of Yokogawa Electric Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

16 In Japan, TCnet is a trade name of TOSHIBA Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

17 EtherCAT™ and EtherCAT-over-Safety™ are trade names of Beckhoff, Verl. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade names. Use of the trade names requires permission of the trade name holder.

18 Ethernet POWERLINK is a trade name of Bernecker&Rainer Industrieelektronik Ges.m.b.H., control of trade name use is given to the non-profit organization EPSG. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

19 EPA™ is a trade name of SUPCON Group Co. Ltd. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

20 Modbus is a trademark of Schneider Automation Inc., registered in the United States of America and other countries. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trademark. Use of the trademark requires permission of the trademark holder.

21 SERCOS is a trade name of SERCOS International e.V. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

22 RAPIEnet is a trade name of LSIS. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name RAPIEnet. Use of the trade name RAPIEnet requires permission of the trade name holder

23 SafetyNET p is a trade name of the Pilz GmbH & Co. KG. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade name holder or any of its products. Compliance does not require use of the trade name SafetyNET p. Use of the trade name SafetyNET p requires permission of the trade name holder.

24 MECHATROLINK is the trade name of YASKAWA ELECTRIC CORPORATION. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade name holder or any of its products. Compliance does not require use of the trade name MECHATROLINK. Use of the trade name MECHATROLINK requires permission of the trade name holder.

25 In Japan, μΣNETWORK-1000 is the trade name of Hitachi. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade name holder or any of its

Family CPF numbers	Technology name
CP 20/2	ADS-net/NX
CP 21/1	FL-net[26]
CP 22/1	AUTBUS®[27]

products. Compliance does not require use of the trade name μΣNETWORK-1000. Use of the trade name μΣNETWORK-1000 requires permission of the trade name holder.

26 FL-net is the trade name of JEMA/FL-net: The Japan Electrical Manufacturers' Association/the Factory Automation Link network. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade name holder or any of its products. Compliance does not require use of the trade name FL-net. Use of the trade name FL-net requires permission of the trade name holder.

27 AUTBUS® is the registered trade name of the Kyland Technology Co., Ltd. This information is given for the convenience of users of this part of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of Kyland Technology Co., Ltd.

Annex N
(informative)

Validation measurements

N.1 General

Annex N describes details of some validation measurements.

N.2 DCR measurements

N.2.1 Purpose of test

The following procedure is applicable for DCR measurements of the installed cabling to validate the following:

- loop resistance;
- DCR of data line;
- DCR of shield;
- absence of shorts between wires;
- absence of shorts between wire and shield.

This procedure can be used for all cable conductor counts.

Performing only sub parts of this procedure may result in an incorrect conclusion.

N.2.2 Assumptions

The length of the installed cable is known.

The proposed method depends on the accuracy and precision of the measurement.

The cable to be measured is at the same temperature as in the datasheet.

N.2.3 Measurements

The measurements are performed in five steps.

- Step 1
  - With the far end open, perform a measurement between all combinations of conductors to verify that the DC resistance is greater than 1 MΩ. If any measurement results in less than 1 MΩ, this indicates a potential problem. Before continuing, the problem should be resolved.
  - Short wire 1 and wire 2 at the far end (see Figure N.1).
  - Measure the loop resistance between wire 1 and wire 2.

Figure N.1 – Loop resistance measurement wire to wire

- Step 2
  – Short wire 1 to the shield at the far end (see Figure N.2).
  – Measure the loop resistance of wire 1 and the shield at the local end.

Figure N.2 – Loop resistance measurement wire 1 to shield

- Step 3
  – Short wire 2 to the shield at the far end (see Figure N.3).
  – Measure the loop resistance of wire 2 and the shield at the local end.

Figure N.3 – Loop resistance measurement wire 2 to shield

- Step 4 (measure for short between wire 1 and wire 2)
  – Short wire 2 to the shield at the far end (see Figure N.4).
  – Measure the loop resistance of wire 1 and the shield at the local end.

Figure N.4 – Resistance measurement for detecting wire shorts

- Step 5
  – No connection between wire 1 and wire 2 at the far end (see Figure N.5).
  – Measure the resistance between wire 1 and wire 2 at the local end.

Figure N.5 – Resistance measurement between wire 1 and wire 2

N.2.4 Calculations

N.2.4.1 Calculated DCR values for wires and shield

Take the typical DCR of a cable from the datasheet provided by the cable manufacturer.

The DCR-calc of each cable installed can be calculated by using this typical value per unit length multiplied by the length of the cable.

$$\text{DCR-calc}_{(\text{wire})} = \text{DCR}_{(\text{wire from datasheet})} \times L$$

$$\text{DCR-calc}_{(\text{shield})} = \text{DCR}_{(\text{shield from datasheet})} \times L$$

where

L is the known length of the installed cable.

NOTE This calculation can be not needed when a cable manufacturer provides other equivalent information, for example a table showing the DCR values depending on the cable length.

N.2.4.2 Derived DCR values for wires and shield

The DCR values for the wire and the shield, as well as the difference of the two DCR values between two wires, can be derived from measurements step 1 to step 3 as follows.

a) $\text{DCR}_{(\text{wire})} = 0{,}5 \times \text{DCR}_{(\text{step1})}$
   1) $\text{DCR}_{(\text{shield\_1})} = \text{DCR}_{(\text{step 2})} - \text{DCR}_{(\text{wire})}$
   2) $\text{DCR}_{(\text{shield\_2})} = \text{DCR}_{(\text{step 3})} - \text{DCR}_{(\text{wire})}$
   3) $\text{DCR}_{(\text{shield})} = 0{,}5 \times (\text{DCR}_{(\text{shield\_1})} + \text{DCR}_{(\text{shield\_2})})$

b) $\text{DC}_{\text{unbal}} = |\text{DCR}_{(\text{step2})} - \text{DCR}_{(\text{step 3})}|$

NOTE This method yields an accuracy of roughly 10 %. Validation of the cable under test is met when the measured and the calculated values are within 10 %.

N.2.5 Measurement results

N.2.5.1 Validation of the cable DCR

Figure N.6 shows the conclusions for the validation of the installed cable DCR against datasheet and the relevant CP installation profile.

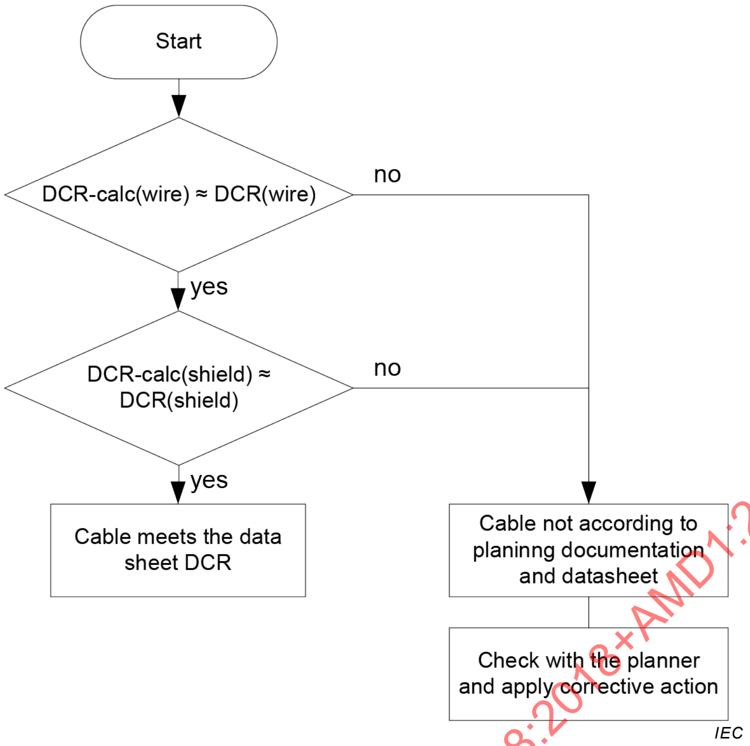


Figure N.6 – Validation of the cable DCR

N.2.5.2 Conclusions for cable open or shorts

Comparing the DCR-calc$_{(wire)}$ value with the DCR$_{(wire)}$ derived from measurements of step 1, step 2 and step 3 allows quality statements of the installed cables.

The DCR$_{(shield)}$ values calculated as in N.2.4.2 a)1) and N.2.4.2 a)2) should be the same, within the measurement accuracy.

Figure N.7 shows the conclusions for cable open or shorts.

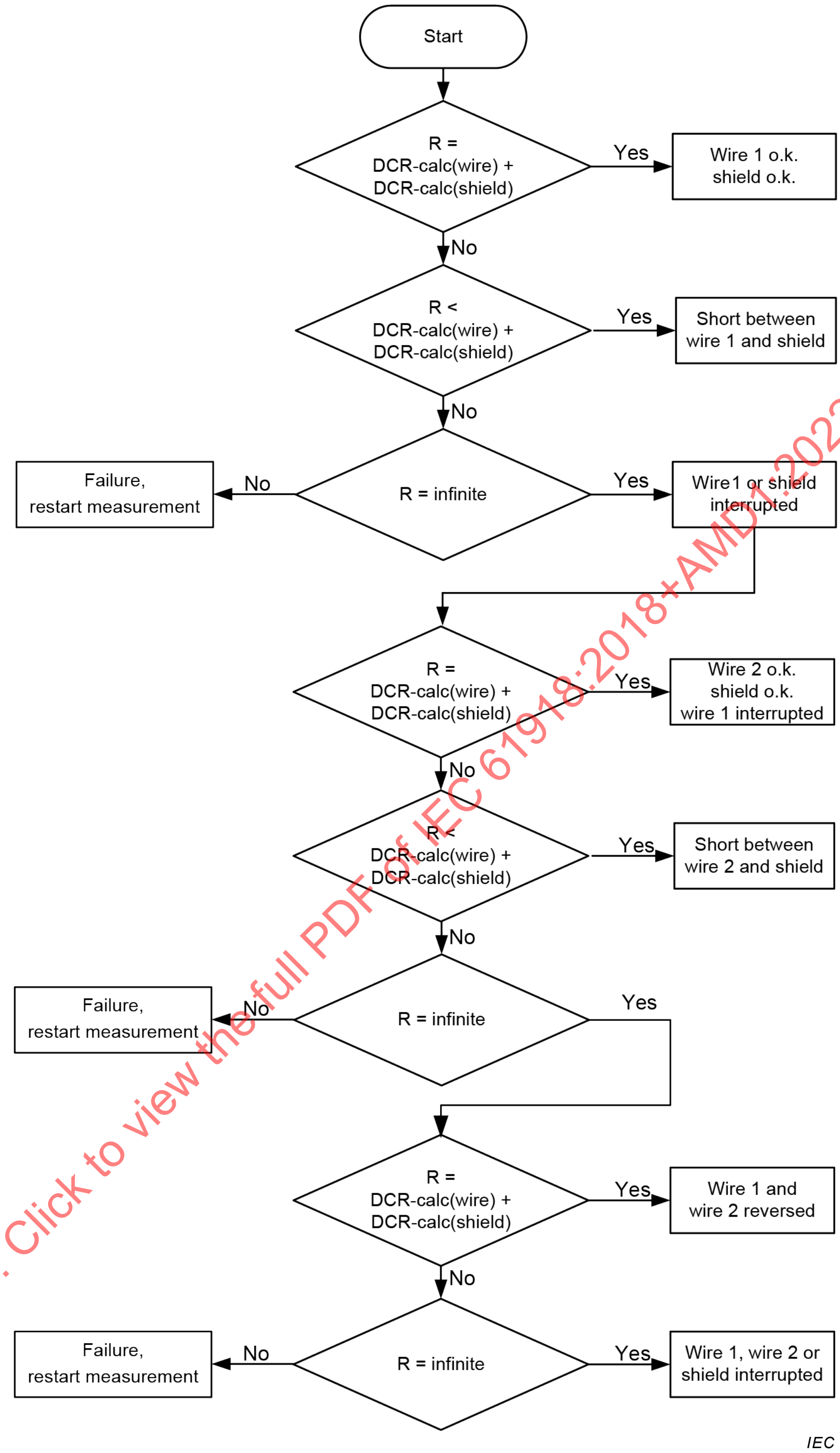
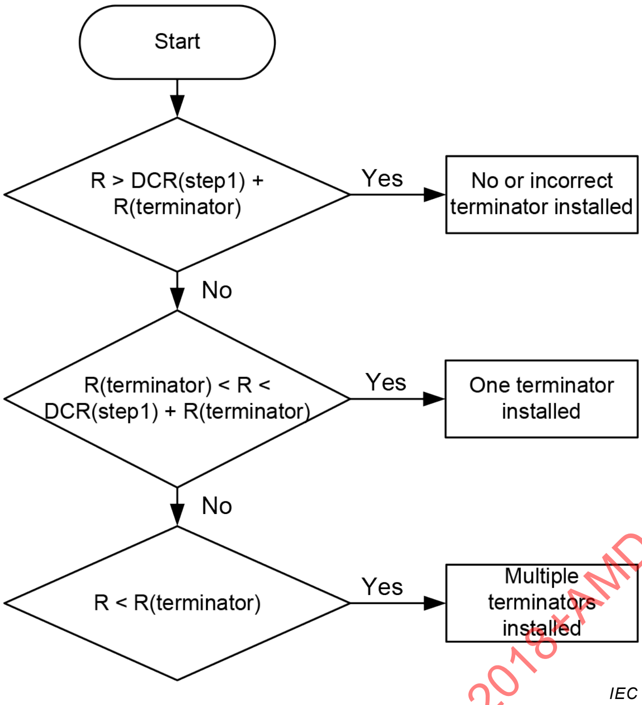


Figure N.7 – Conclusions for cable open or shorts

N.2.5.3 Determination of proper cable terminator value

Figure N.8 shows the conclusions regarding the installation of the correct value and number of terminators according to the relevant CP installation profile.

If the cable loop resistance is significant with respect to the terminator value, further calculations may be necessary to determine if the termination is correct.



Key

R measured value

R(terminator) terminator in accordance with the relevant installation profile

Figure N.8 – Determination of proper cable terminator value

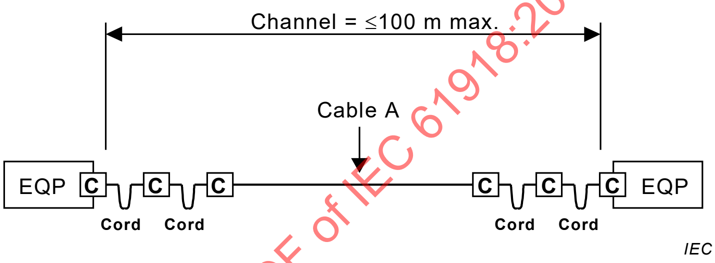
Annex O
(informative)

End-to-end link

O.1 General

End-to-end link (E2E link) is an important concept/approach for the installation and test of communication networks not only in industrial sites but also in other sites (such as building automation). Since most industrial links are constructed in place, the possibility of termination errors may exist. Fail to verify the E2E links may result in loss of production of a plant/factory. These concept/approach and tests only apply for 4-pair cabling.

Network cabling is usually based on the models specified in ISO/IEC 11801-1 and ISO/IEC 11801-3. In these documents, the cabling between two active devices (EQP) is called a channel and consists of different cable types and up to four connections in the channel according to the reference implementation. The plugs on both ends that connect to the jack of the equipment are not part of the channel model as shown in Figure O.1. Typical commercial measurement instruments perform a qualification of the channel according to ISO/IEC 11801 without considering the plugs on both ends of the channel.



Key

C = connection

EQP = equipment

Figure O.1 – Channel according to ISO/IEC 11801

In industrial installations, the usage of pre-assembled cables is often inconvenient and not the practice. The plugs on both ends are usually assembled in the field. Pre-assembled cables are generally subject to a quality-assured manufacturing process. An example of a field-assembled cable may be one contiguous cable spanning distance greater than 20 m and consisting of cable and two plugs. In contrast, the quality of field-assembled cables depends on the skill of the installer. Because the termination in the field may not comply with the required performance (for example, NEXT), a qualification test of these plugs together with the channel is indispensable in eliminating cable terminations problems.

O.2 End-to-end link

End-to-end link is the combination of the channel and the connection at each end of the channel. In this case, the reference level of the measurement includes the plugs and jacks as shown in Figure O.2.

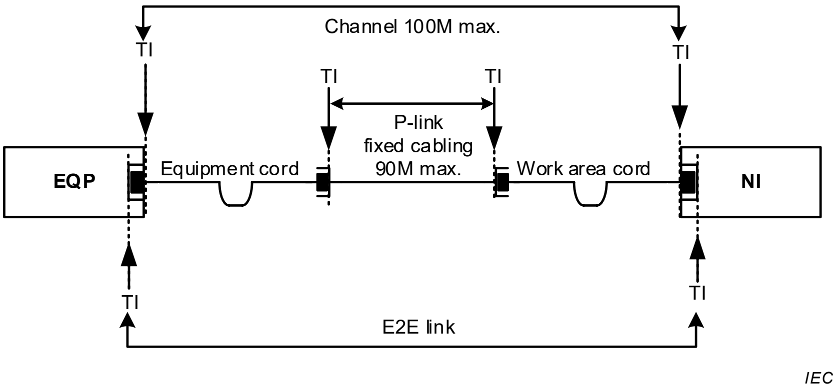


Figure O.2 – End-to-end link

ISO/IEC 11801 counts the number of connections in a channel or permanent link. Since the E2E link adds the connections at the two ends of a link, the number of connections counted increases by two.

In many installations, the design of an E2E link may have some deviations from a channel as it is defined in the reference implementation.

O.3 E2E link normative description

~~ISO/IEC TR 11801-9902 defines several common E2E links and their limits. The difference of each E2E link is in the number of connections in the link and their associated limit lines.~~

~~Figure O.3 to Figure O.9 describe the various E2E links defined in ISO/IEC TR 11801-9902.~~

Figure O.3, Figure O.4, Figure O.5, Figure O.6, Figure O.7, Figure O.8 and Figure O.9 describe several common E2E links. The difference amongst the E2E links is the number of connections in the link.

In these figures, the following keys are used in accordance with ~~ISO/IEC TR 11801-9902~~ ISO/IEC 11801-3/AMD1:

L = channel

TI = test interface

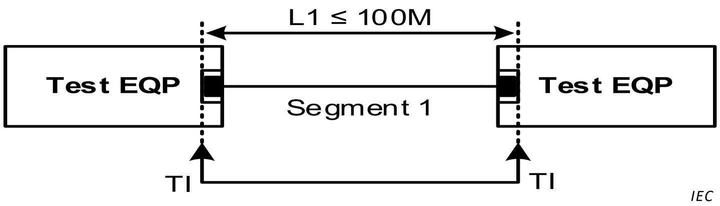


Figure O.3 – One segment, two Connection E2E link

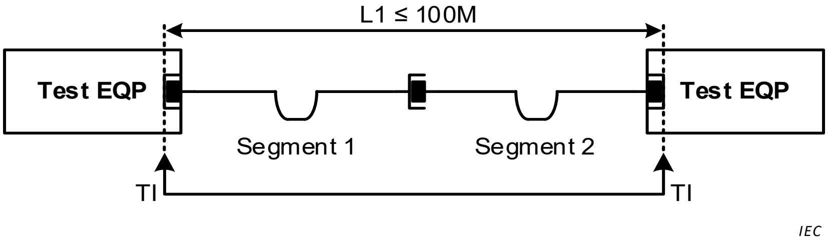


Figure O.4 – Two Segment, three Connection E2E link

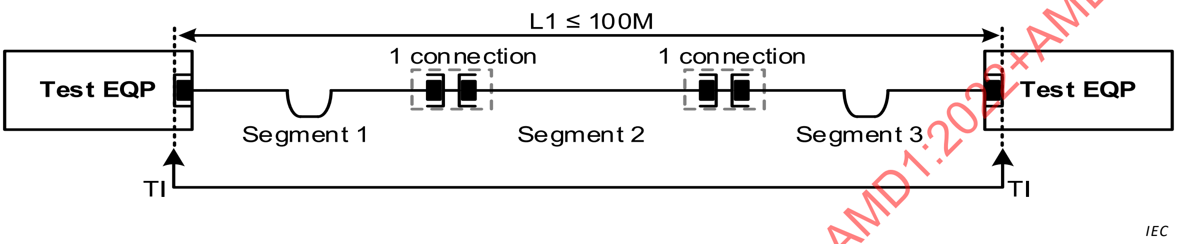


Figure O.5 – Three Segment, one Connection bulkheads, four Connection E2E link

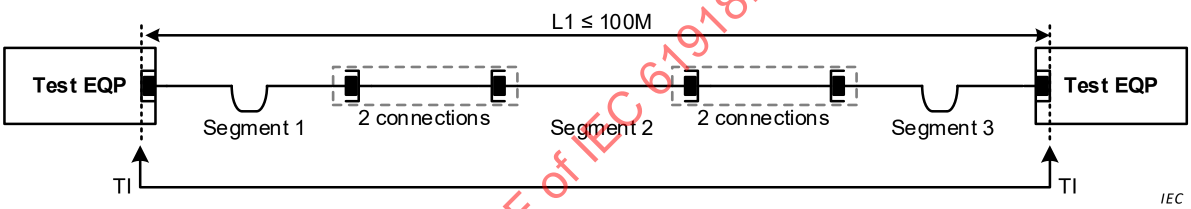


Figure O.6 – Three Segment, two Connection, six Connection E2E link

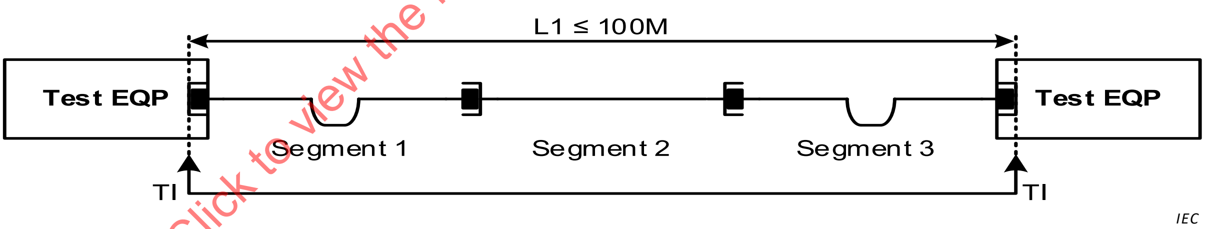


Figure O.7 – Three Segment, four Connection E2E link

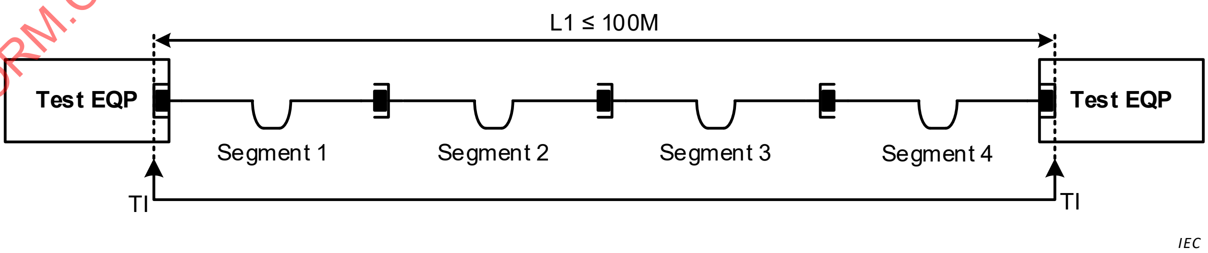


Figure O.8 – Four Segment, five Connection E2E link

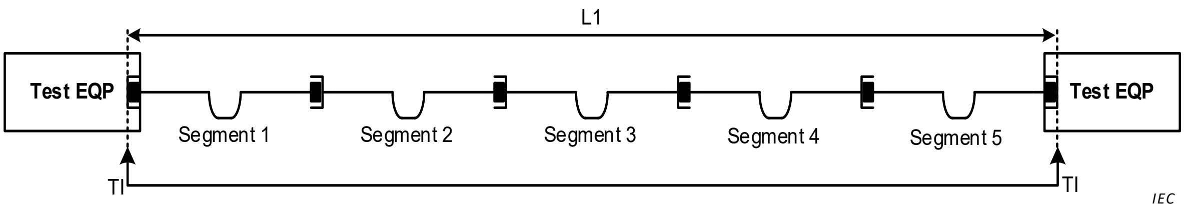


Figure O.9 – Five Segment, six Connection E2E link

~~ISO/IEC TR 11801-9902~~ ISO/IEC 11801-3/AMD1 provides limit line equations for ~~each E2E link above~~ the worst case six connections E2E link and proposes to use these equations to validate any E2E link to simplify the procedure. The equations provide limits for the following Class D and Class E E2E Link parameters;

- IL – Insertion Loss
- RL – Return Loss
- NEXT – Near End Cross Talk
- PSNEXT – Power Sum Near End Cross Talk
- ACRF – Attenuation Cross Talk Ratio Far End
- PSACRF – Power Sum Attenuation Cross Talk Ratio Far End

O.4 E2E link measurement

The measurement of E2E links of two and four pair balanced cabling up to 250 MHz is carried out according to ISO/IEC 14763-4.

The limits of performance are specified in ~~ISO/IEC TR 11801-9902~~ ISO/IEC 11801-3/AMD1 and qualified according to ISO/IEC11801-1 and IEC 61935-2.

The supported configurations are outlined in ~~ISO/IEC TR 11801-9902~~ ISO/IEC 11801-3/AMD1.

The modelling of E2E links assumed the performance of 8 way modular (RJ45) connections. The models are true if the connectors defined in IEC 61918 have equal or better performance and delays. E2E link testers with the appropriate test heads are also required to support testing of non 8 way modular links.

The test head performance is defined in ~~ISO/IEC TR 11801-9902~~ ISO/IEC 11801-3:2017/AMD1:2021.

Annex P
(normative)

Temperature rise of cabling with remote powering

P.1 General

When using Power over Ethernet (PoE) in the industrial environment, the planner shall assure that cable temperature does not exceed the allowable operating temperature. The planner shall consider the additional heat rise that may occur in closed spaces where cabling may be installed. The equation (P.1) can be used to determine the effects of heat on the cabling.

P.2 Scope

This Annex P provides the planner with the way to verify that the de-rating of temperature caused by bundling and or cable routing does not result in a cable temperature that exceeds the allowable operating temperature.

P.3 Temperature de-rating calculation

The temperature de-rating ΔT, expressed in °C, shall be calculated by using the following formula (P.1) that is as defined in Clause B.6 of ISO/IEC TS 29125:2017, Annex B.

$$\Delta T = C \times i_c^2 \times R \quad \text{(P.1)}$$

where

$$C = \frac{pu \times nc \times \sqrt{N}}{(5 \times d)} + \frac{pth \times nc \times N}{12{,}6}$$

and all the parameters are as in Table P.1.

Table P.1 – Parameters used to calculate the temperature derating

Parameters	Description	Value
pu	Constant relating to installation in ventilated conditions for all cable constructions	0,15
	Constant relating to installation in conduits for F/UTP cable constructions and for conduits that have been filled to at least 40 % capacity as defined in EN 50174-2	0,19
	Constant relating to installation in insulated conditions for U/UTP and F/UTP cable constructions	0,70
	Constant relating to installation in insulated conditions for S/FTP cable constructions	0,87
ρth	Constant relating to U/UTP cable constructions	5
	Constant relating to F/UTP cable constructions	3
	Constant relating to S/FTP and SF/UTP cable constructions	2,75
nc	Number of conductors per cable carrying remote power	<number>
N	Number of cables carrying remote power	<number>
d	Cable diameter (m)	<value>
R	Average DC resistance per unit length of conductors carrying remote powering current (Ω/m)	<value>
i_c	The current per conductor (A) = 0,5 × the current delivered by the pair carrying remote power	<value>

Annex Q
(normative)

Additional requirements for the installation of Ethernet-based balanced 1-pair networks in industrial premises

Q.1 Overview

This Annex Q describes the specifications for the installation in the critical environment of industrial premises of networks that use balanced 1-pair cabling in connection with Ethernet specified in 1000BASE-T1 type A, which allows bidirectional signal transmission at 1 000 Mbit/s up to 15 m, 1000BASE-T1 type B for 1 000 Mbit/s up to 40 m, 100BASE-T1 for 100 Mbit/s up to 15 m, 10BASE-T1S for 10 Mbit/s up to 15 m, 10BASE-T1L for 10 Mbit/s up to 1 000 m.

These Ethernet based balanced 1-pair networks use the industrial versions of 1 000 Mbit/s, 100 Mbit/s and 10 Mbit/s specifications given in ISO/IEC/IEEE 8802-3:2022.

The selection of the specifications of this Annex Q, which applies for a given technology, is described in the related profile of the IEC 61784-5 series.

Q.2 Installation planning

Q.2.1 General

Ethernet based balanced 1-pair network provides communication between two devices with 1-pair cable arranged with up to 10 connections, as shown in Figure Q.1.

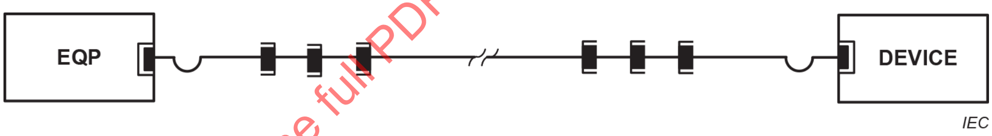


Figure Q.1 – Balanced 1-pair network

For balanced 1-pair network the planning specifications listed in Q.2.2 apply in addition to the specifications given in Clause 4.

Q.2.2 Basic balanced 1-pair network characteristics

Balanced 1-pair networks suitable for industrial applications have the basic characteristics described in Table Q.1.

Table Q.1 – Basic balanced 1-pair network characteristics

Parameter	10BASE-T1 [a]		100BASE-T1 [b]	1000BASE-T1 [b]	
	-T1S	-T1L		type A	type B [d]
Data rate	10 Mbit/s		100 Mbit/s	1 Gbit/s	
Max length (m)	15	1 000	15	15	40
Number of connections or terminals	4	10	4	4	
Wire size (AWG) [c]	26 to 14		26 to 22	26 to 22 UTP	26 to 22

[a] Based on IEEE Std 802.3cg.

[b] Based on ISO/IEC/IEEE 8802-3:2021.

[c] Length limits may apply for 10BASE-T1L. Corresponding nominal cross-sectional areas (mm^2) are shown in Table F.1.

[d] Type B can be also used as a link partner to type A installations.

Q.2.3 Balanced 1-pair cables

Generic specifications regarding balanced 1-pair cables described in IEC 61156-1, IEC 61156-11, IEC 61156-12 and IEC 61156-13 apply. Additional specifications regarding a particular MICE environment apply. For determining appropriate cable type and compatibility with the specified MICE environment, the planner shall also consult the manufacturer.

Additional specifications are described in ISO/IEC 11801-3:2017/AMD1:2021.

Segregation shall be as specified in IEC 61918:2018, Annex B.

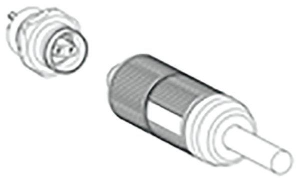
If 4-pair cables are used, unused pairs of the unshielded cables (SF-UTP and F-UTP) shall be terminated. This requirement does not apply to cable constructions that use individual shielded pairs.

Q.2.4 Balanced 1-pair connecting hardware

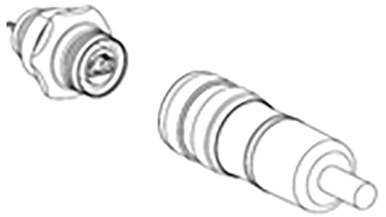
The mechanical and physical requirements of the balanced 1-pair connecting hardware for MICE2 and MICE3 specified in IEC 63171-6 should be used for industrial premises' applications.

The same connecting hardware could be used for MICE1, with the advantages for both the installer and the user, which derives from managing just one type.

Figure Q.2 shows two types of IEC 63171-6 connector. M8 type is recommended for smaller gauge cables up to 22 AWG and for less space at the installation site. M12 type is recommended for bigger gauge cables, e.g. 18 AWG.



M8 screw locking

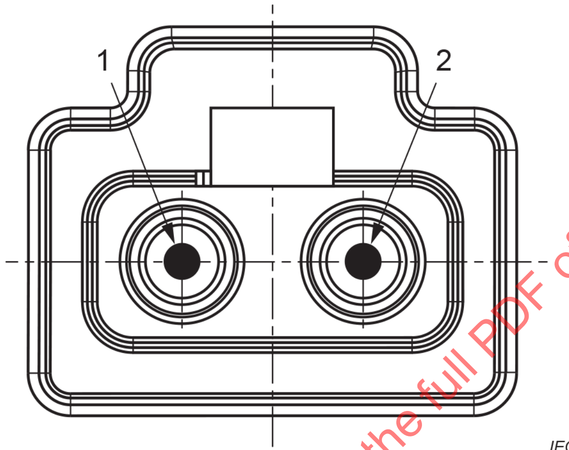


M12 screw locking or push-pull locking

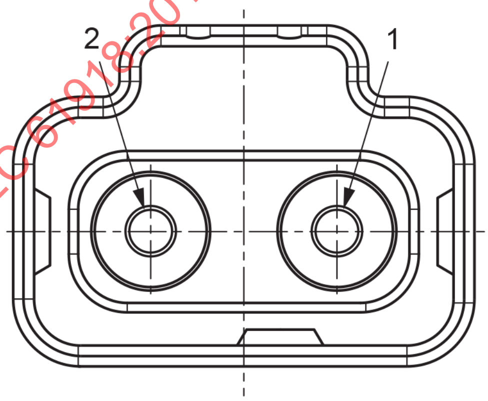
Figure Q.2 – IP65/IP67 IEC 63171-6 connectors

Additional specifications are described in ISO/IEC 11801-3:2017/AMD1:2021.

Figure Q.3 shows the view of the mating parts of the IEC 63171-6 connectors, the pin numbering and the section of the shield embedded in the connector seen just around the two pins, which allows the cable shield connection.



Male contacts



Female contacts

Figure Q.3 – Mating parts of the IEC 63171-6 connectors

Table Q.2 shows colour code and cord set assignments that shall be used in new installations. Colour codes used in refurbished installations may be different and defined in the installation profiles by using the Table Q.2 as a template.

Table Q.2 – IEC 63171-6 colour code and signal assignment

Pair	Pin	Colour	Signal
1	1	BU	BI_DA +
	2	WH/BU	BI_DA -

Additional connectors and other connecting hardware may be used provided that they guarantee the needed performances. If the needed performances are not specified, the planner shall consult the performances described in IEC 63171-6.

Q.2.5 Balanced 1-pair cabling channels

Q.2.5.1 Balanced 1-pair cabling channels specification

Balanced 1-pair cabling channel models are as specified in ISO/IEC 11801-3:2017/AMD1:2021, Annex E, and represented here in Figure Q.4 and Figure Q.5 as adapted for an automation network.

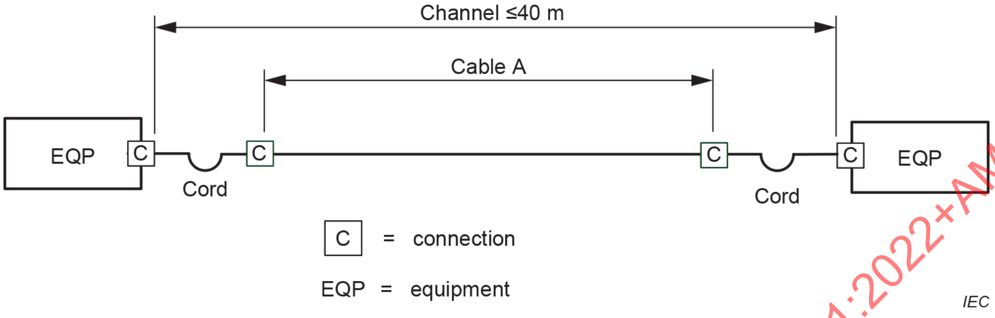


Figure Q.4 – Balanced 1-pair channel model with 40 m max length

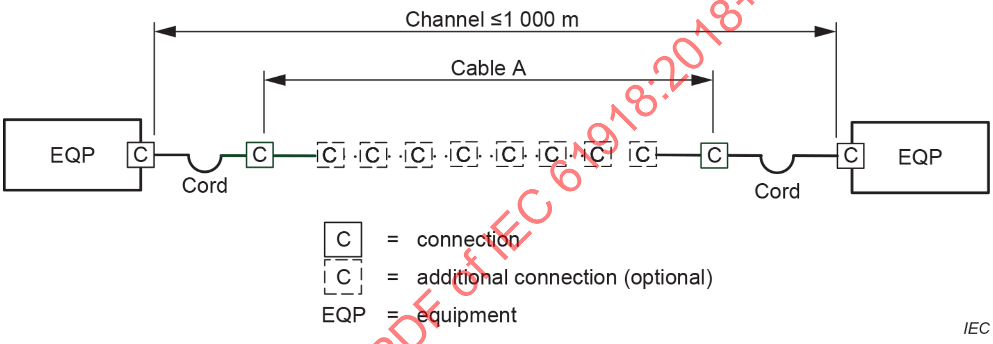


Figure Q.5 – Balanced 1-pair channel model with 1 000 m max length

NOTE Reference implementation formulas of balanced 1-pair cabling are for future study.

Basic requirement for EMI immunity of cabling channels up to E3 is CA ≥ 60 dB for shielded cabling.

It is possible to assess coupling attenuation by laboratory measurements of representative samples of channels assembled using their component and connector practices.

Support for unshielded channels is dependent on environmental conditions and device construction. For more information regarding applicability of unshielded cabling, see Q.2.5.2.

Q.2.5.2 Communication devices

Q.2.5.2.1 General

The specification of the required balanced 1-pair network shall be completed with the selection of proper communication devices. In fact, a proper EMI immunity of balanced 1-pair networks also depends on the performance of the communication devices as is described in Clause B.6.

Q.2.5.2.2 Device selection

The planner shall select communication devices by taking into account the information given in Clause B.6, and particularly the following facts.

- With shielded cabling having CA ≥ 60 dB, all types of devices described in Clause B.6 are suitable for the E3 environment.
- Only unshielded cabling with TCL and ELTCL = 80 − 20log(f), 46 dB maximum may be used in combination with type 2 devices in environment up to E3. The use of unshielded cabling in combination with type 1 devices is not recommended, as is clarified in B.6.2.

For determining appropriate device type and compatibility with the electromagnetic environment, the planner shall also consult the manufacturer.

For industrial premises with several areas characterised by different levels of EMI, the planner should analyse the advantage of using only type 3 devices for all the applications, considering the positive impact on the maintenance of the installation.

Q.2.6 Remote powering

Balanced 1-pair technology, if used together with remote powering technology, not only exchanges data with the field device, but also brings the needed power to the device on the same twisted pair. In this case, the noise introduced by the remote powering can result in a saturation of the communication interface. This requires that, in addition to the filter for the signal, the master Communication device shall be also provided with a proper inductive filter in series to the input from the power supply equipment and the slave communication device is provided with an inductive filter in series to the power input to the device, particularly when this is an actuator. Figure Q.6 shows an example.

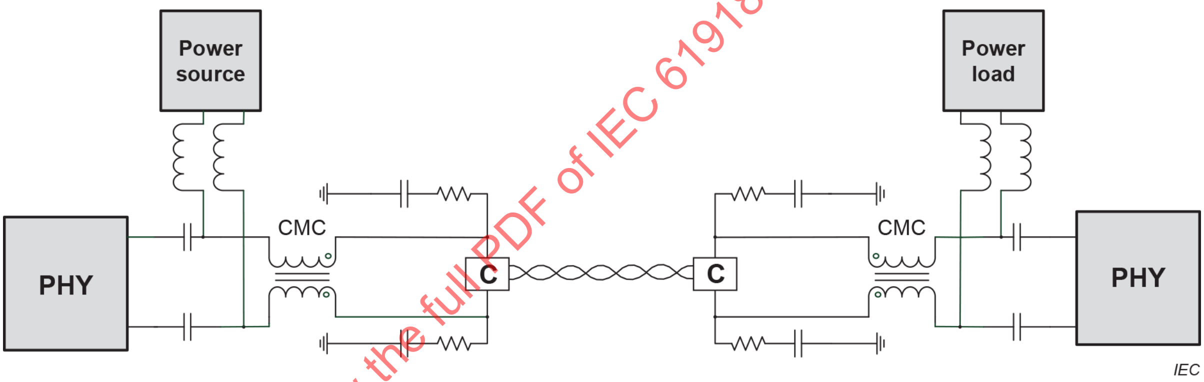


Figure Q.6 – Additional mitigation for remote powering over balanced 1-pair network

In automation applications, typical voltage levels are:

a) 24 V_{DC} nominal,

b) 48 V_{DC} nominal,

c) power provided by data application.

The planner should take care to apply proper separation between areas with different power circuits to prevent wrong application of power.

The planner shall select the proper wiring cross-sectional areas on the basis of the maximum value of the power to transmit.

The maximum current-carrying capacity is installation dependent and therefore not specified but may be indicated in the relevant detail specification. Further guidance with respect to current carrying capacity is provided by ISO/IEC TS 29125.

Q.2.7 Reuse of legacy cabling

The planner shall require that already installed cables may only be used after a field measurement has ensured that the resulting transmission performance satisfies the balanced 1-pair cabling performance requirements in Q.2.5.

Q.3 Installation implementation

Q.3.1 General

For the balanced 1-pair cabling, the following installation implementation specifications apply in addition to the specifications already given in Clause 4.

Q.3.2 Additional installation implementation

When balanced 1-pair technology is used together with remote powering technology, the requirements described in Q.2.6 shall be applied.

Q.4 Installation verification and installation acceptance test

Q.4.1 General

For the balanced 1-pair cabling, the verification and acceptance test requirements as specified in this Clause Q.4 apply in addition to the specifications already given in Clause 6.

Q.4.2 Additional installation verification and acceptance test

The quality of field-assembled cables depends on the skill of the installer. Because the termination in the field might not comply with the required performance, a qualification test of these plugs together with the channel shall be done.

The limits of performance are specified in ISO/IEC 11801-3 and qualified according to ISO/IEC 11801-1.

Figure Q.7 shows the pin/pair assignment for balanced 1-pair cabling. Detection of shorts and reversed pairs is particularly important when remote powering is used.

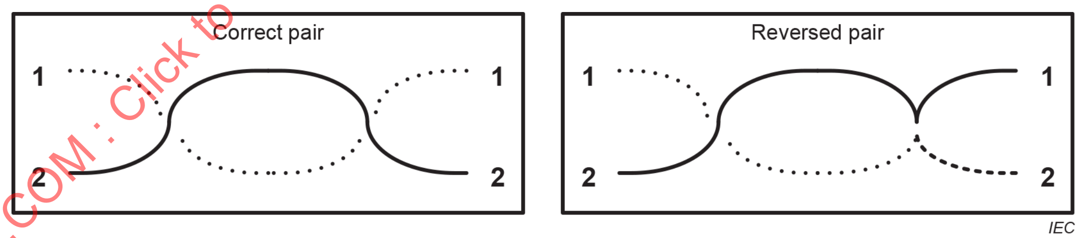


Figure Q.7 – Balanced 1-pair wire mapping

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[3] IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices* (available at <http://www.electropedia.org/)

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[31] ISO/IEC 9314-4, *Information technology – Fibre Distributed Data Interface (FDDI) – Part 4: Single Mode Fibre Physical Layer Medium Dependent (SMF-PMD)*

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INDUSTRIAL COMMUNICATION NETWORKS –

Installation of communication networks in industrial premises

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This consolidated version of the official IEC Standard and its amendments has been prepared for user convenience.

IEC 61918 edition 4.2 contains the fourth edition (2018-09) [documents 65C/928/FDIS and 65C/933/RVD], its amendment 1 (2022-03) [documents 65C/1141/FDIS and 65C/1162/RVD] and its amendment 2 (2024-03) [documents 65C/1282/FDIS and 65C/1290/RVD].

This Final version does not show where the technical content is modified by amendments 1 and 2. A separate Redline version with all changes highlighted is available in this publication.

International Standard IEC 61918 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This fourth edition constitutes a technical revision.

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

a) the reference to ISO/IEC 24702 has been replaced with reference to the new ISO/IEC 11801-3; this affects Table 2;
b) some terms and abbreviated terms have been modified in Clause 3;
c) Subclauses 4.1.2, 4.4.2.5, 4.4.3.4.1 and 5.7 have been updated;
d) Figure 2 and Figure 3 have been updated; Figure 13, Figure 16, Figure 30 and Figure 49 have been added;
e) Table 7 has been updated;
f) Annex D and Annex M have been extended to cover additional communication profile families; Annex H has been extended to cover the M12-8 X-coding connector use;
g) Annex O has been modified by including references to the new edition of the ISO/IEC 11801 series, ISO/IEC TR 11801-9902 and ISO/IEC 14763-4;
h) Annex P has been added.

This standard is to be used in conjunction with the IEC 61784-5 series with regard to the installation of communication profiles (CPs).

Those standards of the IEC 61784-5 series which are still specified for use in conjunction with IEC 61918:2013 can also be used in conjunction with this edition, provided that the user takes into account the fact that the reference to ISO/IEC 24702 has been replaced with a reference to ISO/IEC 11801-3:2017.

NOTE This solution applies for the installation profiles that are affected only by this modified reference.

This standard is referenced by ISO/IEC 14763-2, which covers installation of generic cabling outside the automation islands in industrial premises.

This standard was developed in cooperation with ISO/IEC JTC1/SC25 which is responsible for the ISO/IEC 11801 series.

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

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

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Process and factory automation rely increasingly on communication networks and fieldbuses that are inherently designed to cope with the specific environmental conditions of the industrial premises. The networks and fieldbuses provide for an effective integration of applications among the several functional units of the plant/factory. One of the benefits of integrating field-generated data with higher-level management systems is to reduce production costs. At the same time, integrated data helps to maintain or even increase the quantity and quality of production. A correct network installation is an important prerequisite for communications availability, reliability, and performance. This requires proper consideration of safety and security conditions and environmental aspects such as mechanical, liquid, particulate, climatic, chemicals and electromagnetic interference.

The specifications of these communication networks are provided in the following documents.

ISO/IEC 11801-3 specifies design of generic telecommunications infrastructures within industrial premises and provides the foundations for some of the transmission performance specifications of this document. ISO/IEC 11801-3 specifies only the raw bandwidth capability of a channel; it does not specify useful data transfer rate for a specific network using that channel or expected errors after taking account of interference during the communication process, as is needed for industrial automation.

The IEC 61158 fieldbus standard and IEC 62026-3 and their companion standard IEC 61784-1 and IEC 61784-2 jointly specify several Communication Profiles (CPs) suitable for industrial automation. These CPs specify a raw bandwidth capability and in addition, they specify bit modulation and encoding rules for their fieldbus. Some profiles also specify target levels for useful data transfer rate, and maximum values for errors caused by interference during the communication process.

This document provides a common point of reference for the installation of the media of most used industrial communication networks for most industrial sites.

This document provides a consistent set of installation rules for industrial automation islands where control applications reside. In addition, it offers support for the definition and installation of the interfaces between automation island networks and generic cabling.

One of the problems it seeks to solve is the situation created when different parts of a large automation site are provided by suppliers that use non-homogeneous installation guidelines having different structures and contents. This lack of consistency greatly increases the potential for errors and mismatch situations liable to compromise the communication system.

This document was developed by harmonising the approaches of several user groups and industrial consortia.

The document covers the life cycle of an installation in the following clauses (see the map of the document in Figure 1):

- Clause 4: Installation planning;
- Clause 5: Installation implementation;
- Clause 6: Installation verification and acceptance test;
- Clause 7: Installation administration;
- Clause 8: Installation maintenance and installation troubleshooting.

The methods described in these clauses are written in such a way as to provide installation guidance for a wide range of technician skills.

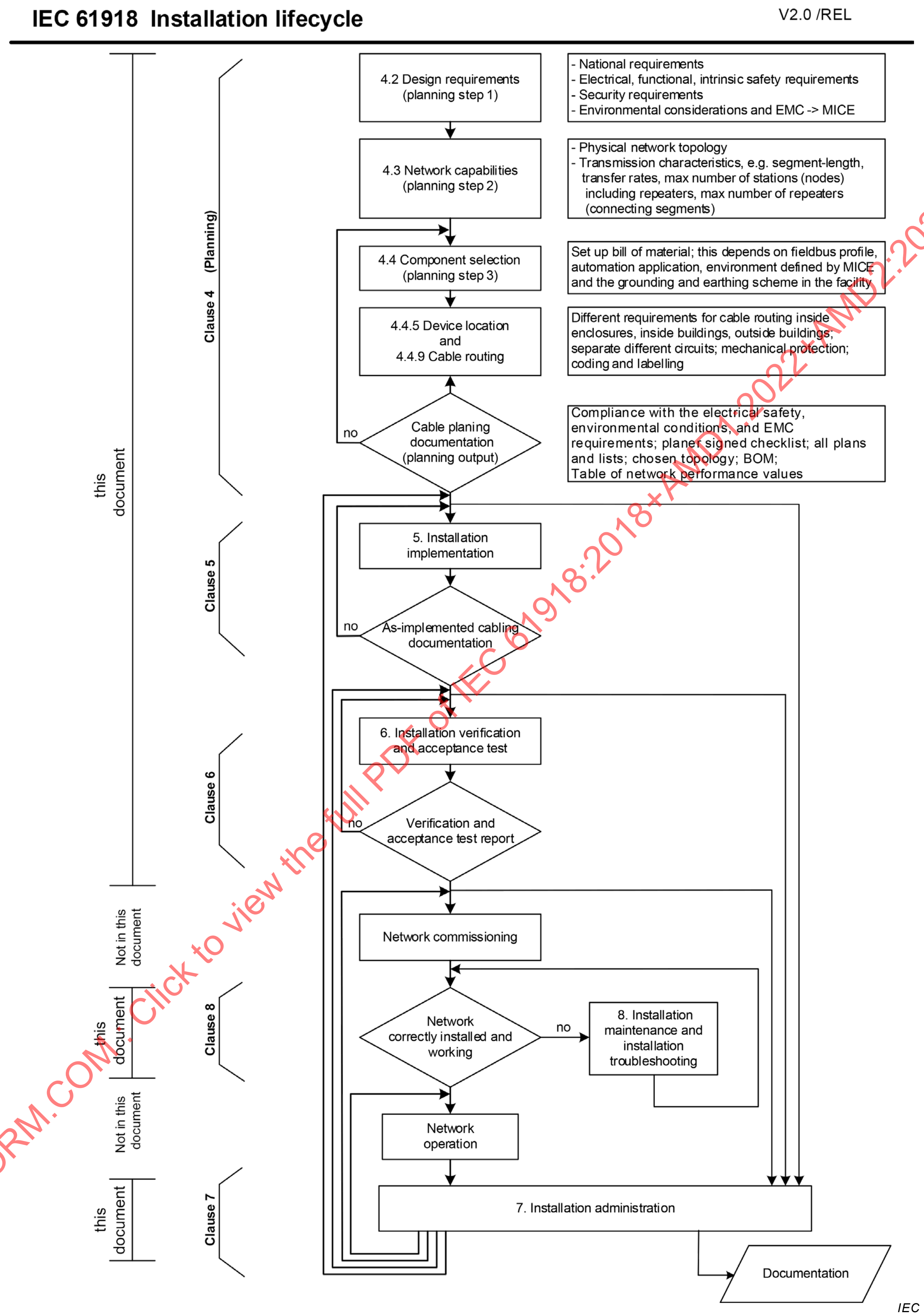


Figure 1 – Industrial network installation life cycle

The installation of a communication system is supported by this document used in conjunction with the relevant installation profile. The installation profile establishes the technology-specific requirements in terms of which requirements apply as they are in this document, or which have been extended, modified, or replaced.

For the fieldbuses that are defined in the IEC 61784 (all parts) as communication profiles (CPs) of the communication profile families (CPF), the installation is specified in the installation profiles that are available in the IEC 61784-5-n documents, where n is the CPF number.
IEC 61158-1 describes the relationship between the fieldbus and the CPs and the relevant installation profiles (see Figure 2).

Those documents of IEC 61784-5 (all parts) that are still specified for use in conjunction with IEC 61918:2013 can also be used in conjunction with this edition 2018, provided that the user takes into account the fact that the reference to ISO/IEC 24702 has been replaced with a reference to ISO/IEC 11801-3:2017.

NOTE This solution applies for the Installation profiles that are affected only by this modified reference

For the installation of generic cabling in industrial premises, IEC 61918 is referenced to by ISO/IEC 14763-2 (see Figure 2).

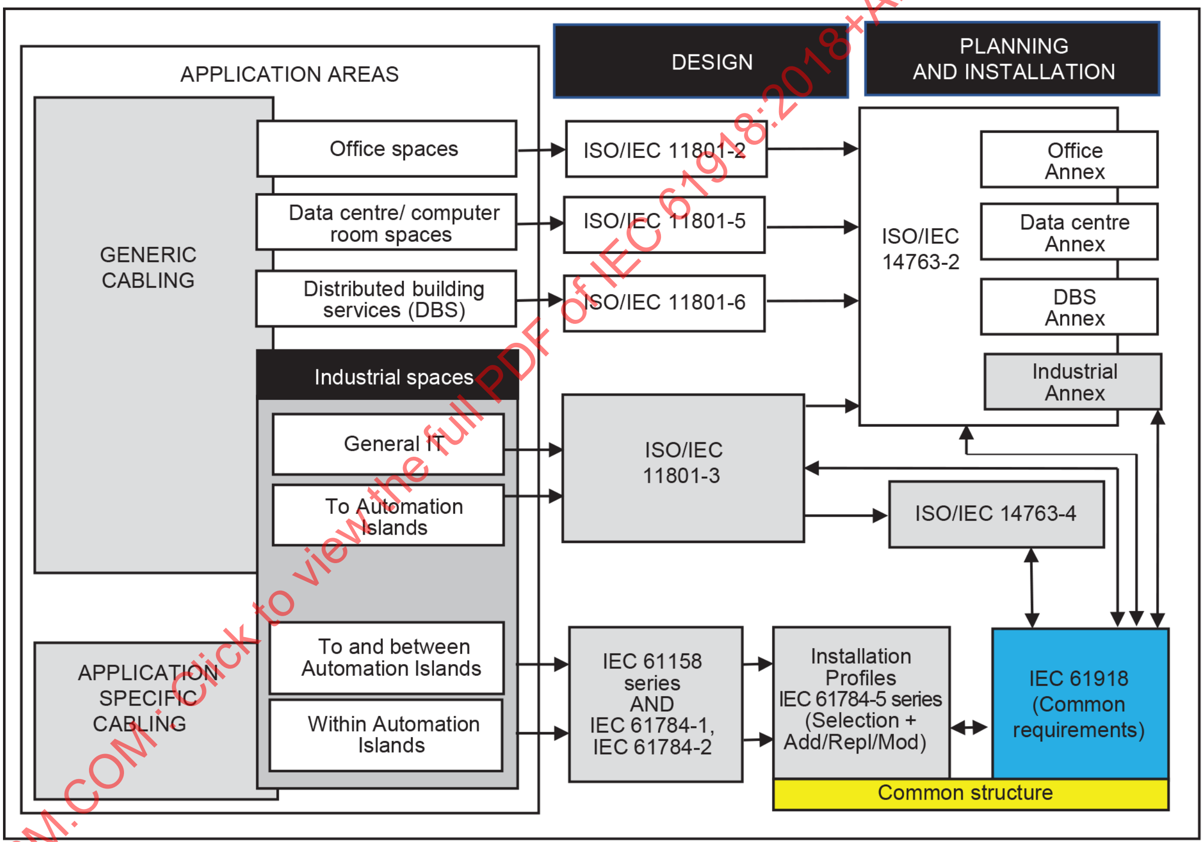


Figure 2 – Standards relationships

One of the advantages of this structure is that the users of a network know which installation requirements are common to most networks and which are specific to a particular network.

Every single plant/factory has its own installation needs in accordance with the specific critical conditions that apply to the specific application. This document and its companion standards described above provide a set of mandatory installation requirements ("shalls") and a number of recommendations ("shoulds"). It is up to the owner of the specific industrial enterprise to explicitly request that the cabling installation be implemented in accordance with these standards and to list all recommendations that shall be considered as mandatory requirements for the specific case.

INTRODUCTION to Amendment 1

This Amendment 1 describes the installation in the critical environment of industrial premises of balanced 1-pair networks that use cabling in connection with Ethernet specified in 1000BASE-T1 type A, which allows bidirectional signal transmission at 1 000 Mbit/s up to 15 m, 1000BASE-T1 type B for 1 000 Mbit/s up to 40 m, 100BASE-T1 for 100 Mbit/s up to 15 m, 10BASE-T1S for 10 Mbit/s up to 15 m, 10BASE-T1L for 10 Mbit/s up to 1 000 m.

These balanced 1-pair networks use the industrial versions of 1 000 Mbit/s and 100 Mbit/s ISO/IEC/IEEE 8802-3:2021, and 10 Mbit/s IEEE Std 802.3cg networks.

INTRODUCTION to Amendment 2

This Amendment 2 describes the result of the maintenance activity of IEC 61918:2018 that takes into account the evolution of the technology, which is being considered during the Installation Profiles revision cycle.

The following technical changes were made in IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024:

a) Subclauses 4.1.2, 4.1.3, 4.2.1.2, 4.2.2, 4.2.3.2, 4.3.2.1, 4.3.2.3, 4.4.1.2.1, 4.4.2.2, 4.4.2.5. 4.4.3.1, 4.4.3.2.1, 4.4.3.4.1, 4.4.7.1.4, 4.4.7.3.1, 5.1.1, 5.7, 6.1, 6.2.8.3, 6.3.2.1.2 and 8.3.3 have been updated;
b) Annex O has been modified by replacing the references to ISO/IEC TR 11801-9902 with references to ISO/IEC 11801-3:2017/AMD1:2021;
c) Table B.3 has been updated;
d) Clause B.6 has been added;
e) Annexes D, I, J, K and M have been updated;
f) Annex Q has been added.

INDUSTRIAL COMMUNICATION NETWORKS –

Installation of communication networks in industrial premises

1 Scope

This document specifies basic requirements for the installation of media for communication networks within and between the automation islands, of industrial sites. This document covers balanced and optical fibre cabling. It also covers the cabling infrastructure for wireless media, but not the wireless media itself. Additional media are covered in IEC 61784-5 (all parts).

This document is a companion standard to the communication networks of the industrial automation islands and especially to the communication networks specified in IEC 61158 (all parts) and IEC 61784 (all parts).

In addition, this document covers the connection between the generic telecommunications cabling specified in ISO/IEC 11801-3 and the specific communication cabling of an automation island, where an automation outlet (AO) replaces the telecommunication outlet (TO) of ISO/IEC 11801-3.

NOTE If the interface used at the AO does not conform to that specified for the TO of ISO/IEC 11801-3, the cabling no longer conforms to ISO/IEC 11801-3 although certain features, including performance, of generic cabling may be retained.

This document provides guidelines that cope with the critical aspects of the industrial automation area (safety, security and environmental aspects such as mechanical, liquid, particulate, climatic, chemicals and electromagnetic interference).

This document deals with the roles of planner, installer, verifier, and acceptance test personnel, administration and maintenance personnel and specifies the relevant responsibilities and/or gives guidance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

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

IEC 60364-4-44, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

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

IEC 60512-29-100, *Connectors for electronic equipment – Tests and measurements – Part 29-100: Signal integrity tests up to 500 MHz on M12 style connectors – Tests 29a to 29g*

IEC 60603-7 (all parts), *Connectors for electronic equipment – Part 7: Detail specification for 8-way, unshielded, free and fixed connectors*

IEC 60757, *Code for designation of colours*

IEC 60793 (all parts), *Optical fibres*

IEC 60793-2-10, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*

IEC 60794 (all parts), *Optical fibre cables*

IEC 60807-2, *Rectangular connectors for frequencies below 3 MHz – Part 2: Detail specification for a range of connectors, with assessed quality, with trapezoidal shaped metal shells and round contacts – Fixed solder contact types*

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

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*

IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

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

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

IEC 61010-2-201, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-201: Particular requirements for control equipment*

IEC 61010-2-203:—[1], *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-203: Particular requirements for industrial communication circuits and communication port interconnection*

IEC 61076-2-101, *Connectors for electronic equipment – Product requirements – Part 2-101: Circular connectors – Detail specification for M12 connectors with screw-locking*

IEC 61076-2-104, *Connectors for electronic equipment – Product requirements – Part 2-104: Circular connectors – Detail specification for circular connectors with M8 screw-locking or snap-locking*

IEC 61076-2-109, *Connectors for electronic equipment – Product requirements – Part 2-109: Circular connectors – Detail specification for connectors with M 12 x 1 screw-locking, for data transmission frequencies up to 500 MHz*

1 Under preparation. Stage at the time of publication: IEC/ACDV 61010-2-203:2021.

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

IEC 61076-3-122, *Connectors for electrical and electronic equipment – Product requirements – Part 3-122: Detail specification for 8-way, shielded, free and fixed connectors for I/O and data transmission with frequencies up to 500 MHz and current-carrying capacity in industrial environments*

IEC 61076-3-124, *Connectors for electrical and electronic equipment – Product requirements – Part 3-124: Rectangular connectors – Detail specification for 10-way, shielded, free and fixed connectors for I/O and data transmission with frequencies up to 500 MHz*

IEC 61076-3-106, *Connectors for electronic equipment – Product requirements – Part 3-106: Rectangular connectors – Detail specification for protective housings for use with 8-way shielded and unshielded connectors for industrial environments incorporating the IEC 60603-7 series interface*

IEC 61076-3-117, *Connectors for electronic equipment – Product requirements – Part 3-117: Rectangular connectors – Detail specification for protective housings for use with 8-way shielded and unshielded connectors for industrial environments incorporating the IEC 60603-7 series interface – Variant 14 related to IEC 61076-3-106 – Push-pull coupling*

IEC 61156 (all parts), *Multicore and symmetrical pair/quad cables for digital communications*

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

IEC 61156-11, *Multicore and symmetrical pair/quad cables for digital communications – Part 11: Symmetrical single pair cables with transmission characteristics up to 600 MHz – Horizontal floor wiring – Sectional specification*

IEC 61156-12, *Multicore and symmetrical pair/quad cables for digital communications – Part 12: Symmetrical single pair cables with transmission characteristics up to 600 MHz – Work area wiring – Sectional specification*

IEC 61156-13:2023, *Multicore and symmetrical pair/quad cables for digital communications – Part 13: Symmetrical single pair cables with transmission characteristics up to 20 MHz – Horizontal floor wiring – Sectional specification*

IEC 61158 (all parts), *Industrial communication networks – Fieldbus specifications*

IEC 61158-2:2023, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

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

IEC 61753 (all parts), *Fibre optic interconnecting devices and passive components performance standard*

IEC 61753-1, *Fibre optic interconnecting devices and passive components performance standard – Part 1: General and guidance for performance standards*

IEC 61753-1-3, *Fibre optic interconnecting devices and passive components – Performance standard – Part 1-3: General and guidance for single-mode fibre optic connector and cable assembly for industrial environment, Category I*

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

IEC 61754-4, *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces – Part 4: Type SC connector family*

IEC 61754-20, *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces – Part 20: Type LC connector family*

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

IEC 61754-24, *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces – Part 24: Type SC-RJ connector family*

IEC 61784 (all parts), *Industrial communication networks – Profiles*

IEC 61784-1-x, *Industrial networks – Profiles – Part 1-x: Fieldbus profiles*

IEC 61784-2-x, *Industrial networks – Profiles – Part 2-x: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3*

IEC 61784-3 (all parts), *Industrial communication networks – Profiles – Part 3: Functional safety fieldbuses – General rules and profile definitions*

IEC 61784-5 (all parts), *Industrial communication networks – Profiles – Part 5: Installation of fieldbuses*

IEC 61935-1:2019, *Specification for the testing of balanced and coaxial information technology cabling – Part 1: Installed balanced cabling as specified in ISO/IEC 11801-1 and related standards*

IEC 61935-1-1:2019, *Specification for the testing of balanced and coaxial information technology cabling – Part 1-1: Additional requirements for the measurement of transverse conversion loss and equal level transverse conversion transfer loss*

IEC 61935-2, *Specification for the testing of balanced and coaxial information technology cabling – Part 2: Cords as specified in ISO/IEC 11801 and related standards*

IEC 62439 (all parts), *Industrial communication networks – High availability automation networks*

IEC 62443 (all parts), *Security for industrial automation and control systems*[2]

IEC 62708, *Documents kinds for electrical and instrumentation projects in the process industry*

IEC 63171-2:2021, *Connectors for electrical and electronic equipment – Part 2: Detail specification for 2-way, shielded or unshielded, free and fixed connectors: mechanical mating information, pin assignment and additional requirements for type 2*

2 Check http://webstore.iec.ch for the published parts. Other parts are under consideration.

IEC 63171-5:2022, *Connectors for electrical and electronic equipment – Part 5: Detail specification for 2-way M8 and M12 circular connectors, shielded or unshielded, free and fixed – Mechanical mating information, pin assignment and additional requirements for Type 5*

IEC 63171-6, *Connectors for electrical and electronic equipment – Part 6: Detail specification for 2-way and 4-way (data/power), shielded, free and fixed connectors for power and data transmission with frequencies up to 600 MHz*

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

ISO/IEC 11801 (all parts), *Information technology – Generic cabling for customer premises*

ISO/IEC 11801-1:2017, *Information technology – Generic cabling for customer premises – Part 1: General requirements*

ISO/IEC 11801-3:2017, *Information technology – Generic cabling for customer premises – Part 3: Industrial premises*
ISO/IEC 11801-3:2017/AMD1:2021

ISO/IEC 14763-2:2019, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

ISO/IEC 14763-3:2014, *Information technology – Implementation and operation of customer premises cabling – Part 3: Testing of optical fibre cabling*
ISO/IEC 14763-3:2014/AMD1:2018

ISO/IEC 14763-4:2021, *Information technology – Implementation and operation of customer premises cabling – Part 4: Measurement of end-to-end (E2E) links, modular plug terminated links (MPTL) and direct attach cabling*

ISO/IEC TS 29125:2017, *Information Technology – Telecommunications cabling requirements for remote powering of terminal equipment*
ISO/IEC TS 29125:2017/AMD1:2020

EN 50174-2, *Information technology – Cabling installation – Part 2: Installation planning and practices inside buildings*

EN 50310, *Application of Equipotential Bonding and Earthing in Buildings with Information Technology Equipment*

IEEE Std 802.3-2022, *Standard for Ethernet,* available at http://www.ieee.org

NOTE 1 The contents of IEEE Std 802.3cg have been integrated in IEEE Std 802.3-2022, Clause 146.

NOTE 2 Physical Layer specifications for 100BASE-T1 and 1000BASE-T1 are provided in IEEE Std 802.3-2022, Clause 96 and Clause 97 respectively.

ANSI/(NFPA) T3.5.29 R1-2007, *Fluid power systems and components – Electrically-controlled industrial valves – Interface dimensions for electrical connectors*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61158 (all parts), IEC 61784 (all parts), ISO/IEC/IEEE 8802-3:2021, ISO/IEC 11801-1, and ISO/IEC 11801-3, some of which have been repeated here for convenience of the user, and the following apply.

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

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

3.1.1
acceptance test
contractual test to prove to the customer that the installed cabling meets certain conditions of its specification

Note 1 to entry The network owner or a third party usually performs this action.

[SOURCE: IEC 60050-151:2001, 151-16-23, modified – "Item" has been changed to "installed cabling" and Note 1 to entry has been added]

3.1.2
active network element
network element containing electrically and/or optically active components that allows extension of the network

Note 1 to entry: Examples of active network elements are repeaters and switches.

3.1.3
active network
network in which data transmission between non-immediately-connected devices is dependent on active elements within those intervening devices that form the connection path

Note 1 to entry: A failure of an active network element can disrupt the network communications.

3.1.4
administration
methodology defining the documentation requirements of a cabling system and its containment, the labelling of functional elements and the process by which moves, additions and changes are recorded

3.1.5
apparatus
one or more pieces of equipment having specific and defined overall functions within industrial premises served by one or more network interfaces

Note 1 to entry: This definition applies only to IT equipment. It does not apply to devices that implement automation functions.

[SOURCE: ISO/IEC 11801-3:2017, 3.1.1, modified – Note 1 to entry has been added]

3.1.6
automation island
AI
premises where combination of all systems that control, monitor, and protect the process of a plant is installed

Note 1 to entry: A plant may contain one or more AIs. Examples of a plant that has more than one AI are: a plant that is divided in various distinct physical (geographical) areas, or a plant that is composed of several distinct processes, or a plant where a large process is divided in various distinct sub-processes.

3.1.7
automation island attachment cabling
AI attachment cabling
cabling used to connect the automation outlet (AO) to the network interface (NI) for the automation island

3.1.8
automation island network
network used for the communication within and among systems of an AI

3.1.9
automation outlet
AO
fixed connecting hardware which provides an interface to the network(s) of an automation island

Note 1 to entry: For generic cabling in accordance with ISO/IEC 11801-3, the AO replaces the TO and is the demarcation point between the generic communications cabling and the automation communication cabling.

Note 2 to entry: Where the interface used at the AO does not conform to that specified for the TO of ISO/IEC 11801-3, the generic cabling no longer conforms to ISO/IEC 11801-3.

3.1.10
balanced cable
cable consisting of one or more metallic symmetrical cable elements (twisted pairs or quads)

Note 1 to entry: There is a great variety of shielded cable and unshielded cable construction and a number of systems to identify these constructions in a shortened form. See ISO/IEC 11801-1:2017, Annex D for acronyms to use.

[SOURCE: ISO/IEC 11801-1:2017, 3.1.12, modified – Note 1 to entry has been added]

3.1.11
bonding
act of connecting together exposed conductive parts and extraneous conductive parts of apparatus, systems, or installations that are at essentially the same potential

Note 1 to entry: For safety purposes, bonding generally involves (but not necessarily) a connection to the immediately adjacent earthing system.

[SOURCE: IEC TR 61000-5-2:1997, 3.1]

3.1.12
bridge
device, operating at the data link layer of the OSI model, used to connect two networks

3.1.13
bulkhead
wall or barrier which maintains the ingress and climatic environmental classifications applicable on either side

[SOURCE: ISO/IEC 11801-3:2017, 3.1.5]

3.1.14
bulkhead connector
connector assembly mounted to a bulkhead which provides electrical or optical signal pass-through while maintaining environmental integrity

3.1.15
bulkhead connection
one (or two) optical or electrical connection(s) within a bulkhead connector assembly

3.1.16
bulkhead cable gland
hardware at an enclosure bulkhead that provides cable passage for power or signals while maintaining environmental integrity

Note 1 to entry: This hardware has no electrical connections.

3.1.17
bus
passive network having a long trunk and a number of spurs where each spur is used to connect a device to the trunk

Note 1 to entry: In a bus, all the communicating devices share a common medium to transfer data.

3.1.18
bus bar
low-impedance conductor to which several electric circuits can be connected at separate points

Note 1 to entry: In many cases, the bus bar consists of a bar.

[SOURCE: IEC 60050-151:2001, 151-12-30]

3.1.19
cable
assembly of one or more conductors and/or optical fibres, with a protective covering and possibly filling, insulating and protective material

[SOURCE: IEC 60050-151:2001, 151-12-38]

3.1.20
cable gland
installation hardware designed to permit the entry of a cable into an enclosure and which provides sealing and retention

[SOURCE: IEC 60670-1:2015, 3.10, modified – Definition has been adapted for all kinds of cables]

3.1.21
cabling
system of communication cables, cords and connecting hardware that can support the connection of automation equipment

[SOURCE: ISO/IEC 11801-1:2017, 3.1.21, modified – A reference to automation equipment has been added]

3.1.22
channel
end-to-end transmission path connecting any two pieces of application specific equipment

Note 1 to entry: Equipment cords are included in the channel, but not the connecting hardware into the application specific equipment.

Note 2 to entry: Channels specified in this document may only comprise passive components.

[SOURCE: ISO/IEC 11801-1:2017, 3.1.26, modified – Note 1 to entry and Note 2 to entry have been added]

3.1.23
condition-based (conditional) maintenance
preventive activity performed on the basis of the documentation of the performance degradation of an item (as results of, for example, auto diagnostic or wear measurement)

Note 1 to entry: It is based on a proper visibility of performance degradation or intermittent failures.

3.1.24
connection (of conductors)
intentional electric contact between conductors

[SOURCE: IEC 60050-151:2001, 151-12-07, modified – Text referring to conductors has been selected]

3.1.25
connection (of optical fibres)
intentional alignment between optical fibres to allow light to pass through

[SOURCE: IEC 60050-151:2001, 151-12-07, modified – Text has been adapted to cover optical fibres.]

3.1.26
connector
<conductors> component providing conductor connection and disconnection

Note 1 to entry: The connector is the mated pair.

Note 2 to entry: A connector has one or more contact members.

[SOURCE: IEC 60050-151:2001, 151-12-19, modified – The definition has been adapted and Note 1 to entry has been added]

3.1.27
connector
<optical fibres> component normally attached to an optical cable or piece of apparatus, for the purpose of providing optical interconnection/disconnection of optical fibres or cables

Note 1 to entry: The connector is the mated pair.

Note 2 to entry: The connector usually consists of two plugs mated together in an adaptor.

3.1.28
cord
cable, cable unit, or cable element, with a minimum of one termination

[SOURCE: ISO/IEC 11801-1:2017, 3.1.36]

3.1.29
corrective maintenance
maintenance carried out after a fault recognition and intended to put an item into a state in which it can perform a required function

[SOURCE: IEC 60050-191:1990[3], 191-07-08]

3.1.30
daisy chain
bus where each passive network interface connects two trunk sections and provides a DC coupling between those sections

Note 1 to entry: One of the sections may be a bus terminator.

Note 2 to entry: With regard to the use of "daisy chain" term for active networks, see the definition given for linear topology.

3.1.31
device
physical entity connected to the fieldbus composed of communication element and possibly other functional elements

[SOURCE: IEC 61158-2:2014, 3.1.13, modified – Some details have been deleted.]

3.1.32
distributor
functional element enabling the termination and connection of cabling subsystems to other cabling subsystems or transmission equipment

[SOURCE: ISO/IEC 11801-1: 2017, 3.1.41]

3.1.33
earth (noun), en GB
ground (noun), en US
conductive mass of the Earth, whose electric potential at any point is conventionally taken as zero

[SOURCE: IEC 61131-2: 2017, 3.1.10]

3.1.34
earth (verb), en GB
ground (verb), en US
make an electric connection between a given point in a system or in an installation or in equipment and a local earth

Note 1 to entry: The connection to local earth may be intentional, or unintentional or accidental.

Note 2 to entry: The connection may be permanent or temporary.

[SOURCE: IEC 60050-195:1998, 195-01-08]

3.1.35
enclosure
housing affording the type and degree of protection suitable for the intended application

[SOURCE: IEC 61131-2: 2017, 3.1.13]

[3] Withdrawn.

3.1.36
end-to-end link
E2E link
end to end transmission path formed by structured cabling based on passive components including the portion of the end connection that is attached to the link and the portion of the end connection that is attached to the end equipment

[SOURCE: ISO/IEC TR 11801-9902:2017, 3.1.1]

3.1.37
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality

[SOURCE: IEC 60050-195:1998, 195-01-10]

3.1.38
equipotential bonding system
interconnection of conductive parts providing equal potential between those parts

Note 1 to entry: If an equipotential bonding system is earthed, it forms part of an earthing arrangement.

[SOURCE: IEC 60050-195:1998, 195-02-22]

3.1.39
failure
termination of the ability of an item to perform a required function

Note 1 to entry: After failure, the item has a fault.

Note 2 to entry: Failure is an event, as distinguished from fault, which is a state.

[SOURCE: IEC 60050-191:1990, 191-04-01]

3.1.40
fault
state characterized by the inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

Note 1 to entry: IEC 61508-4 defines fault as an abnormal condition that may cause a reduction in, or loss of, the capability of a functional unit to perform a required function.

[SOURCE: IEC 60050-191:1990, 191-05-01, modified – Note 1 to entry has been changed and Note 2 to entry has been deleted]

3.1.41
functional earth, en GB
functional ground, en US
earthing point or points in a system or in an installation or in equipment, used for purposes other than electrical safety

[SOURCE: IEC 60050-195:1998, 195-01-13]

3.1.42
high flex cable
cable that can withstand high number of repeated flexes (usually millions of cycles) while maintaining the specified performance

3.1.43
inactive metal part
any non-current carrying metal that may be contacted by a person

3.1.44
inspection
taking measures for the observation and evaluation of the actual condition

3.1.45
intermediate cable
cable connecting the intermediate distributor to the telecommunication outlet

[SOURCE: ISO/IEC 11801-3:2017, 3.1.9]

3.1.46
intermediate distributor
distributor used to make connections between the intermediate cable, other cabling subsystems and active equipment

[SOURCE: ISO/IEC 11801-3:2017, 3.1.10]

3.1.47
intermediate industrial distributor
intermediate distributor used to make connections to and between automation islands and transmit critical process control, monitoring and automation data (PCMA) between them

[SOURCE:ISO/IEC 11801-3:2017, 3.1.11]

3.1.48
jack
part of the connector which mates with a plug

Note 1 to entry: This document uses the term jack to refer to a fixed connector.

[SOURCE: IEC 60050-581:2008, 581-26-24, modified – Text has been adapted for automation applications and Note 1 to entry has been added]

3.1.49
jack-to-jack adaptor
J-J adaptor
back-to-back jacks that have one type of jack on one side and another type of jack on the other side and do not are on an enclosure/environmental barrier

3.1.50
jack-to-jack coupler
J-J coupler
back-to-back jacks that have the same type of jack on both sides and do not are on an enclosure/environmental barrier

3.1.51
linear topology
topology where the nodes are connected in series, with two nodes connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

Note 1 to entry: This topology corresponds to that of an open ring.

3.1.52
maintenance
combination of all technical and corresponding administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function

Note 1 to entry: See "preventive maintenance", and "corrective maintenance", for a more detailed definition of maintenance.

Note 2 to entry: The required function may be defined as a stated condition.

[SOURCE: IEC 60050-191:1990, 191-07-01, modified – "Administrative actions" has been replaced by"corresponding administrative actions" and the two notes to entry have been added]

3.1.53
maintenance intervention
taking measures for retaining the specified condition

3.1.54
mean time between failures
MTBF
expectation of the time between failures

[SOURCE: IEC 60050-191:1990, 191-12-08]

3.1.55
mean time to recovery
MTTR
expectation of the time to restoration

Note 1 to entry: In IEC 60050-191:1990, 191-13-08, the use of "mean time to repair" (MTTR) is deprecated.

[SOURCE: IEC 60050-191:1990, 191-13-08]

3.1.56
network
all of the media, connectors, repeaters, routers, gateways and associated node communication elements by which a given set of communicating devices are interconnected

[SOURCE: IEC 61158-2:2014, 3.1.30]

3.1.57
node
end-point of a branch in a network

3.1.58
passive network
network in which data transmission is independent of active elements within the device attached to the network

Note 1 to entry: Failure of a device does not affect the propagation of information.

3.1.59
pathway
cable route used to accommodate cables between termination points

Note 1 to entry: The cable route (e.g., conduit, ductwork, tray, or tube) is defined by a physical structure.

[SOURCE: ISO/IEC 14763-2:2012, 3.1.43, modified – The definition has been adapted and Note 1 to entry has been added.]

3.1.60
permanent link
transmission path between distributors or between the telecommunications/automation outlet and the intermediate distributor

Note 1 to entry: It excludes apparatus attachment cords, equipment cords, patch cords and jumpers but includes the connection at each end.

Note 2 to entry: This is a modification to the definition of ISO/IEC 11801 in order to allow it be used for the CPs in accordance with IEC 61784-5 (all parts).

[SOURCE: ISO/IEC 11801-1:2017, 3.1.69, modified – The definition and Note 1 to entry have been adapted and Note 2 to entry has been added]

3.1.61
plug
connector used to make connections to a jack

Note 1 to entry: This document uses the term plug to refer to a free connector.

3.1.62
preventive maintenance
maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item

[SOURCE: IEC 60050-191:1990, 191-07-07]

3.1.63
protective earthing conductor
protective conductor provided for protective earthing

[SOURCE: IEC 60050-195:1998, 195-02-11]

3.1.64
quad
cable element that comprises four insulated conductors twisted together

Note 1 to entry: Two diametrically facing conductors form a transmission pair also referred to as a side circuit.

[SOURCE: ISO/IEC 11801-1:2017, 3.1.75]

3.1.65
RC earthing
earthing via a parallel RC circuit

3.1.66
recovery (of a high resilience item)
event when an item regains its specified degree of communication performance and fault resilience after correction of a fault

Note 1 to entry: High availability networks provide resilience to enable acceptable communication to continue after one fault and possibly after multiple faults.

3.1.67
repair
take measures for the re-establishment of the specified condition

3.1.68
repeater
two-port active physical layer device that receives and retransmits all signals to increase the distance and number of devices for which signals can be correctly transferred for a given medium

[SOURCE: IEC 61158-2:2014, 3.1.38]

3.1.69
resistance to earth
real part of an impedance to earth

[SOURCE: IEC 60050-195:1998, 195-01-18]

3.1.70
restoration
state when a communication network regains its designed level of resilience redundancy

3.1.71
ring
active network where each node is connected in series to two other nodes

3.1.72
scheduled maintenance
preventive activity (time or number-of-actions directed) performed either on predefined schedule or on units of use (e.g. number of start-ups)

[SOURCE: IEC 60050-191:1990, 191-07-10, modified – The definition has been adapted and a reference to units of use has been added]

3.1.73
segment
trunk-cable section of a network that is terminated at both ends by its characteristic impedance

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

[SOURCE: IEC 61158-2:2014, 3.1.39 modified – The definition and the note to entry have been adapted]

3.1.74
shield (of a cable), en US
screen (of a cable), en GB
surrounding metallic layer to confine the electromagnetic field within the cable and to protect the cable from external electrical influence

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

Note 2 to entry: For generic cabling in industrial premises, ISO/IEC 11801-3 uses the term screen instead of shield.

Note 3 to entry: See also Note 1 to entry of the balanced cable definition.

[SOURCE: IEC 61158-2:2014, 3.1.41 modified – The definition has been adapted and the term screen has been added; Notes 2 and 3 to entry have been added]

3.1.75
(optical fibre or electrical conductor) splice
a permanent, or semi-permanent, joint whose purpose is to couple optical power between two optical fibres or to joint two electrical conductors

Note 1 to entry: Joining without connectors.

3.1.76
spur
branch-line (i.e. a link connected to a larger one at a point in its route) that is a final circuit

Note 1 to entry: The alternative term "drop cable" is used in IEC 61158.

[SOURCE: IEC 61158-2:2014, 3.1.42]

3.1.77
star
network of three or more devices where all devices are connected to a central point (which may be active or passive)

3.1.78
tap
point of attachment from a node or spur to the trunk cable

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

[SOURCE: IEC 61158-2:2014, 3.3.34]

3.1.79
telecommunication outlet
TO
fixed connecting device which provides an interface to the terminal equipment

[SOURCE: ISO/IEC 11801-1:2017, 3.1.80]

3.1.80
terminator
entity used to terminate a transmission line in its characteristic impedance to prevent reflections

Note 1 to entry: In some instances, the terminator may be embedded in an end device or in a connector.

[SOURCE: IEC 61158-2:2014, 3.1.43, modified – The definition and Note 1 to entry have been modified]

3.1.81
(network) topology
pattern of the relative positions and interconnections of the individual elements (of the network)

Note 1 to entry: The term topology is sometimes overloaded to include considerations of the delay, attenuation and physical media classes of the paths interconnecting network nodes.

[SOURCE: IEC 60050-131:2002, 131-13-02, modified – Text has been adapted for communication networks and a Note 1 to entry has been added]

3.1.82
troubleshooting
locating the fault(s)

3.1.83
trunk
main communication highway acting as a source of main supply to a number of other lines (spurs)

[SOURCE: IEC 61158-2:2014, 3.1.46]

3.1.84
validation
part of the acceptance test that is solved with measurements

3.1.85
verification
action to assess that an installation is in accordance with its specification

Note 1 to entry: The installer usually performs this action.

Note 2 to entry: This action usually covers verification of component correct selection, physical layout, communication earthing, isolation and continuity of network components.

3.1.86
wire map
mapping of connector pin-to-pin terminations of a cable

3.1.87
balanced 1-pair cable
cable consisting of a single pair of conductors, optional screen, and overall jacket, primarily intended for use in differential-mode signal transmission and power delivery applications

[SOURCE: ISO/IEC TR 11801-9906:2020, 3.1.2]

3.1.88
balanced 1-pair cabling
cabling composed of balanced 1-pair cables and balanced 1-pair connectors

3.1.89
balanced 1-pair cabling channel
transmission path between equipment constructed from balanced 1-pair cables, balanced 1-pair connectors and balanced 1-pair cable assemblies to facilitate signal and power delivery

[SOURCE: ISO/IEC 11801-3:2017/AMD1:2021, 3.1.14]

3.1.90
balanced 1-pair connector
connector intended for use with balanced 1-pair cable in differential-mode signal transmission and power delivery applications

[SOURCE: ISO/IEC TR 11801-9906:2020, 3.1.3]

3.1.91
balanced 1-pair cord
cable assembly constructed from a 1-pair cable and 1-pair connectors

[SOURCE: ISO/IEC TR 11801-9906:2020, 3.1.4]

3.1.92
edge distributor
optional additional distributor to accommodate active equipment to allow transition from balanced 4-pair cabling to balanced 1-pair cabling

[SOURCE: ISO/IEC 11801-3:2017/AMD1:2021, 3.1.15]

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

AC	Alternating current
A.I.	Action item
AI	Automation island
AO	Automation outlet
AWG	American Wire Gauge
BD	Building distributor (ISO/IEC 11801-1)
BER	Bit error rate
BFOC	Bayonet fibre optic connector
BNC	Bayonet Neill Concelman (connector for coaxial cable having a bayonet-type shell)
CBN	Common bonding network
CP	Communication profile (IEC 61784-1)
CPF	Communication profile family (IEC 61784-1)
DC	Direct current
DCR	Direct current resistance
ED	edge distributor
EFT	Electrical fast transient
EFT/B	Electrical fast transient / burst (IEC 61000-4-4)
ELFEXT	Equal level far-end crosstalk
ELTCTL	Equal level transverse conversion transfer loss
EMC	Electromagnetic compatibility (IEC 60050-161, 161-01-07)
EMI	Electromagnetic interference (IEC 60050-161, 161-01-06)
ESD	Electrical static discharge
E2E	End-to-end
FD	Floor distributor (ISO/IEC 11801-1)
FE	Functional earth
ffs	For further study
FI	Fieldbus interface
FOC	Fibre optical connector
F-SMA	Fibre sub miniature version A (IEC 61754-22)
HP	Horse power
ID	Intermediate distributor
IDC	Insulation displacement contact
IID	Industrial intermediate distributor
IP	International protection (IEC 60529)

J-J	Jack-to-jack
kbit/s	One thousand bits per second
LC	Optical fibre connector in accordance with IEC 61754-20
LV	Low voltage
Max.	Maximum
Mbit/s	Million bits per second
MD	Machine distributor (ISO/IEC 11801-1)
MDI	Medium dependent interface (IEEE 803.2)
MDIX	Medium dependent crossover interface (IEEE 803.2)
MHV	Medium high voltage
MICE	Mechanical, Ingress, Climatic and Chemical, Electromagnetic (ISO/IEC 11801-1)
Min.	Minimum
MTBF	Mean time between failures
MTTR	Mean time to repair (use deprecated in IEC 60050-191:1990, 191-13-08) replaced with mean time to recovery
N	Neutral
NA	Numerical aperture (IEC 60793 (all parts))
na	Not available
NEXT	Near end crosstalk loss
NI	Network interface (ISO/IEC 11801-3)
No.	Number
OF	Optical fibre
OMx	Cabled multimode optical fibre category x; where x=1, 2, 3, 4
OSx	Cabled single mode optical fibre category x; where x=1, 1a, 2
PE	Protective earthing conductor (IEC 60050-195:1998, 195-02-11)
PHY	Physical layer
P&ID	Pipe and instrumentation diagram
PMA	Physical medium attachment (IEEE 803.2)
PoE	Power over Ethernet
POF	Plastic optical fibre
PSELFEXT	Power sum equal-level far-end crosstalk loss
RC	Resistor-capacitor (circuit)
Rep	Repeater
SC	Optical fibre connector in accordance with IEC 61754-4
SC-RJ	Optical fibre connector in accordance with IEC 61754-24
TCL	Transverse conversion loss
TNC	Threaded Neill Concelman (threaded version of the BNC connector)
TO	Telecommunication outlet
UV	Ultraviolet
Var.	Variant

3.3 Conventions for installation profiles

Conventions for installation profiles are described in IEC 61784-5 (all parts).

4 Installation planning

4.1 General

4.1.1 Objective

Clause 4 addresses the planning of cabling and associated infrastructures to support communication networks used between and within automation islands in industrial premises.

4.1.2 Cabling in industrial premises

The cabling may comprise:

- automation communication cabling for use within or between AIs as specified in the communication profiles of IEC 61784-1 or IEC 61784-2 and in the relevant installation profiles of IEC 61784-5 (all parts); this includes the balanced 1-pair cablings that are specified in Annex Q;
- generic telecommunications cabling for industrial premises as specified in ISO/IEC 11801-3 (see Annex A);
- elements of generic cabling modified to meet the needs of automation communication cabling within an AI in accordance with the installation profiles of IEC 61784-5 (all parts);
- the apparatus attachment cabling between the TO and the AI in accordance with ISO/IEC 11801-3 with regard to the connection and with this document with regard to the cables;
- the AI attachment cabling between the AO and the AI in accordance with this document and the relevant installation profile(s) of IEC 61784-5 (all parts).

ISO/IEC 11801-3 specifies the structure of generic cabling connected to an AI where the TO interface allows connection of wide range of networking equipment.

Where a designated connection from generic cabling to automation communication cabling within an AI is desired, an AO specified within this document may replace the TO, as shown in Figure 3. The industrial cabling may include an edge distributor to accommodate active equipment to allow transition from balanced 4-pair cabling to balanced 1-pair cabling.

An AI may contain (see Figure 4)

- one or more industrial automation apparatus conforming to generic cabling requirements,
- one or more industrial automation applications implemented with an AI network that uses Ethernet (ISO/IEC/IEEE 8802-3)-based and non-Ethernet-based cabling that conform to IEC 61784-1 or IEC 61784-2.

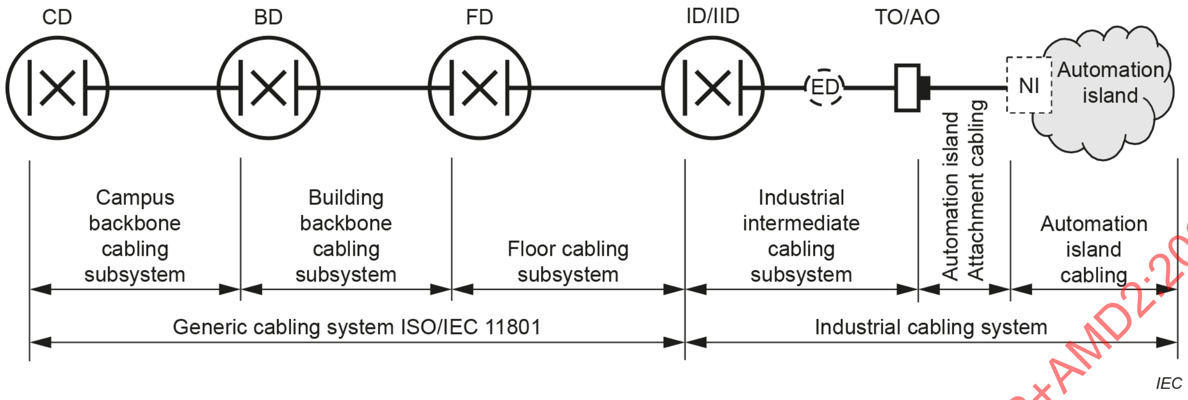


Figure 3 – Automation island cabling attached to elements of generic cabling

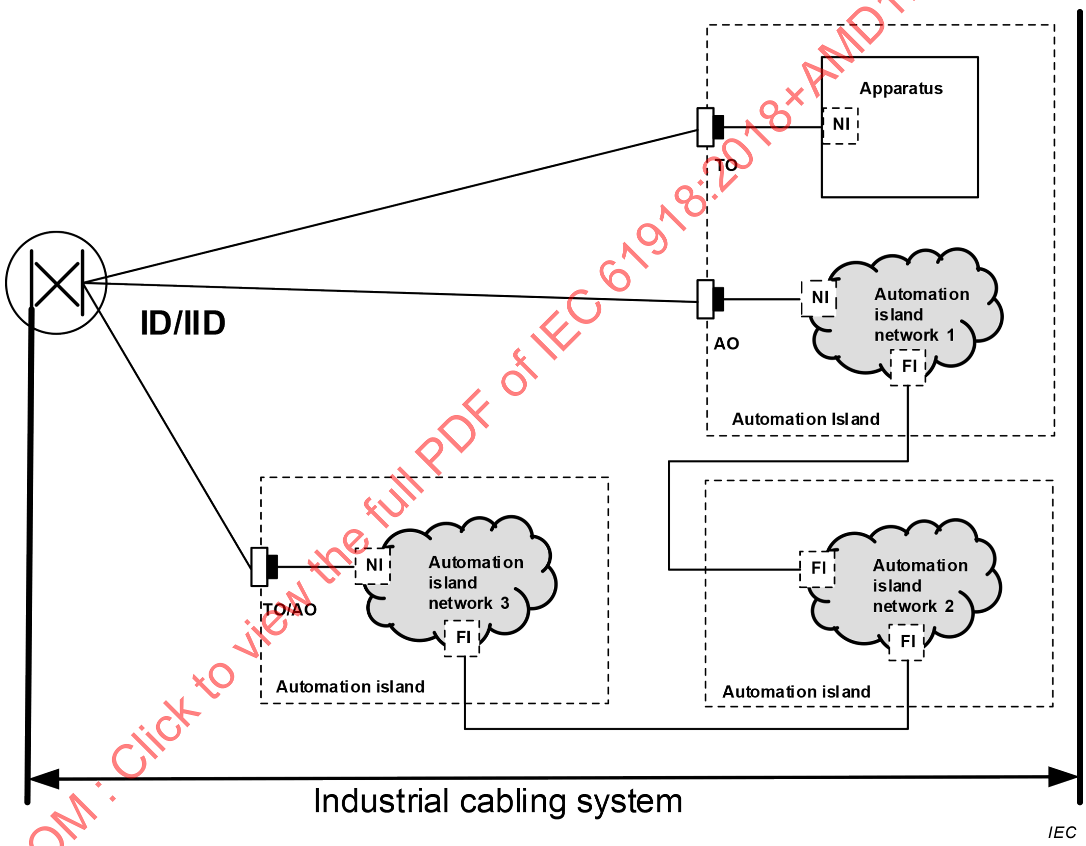


Figure 4 – Automation islands

The interconnections between the AI network and the generic cabling may be achieved through an appropriate converter/adapter (see Figure 5), while the connections among AIs may be achieved through one or more fieldbus to fieldbus connections (defined in the installation profiles in IEC 61784-5 (all parts)) and appropriate converter/adapters or through the generic cabling (see Figure 4).

In general, converter/adapters, such as routers, bridges, and gateways, shall be used to provide physical conversion and protocol transformation between different fieldbuses as specified in the relevant CP installation profiles. If the two interconnected interfaces (NI and FI) have matching specifications, then the converter/adapter function may not be necessary.

If the interconnection between the AIs is through the intermediate distributor/intermediate industrial distributor (ID/IID in Figure 4), it is the responsibility of the planner to check the suitability of the generic cabling to support the requirements for the installation of the communication networks as defined by this document. In this case, the channel performance shall be met from the ID/IID up to the NI (excluding the connector interface at the NI).

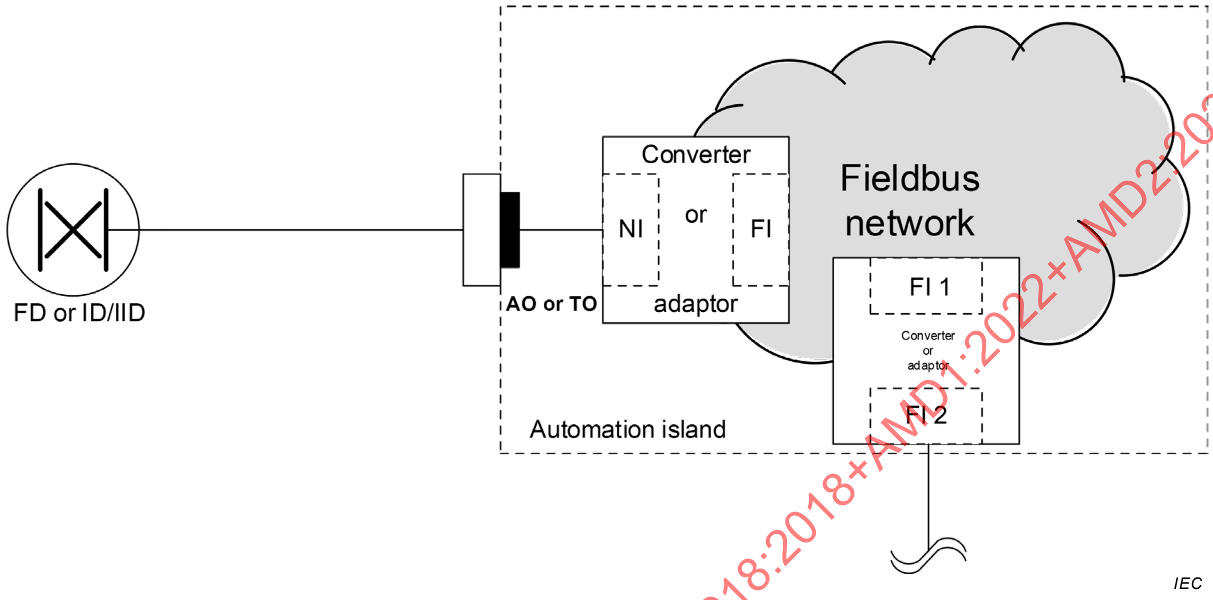


Figure 5 – Automation island network external connections

4.1.3 The planning process

The planning of the communication of an automation system is the responsibility (see Annex L) of one or more of the following: building network designer, automation designer and or machine designer.

The input for the installation planning depends on the kind of industrial automation application. This input is made up of general design requirements, operating manuals for machines or piping and instrumentation diagrams (P&ID) for process installations.

This input is made up of general design requirements, operating manuals for machines or piping and instrumentation diagrams (P&ID) for process installations according to IEC 62708.

Installation planning of industrial communication networks is accomplished through three basic steps.

Step 1 addresses the following installation-specific factors (see 4.2):

- safety
  - the solutions shall comply with existing local and national regulations. Under this condition, safety requirements specified in IEC 61010-2-201 may be taken into consideration;
  - if a communication network is installed with easily accessible terminals and wires, IEC 60364-4-41 concerning protection against electrical shock and EMC requirements should be applied;
  - intrinsic safe network is out of scope for this document but may be addressed in the CP installation profiles (IEC 61784-5 (all parts)).
- security;
- environmental

- the use of the MICE (Mechanical, Ingress, Climatic and Chemical, and Electromagnetic) methodology for description of environmental performance, as described in 4.2.3, is recommended;
- distinctive of industrial sites is the presence of low voltage (LV) and medium-high-voltage (MHV) power networks in close neighbourhood of the communication network. The RF influence of neighbouring high-power transmitters (e.g. television transmitters) shall be taken into account;

- electromagnetic compatibility.

Step 2 addresses the capabilities of the different communication networks (see 4.3):

- topologies;
- network characteristics.

Step 3 addresses the selection and use of cabling components in response to steps 1 and 2 (see 4.4).

The result of the planning process in 4.2, 4.3 and 4.4 is the production of the cabling planning documentation described in 4.5, which shall comprise:

a) a statement, signed by the responsible planner, explaining how the planned installation complies with the safety and security requirements and environmental conditions such as mechanical, liquid, particulate, climatic, chemicals and electromagnetic interference and including all necessary documents (e.g. plans and lists) for the installation that result from step 1;
b) documentation of the planned network topology, characteristics, physical extension and transmission performances that results from step 2;
c) the component specifications, where the conformity of the component data with the planned network requirements (functional and electrical safety, environmental conditions, and EMC requirements) is documented as result of step 3;
d) a table for comparison of nominal and actual network performance values.

4.1.4 Specific requirements for CPs

Additional information for a specific industrial network may be found in the respective installation profile.

4.1.5 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.2 Planning requirements

4.2.1 Safety

4.2.1.1 General

The planner shall take into consideration regulations for safety in communication networks with specific attention to mounting, cabling, verification, and validation.

The planner shall include all applicable requirements for safety in the cabling planning documentation.

4.2.1.2 Electrical safety

The proper implementation of the requirements of this document assumes that electrical installations are in accordance with the relevant standards within IEC 60364 (all parts), IEC 61010-2-201, IEC 61010-2-203 or local and national regulations as required.

4.2.1.3 Functional safety

Where digital communications are used to contribute to one or more safety functions, the communication system should have sufficient integrity (taking into account hardware, software, and the specified environment) to meet the safety integrity requirements of every safety function.

For example, wiring used to support safety instrumented systems may require special installation practice (e.g. complete segregation from all other cabling) and labelling (e.g. special conduit colouring) to meet enhanced integrity requirements.

The requirements for safety integrity may include special measures applicable to the several phases of the life cycle of the related communication media (see the relevant technology parts of the IEC 61784-3 and/or IEC 61784-5 (all parts)). The planner shall apply such special measures.

4.2.1.4 Intrinsic safety

Where required, the planner shall plan the network in accordance with applicable intrinsic safety standards and IEC 61158-2 and the applicable CPs of IEC 61784-1.

4.2.1.5 Safety of optical fibre communication systems

Optical fibre cabling shall be planned in accordance with the safety requirements of IEC 60825-2 or local regulations.

4.2.2 Security

Where communication networks in accordance with IEC 62443 are planned, the planner shall apply all additional technical and organizational measures aimed at mitigating the specific security risk for the communication subset identified during the security design of the whole automation system.

The universal nature of generic cabling produces additional security concerns since the cabling may be used to provide applications that are managed by different groups within industrial premises. For example, generic cabling may provide basic telephony services, information technology and building control services in addition to the connections to the AIs. The prevention of accidental disruption to any of these services requires careful consideration.

IEC 62443 breaks down the design of security within a system to security levels based on risk level. For each level there are different measures. For this purpose, cabling, planning and installation play a role in implementing countermeasures and are central to achieving physical and environmental security countermeasures, in accordance with Clause 4 and Clause 5, in general, and requirements described in 4.4.9.1 (Routing of cables), 4.4.9.6 (Installing redundant communication cables), 4.4.11 (Mechanical protection of cabling components), 5.2.1.2 (Protecting communication cables against potential mechanical damage), in particular.

Moreover, the first security level defined in IEC 62443 requires that a protection against unintentional failures be implemented. An important contribution to this protection comes from the application of the rules for installation verification and installation acceptance tests, installation administration and installation maintenance and troubleshooting, described in Clause 6, Clause 7 and Clause 8, which reduce the risk of intermittent system malfunction due to incorrect cabling (e.g. insufficient implemented protection from electromagnetic interferences, instable connections, etc.).

4.2.3 Environmental considerations and EMC

4.2.3.1 Description methodology

The planner shall provide a precise description of the environment to be used as a basis for the selection of components and for the mitigation requirements.

ISO/IEC 11801-1 applies an environmental assessment called "MICE" classification. This approach is recommended for all CPs because it allows the planner to describe the environmental conditions in a precise and unambiguous way.

The use of this approach is explained here and in Annex B for the benefit of the planner and the installer.

NOTE 1 The MICE classification system of ISO/IEC 11801-1 is not a component test specification.

NOTE 2 The MICE classification system of ISO/IEC 11801-1 does not replace existing international or national standards.

NOTE 3 Existing international or national standards for components contain the test requirements and schedules for product qualification.

4.2.3.2 Use of the described environment to produce a bill of material

The planner shall produce a bill of material of components that meets the targeted environment through the following steps.

a) Establish the ambient environmental conditions for each significantly different region within the application space (for example, beside the machine, in the control room, between the above).
b) Define the components that make up the communications system including their environmental specifications.
c) Define the additional mitigation to bridge between the component(s) specifications and the targeted environment, if the component does not meet the targeted environment.

The planner shall provide the environmental description either through the use of the MICE tables (that provides a precise classification of the environment) or by an equivalent methodology. The planner shall address the environmental requirements by specifying a combination of component selection and mitigation techniques to be applied (see Figure 6).

Products, such as enclosures, necessary to provide mitigation shall also be included in the bill of material.

Compatibility of components can be met by any combination of the following three methods:

- installation related isolation (for example protection with enclosure);
- separation (for example physical separation from other components);
- component enhancement (design enhancement of the component parameters, for example by adding a cable shield or external shield). The supplier of the equipment may provide enhancements to the components reducing the installation requirements.

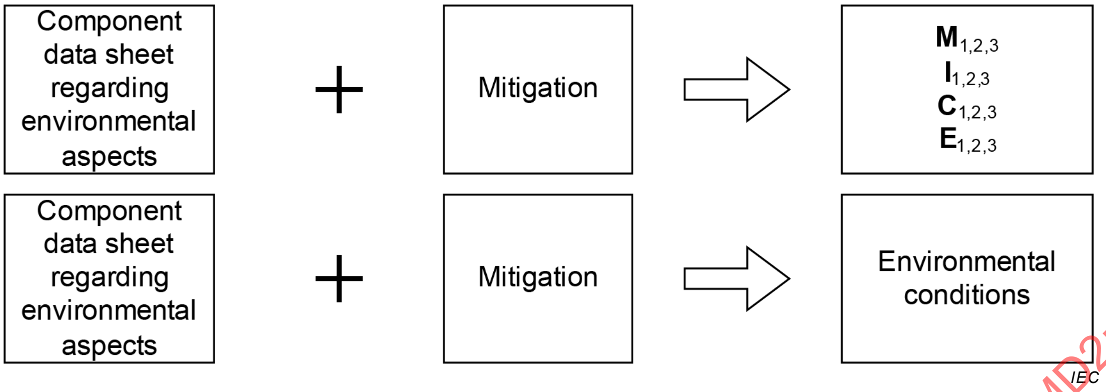


Figure 6 – How to meet environmental conditions

Figure 7 shows how the three methods (isolation, separation and enhancement) work together to provide a cost effective, technically feasible solution for a given application with regard to the environment. Examples of use of the MICE concept are provided in Annex B, where the meaning of the subscripts 1, 2, 3 is explained.

The planner, when consulting the device and cabling manufacturer, shall take into account the guidance provided in Clause B.6 for the correct selection of the device and cabling in relation to the environment EMI of the installation under consideration.

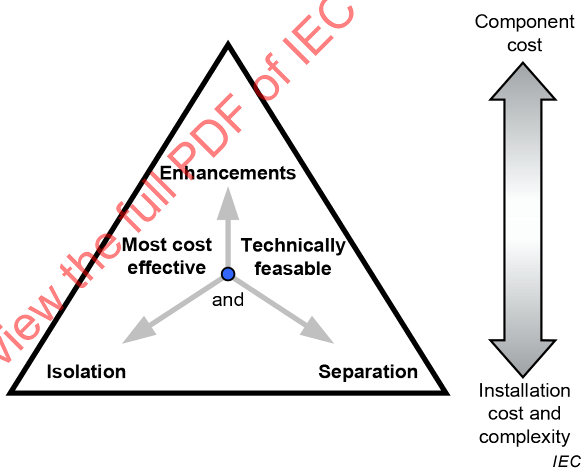


Figure 7 – How enhancement, isolation and separation work together

Passive optical components in the harsh industrial environment should be protected with suitable mitigation techniques or tested according to IEC 61753-1.

4.2.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.3 Network capabilities

4.3.1 Network topology

4.3.1.1 Common description

For the industrial AI networks, there are two fundamental themes.

a) Physical topology of the communication network, from a physical composition standpoint.

   Hereafter the basic physical topologies of a network are divided in two groups:

   – physical topology for passive networks;

   – physical topology for active networks.

b) Logical topology of the communication network, from an information propagation standpoint. This is outside the scope of this document and may be covered by IEC 61784-1 and IEC 61784-2.

NOTE 1 As an example of the difference between the physical and the logical topology, a planner can select a physical star to be installed in order to support a logical ring topology.

The planner shall select the most appropriate physical topology on the basis of the application requirements (see also Annex C) and according to the topologies that are specified for the specific CP. The basic topologies defined in 4.3.1.2 and in 4.3.1.3, and combinations of them (see 4.3.1.4) are the appropriate physical topologies for AI networks.

NOTE 2 Not all fieldbuses support all the basic topologies and combination of them.

4.3.1.2 Basic physical topologies for passive networks

The basic physical topologies for passive network, represented in Figure 8, are the following.

- Bus
- Star

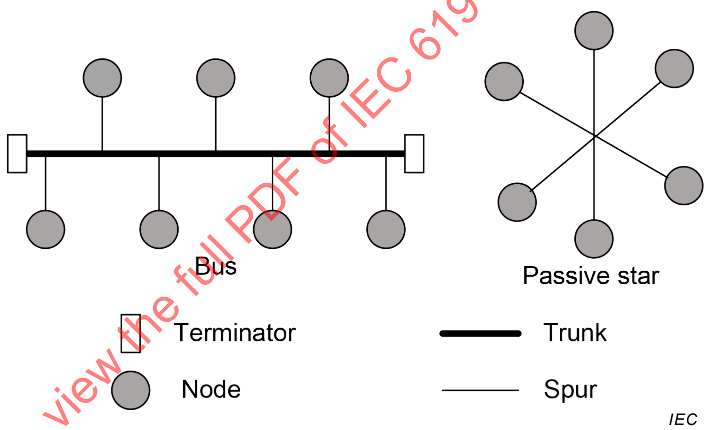


Figure 8 – Basic physical topologies for passive networks

4.3.1.3 Basic physical topologies for active networks

The basic physical topologies for active networks, represented in Figure 9, are the following.

- Star
- Ring
- Linear

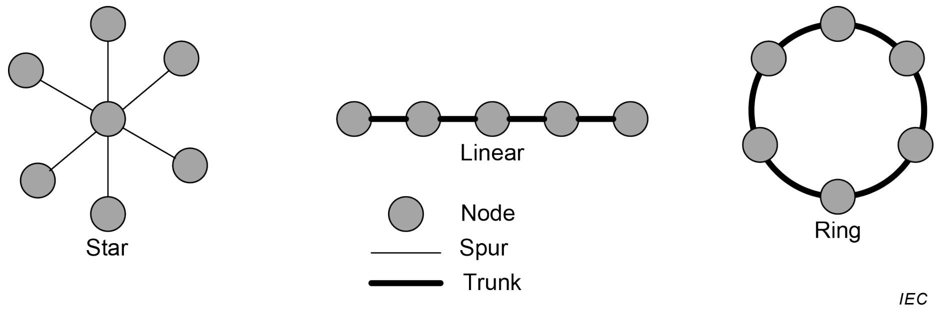


Figure 9 – Basic physical topologies for active networks

4.3.1.4 Combination of basic topologies

Combinations of basic topologies are permitted and are defined in the CP installation profile.

Figure 10 provides an example of a common configuration of two passive bus segments interconnected by an active bus repeater.

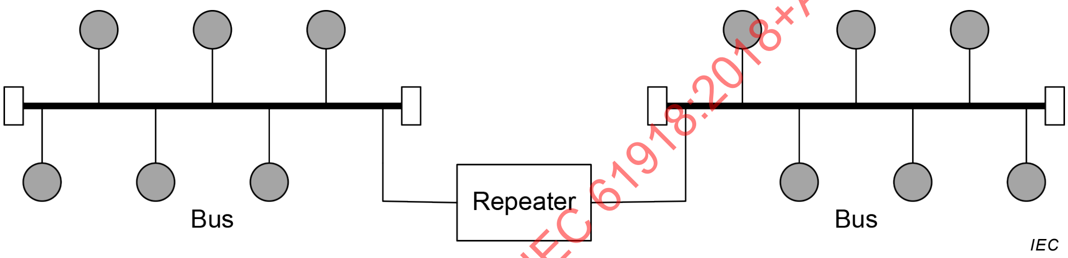


Figure 10 – Example of combination of basic topologies

A mesh configuration is composed of linear configurations where the active nodes are partially (as in Figure 53, with one linear configuration in green and a second one in blue) or totally directly interconnected.

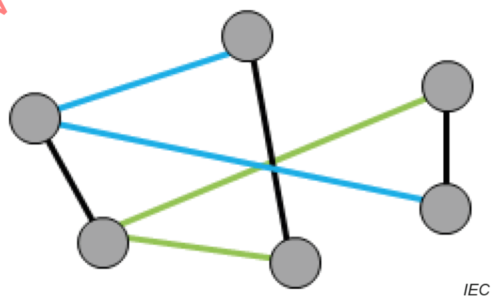


Figure 53 – Example of mesh topology

4.3.1.5 Specific requirements for CPs

Additional information regarding topology requirements for a specific industrial network may be found in the respective installation profile.

4.3.1.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

Generic cabling channels in accordance with ISO/IEC 11801-3 may constitute elements of the networks described in 4.3.1.2 to 4.3.1.5. Specific restrictions are detailed in ISO/IEC 11801-3 and may be expanded upon or modified by the respective installation profile.

4.3.2 Network characteristics

4.3.2.1 General

It is common practice to subnet an industrial AI network when there are a large number of devices to be connected.

Every network specification consists of the following basic characteristics:

- transfer rates;
- media type and performance;
- maximum number of devices (nodes) including repeaters per segment;
- maximum number of devices (nodes) including repeaters per network;
- maximum number of repeaters (that connect segments);
- maximum segment length.

NOTE Transfer rates can be expressed as bandwidth capacity or effective data throughput rates using the modulation and encoding methods of a specific Fieldbus technology. Requirements for effective data rate values can also include statements of maximum acceptable values for BER and burst errors (such as in 23.9 of IEC 61158-2:2014 and Annex K).

Media types consist of optical fibre cabling, balanced cabling (4-pair, 2-pair, 1-pair), wireless, and other CP specific media types. Wireless network installation is not within the scope of this document. Selection of physical media technologies should partner with architectural considerations, taking into account network topology, network characteristics, as well as data propagation and aggregation throughout the network.

Optical fibre is generally recommended where high bandwidth is needed or a high data integrity is required. Where powering is required or for reduced bandwidth or length compared to optical fibre, wire cabling is recommended. 4-pair is mostly recommended for connecting control and automation equipment. 1-pair (see Annex Q) is mostly limited to connecting control and automation equipment with field devices.

The planner should take into account EMI performance when selecting cabling types and spacings from types of conductors. In practice, need for EMI reduction equates to increase in spacing, which can translate to installation cost. Failure to consider EMI performance and mitigations can ultimately lead to areas of high disturbance at critical points in the network.

Comparative measurements (unshielded versus shielded) have shown that shielded constructions can provide a higher level of protection against EMI when applied according to equipment manufacturers specifications.

4.3.2.2 Network characteristics for balanced cabling not based on Ethernet

For balanced cabling not based on Ethernet, the planner shall use the basic network characteristics defined in the respective installation profile according to the templates given in Table 1.

Table 1 – Basic network characteristics for balanced cabling not based on Ethernet

Characteristic	CP x/y
Basic transmission technology	
Length / transmission speed	**Segment length** m
9 kbit/s to 33 kbit/s	
33 kbit/s to 93 kbit/s	
125 kbit/s	
187 kbit/s	
250 kbit/s	
500 kbit/s	
1,5 Mbit/s	
2 Mbit/s	
3 Mbit/s, 6 Mbit/s, 12 Mbit/s	
5 Mbit/s	
8 Mbit/s	
16 Mbit/s	
Maximum capacity	**Max. No.**
Devices/segment	
Devices/network	

4.3.2.3 Network characteristics for balanced cabling based on Ethernet

For balanced cabling based on Ethernet, the planner shall use the basic network characteristics defined in the respective installation profile according to the template given in Table 2.

NOTE The letter X in Table 2 is the reference to Annex X of the installation profile where the profile is specified.

Table 2 – Network characteristics for balanced cabling based on Ethernet

Characteristic	CP x/y
Supported data rates (Mbit/s)	
Supported channel length (m) [b]	
Number of connections in the channel (max.) [a] [b]	
Patch cord length (m) [a]	
Channel class per ISO/IEC 11801-3 (min.) [b]	
Cable category per ISO/IEC 11801-3 (min.) [c]	
Connecting HW category per ISO/IEC 11801-3 (min.)	
Cable types	

[a] See X. 4.4.3.2.

[b] For the purpose of this table, the channel definitions of ISO/IEC 11801-3 are applicable.

[c] For additional information, see IEC 61156 (all parts).

For balanced 1-pair networks, the requirements specified in Annex Q apply.

4.3.2.4 Network characteristics for optical fibre cabling

For optical fibre cabling, the planner shall use the basic network characteristics for each wavelength defined in the respective installation profile according to the templates given in Table 3 and to the conditions expressed hereafter.

For the purpose of this document, channel insertion loss and optical power budget are considered to be equivalent. The connecting hardware used for optical fibre cabling is as specified in X.4.4.2.5 of the relevant installation profile.

NOTE The letter X is the reference to Annex X of the installation profile where the profile is specified.

Table 3 – Network characteristics for optical fibre cabling

CP x/y		
Optical fibre type	**Description**	
Single mode silica	Bandwidth (MHz) or equivalent at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5
Multimode silica	Modal bandwidth (MHz × km) at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5
POF	Modal bandwidth (MHz × 100 m) at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5
Hard clad silica	Modal bandwidth (MHz × km) at λ (nm)	
	Minimum length (m)	
	Maximum length [a] (m)	
	Maximum channel insertion loss/optical power budget (dB)	
	Connecting hardware	See X.4.4.2.5

[a] This value is reduced by connections, splices and bends in accordance with formula (1) in 4.4.3.4.1.

4.3.2.5 Specific network characteristics

Additional information regarding the characteristics of a specific industrial network may be found in the respective installation profile.

4.3.2.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

Certain generic cabling channels in accordance with ISO/IEC 11801-3 may provide transmission performance in support of the networks described by reference to the templates of 4.3.2.2 to 4.3.2.5. See ISO/IEC 11801-3 for further details.

4.4 Selection and use of cabling components

4.4.1 Cable selection

4.4.1.1 Common description

The planner shall ensure that cables provide the required transmission performance in the specified environment (by reference to the MICE classification system or equivalent, see 4.2.3.1).

Industrial cables can be subjected to extreme mechanical stresses.

EXAMPLE The cable can provide connectivity for festooning, “C” track (drag chains) or robotic flexing applications.

In these cases, the planner shall select the cabling in accordance with the needs of the intended application. The respective manufacturer's instructions shall be observed.

The planner may decide to use part of an existing generic cabling system to connect AI networks. In this case, it is the planner’s responsibility to make sure that this cabling system meets the requirements for the application.

NOTE Generic cabling in accordance with ISO/IEC 11801-3 can be not suitable for some CPs.

The planner shall ensure that cables to be installed underground are suitable and satisfy the following requirements:

- local regulations;
- safety from lightning;
- resistance to damage from rodents;
- chemical resistance.

Metal cladding on optical fibre cables provides additional mechanical protection. The planner should select metal clad optical fibre cables for direct burial applications and other areas where mechanical protection is necessary.

If the equipment location requires the use of special cables and/or connecting elements not complying with the network-related requirements of this specification, the planner shall consult the cable/connector manufacturer to obtain the information necessary for determining the channel/permanent link length.

4.4.1.2 Copper cables

4.4.1.2.1 Balanced cables for Ethernet-based CPs

Balanced cables for Ethernet-based CPs shall meet the requirements of Table 2. For balanced 1-pair cables, the requirements specified in Annex Q apply.

The planner shall review the relevant installation profile for additional requirements or recommendations for balanced cables.

The planner shall have considered the following information when specifying the number of pairs in each balanced cable:

- all cables within a channel should be of the same pair count;
- two pair cabling is not generic and cannot support all applications (for example, if future plans are to migrate to higher data rates or PoE, then four pair cables should be considered);
- more than 4 pair count cables are not recommended for control applications;

- in an active channel and with cabling that uses cable elements with a different pair count in the same channel (e.g., 2- and 4-pair or 1- and 4-pair), all un-used pairs shall be terminated with the differential or common mode impedance of the cable at both ends (i.e. four pair cables shall not be housed in two pair connecting hardware). This requirement does not apply to cable constructions that use individual shielded pairs.

For the channels where there is power sourcing equipment (PSE) connected to non-powered devices, the planner shall specify that the PSE function is disabled to prevent application of power.

The planner shall use the data defined in the respective installation profile according to the templates given in Table 4 and Table 5.

Table 4 – Information relevant to copper cable: fixed cables

Characteristic	CP x/y
Nominal impedance of cable (tolerance)	
DCR of conductors	
DCR of shield	
Number of conductors	
Shielding	
Colour code for conductor	
Jacket colour requirements	
Jacket material	
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	
Agency ratings	
Other characteristics [a]	

[a] Replace "Other characteristics" with the name of the other needed characteristics (one or more, as needed). Otherwise delete the row.

Table 5 – Information relevant to copper cable: cords

Characteristic	CP x/y
Nominal impedance of cable (tolerance)	
DCR of conductors	
DCR of shield	
Number of conductors	
Length	
Shielding	
Colour code for conductor	
Jacket colour requirements	
Jacket material	
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	
Agency ratings	
Other characteristics [a]	

[a] Replace "Other characteristics" with the name of the needed additional characteristics (one or more, as needed). Otherwise delete the row.

4.4.1.2.2 Copper cables for non-Ethernet-based CPs

Copper cables for non-Ethernet-based CPs, shall meet the requirements of Table 1 and any additional requirements or recommendations of the installation profile.

The planner shall use the data defined in the respective installation profile according to the templates given in Table 4 and Table 5.

4.4.1.3 Cables for wireless installation

Communication cables connecting to wireless devices shall conform to the requirements of this document.

4.4.1.4 Optical fibre cables

Optical fibre cables to support specific CPs shall meet the requirements or recommendations of the CP (see IEC 60794 (all parts)).

The planner shall select the appropriate optical fibre cable to support the required channel lengths and number of connections for the CP to be installed.

The planner shall review the relevant installation profile for additional requirements or recommendations for optical fibre cables.

The planner shall use the data defined in the respective installation profile according to the templates given in Table 6. The applicable standard is defined in the installation profiles with either a reference to IEC 60793 or IEC 60794 or OM1, OM2, OM3, OM4 or OS1, OS2. OM1, OM2, OM3 and OS1, OS2 are as specified in ISO/IEC 11801-1 and OM4 is as specified in IEC 60793-2-10, type A1a.3 (A1-OM4).

NOTE Some additional information to be considered by the installer and maintenance personnel is given in 5.2.1.13 and in Clause 8 of this document.

Table 6 – Information relevant to optical fibre cables

Characteristic	9..10/125 µm single mode silica	50/125 µm multimode silica	62,5/125 µm multimode silica	980/1 000 µm step index POF	200/230 µm step index hard clad silica
Standard					
Attenuation per km (650 nm)					
Attenuation per km (820 nm)					
Attenuation per km (1 310 nm)					
Number of optical fibres					
Jacket colour requirements					
Jacket material					
Resistance to harsh environment (e.g. UV, oil resist, LS0H)					
Other characteristics [a]					

[a] Replace "Other characteristics" with the name of the needed other characteristics (one or more, as needed). Otherwise delete the row.

4.4.1.5 Special purpose balanced and optical fibre cables

The following cables provide support for special applications. The planner shall consider any additional cabling attributes required to provide the desired life cycle of the cabling system.

Some examples of special purpose balanced cables and optical fibre cables are the following:

a) festoon cables;
b) high flex cables;
c) high flex cables for three dimensional movement;
d) UV-resistant cables;
e) weld splatter cables.

Selection of high flex cables should take the following into account:

- cables are rated differently for rolling “C” track (also known as a drag chain) and robotic applications where the cable is moved in a bending flex way (also known as “tic-toc”);
- cables should only be used where needed, i.e. in the high flex area;
- increased attenuation of copper cables (for example due to conductor stranding) that may affect channel length;
- cables should be properly secured to the moving machinery to minimize bending, twisting and abrasion;
- specified cable bending radius shall be maintained;
- cables should be installed with connectors at each end for maintenance purposes;
- only approved lubricants shall be used to minimise jacket abrasion.

It is common for high flex cables to be used in robotic welding applications. In this case weld splatter sheath materials should be considered.

4.4.1.6 Specific requirements for CPs

Additional information regarding the cable requirements for a specific industrial network may be found in the respective installation profile.

If hybrid cables are supported for a network, the requirements shall be specified in the relevant installation profile.

4.4.1.7 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

ISO/IEC 11801-3 requires the components to be selected and used in order that the desired channel performance is provided within the specified environment.

ISO/IEC 11801-3 also

- specifies reference implementations which link particular component specifications to channel transmission performance;
- provides appropriate methods of component specification, for example by reference to detailed specifications produced by other IEC committees.

The planner shall ensure that the components specified and their use within a channel provides the required transmission performance.

The planner shall ensure that a maintenance system is in place to maintain channel performance during the operational life of the cabling.

4.4.2 Connecting hardware selection

4.4.2.1 Common description

The planner shall ensure that connectors provide the required transmission performance in the specified environment (by reference to the MICE classification system or equivalent, see 4.2.3.1).

The planner shall use the appropriate pin-pair assignment based on Annex H and the specific installation profile in use.

The wire colour codes for CP specific connectors are defined in Annex D.

4.4.2.2 Connecting hardware for balanced cabling CPs based on Ethernet

This document recognizes sealed connector housings variants 1 and 6 of IEC 61076-3-106 and sealed connector housing variant 14 described in IEC 61076-3-117 for the encapsulation of 8-way modular connector compliant with IEC 60603-7. In the case of applications requiring the non-sealed connectivity, 8-way modular connectors specified in IEC 60603-7 shall be used. The installation of the variant 1, 6 or 14 at the AO and in the AI is dependent on the selected CP. In addition, the M12-4 with D-coding connector described in IEC 61076-2-101 and the M12-8 with X-coding connector described in IEC 61076-2-109 may be used at the AO and in the AI.

NOTE The above connector variants (1, 6 and 14) are reverse compatible with cords as defined by ISO/IEC 11801-3 and ensure a reverse compatibility to IEC 60603-7. Therefore, the standard test equipment can be used for network validation and troubleshooting.

Devices and AOs shall be fitted with sockets. Cables shall be fitted with plugs to interface with devices and AOs.

The planner shall use the data defined in the respective installation profile according to the template given in Table 7.

Table 7 – Connectors for balanced cabling CPs based on Ethernet

	IEC 60603-7 series[a]		IEC 61076-3-106[b]		IEC 61076-3-117[b]	IEC 61076-2-101	IEC 61076-2-109
	shielded	unshielded	Var. 1	Var. 6	Var. 14	M12-4 with D-coding	M12-8 with X-coding
CP x/y							

[a] For the IEC 60603-7 series, the connector selection is based on the desired channel performance.

[b] Housings to protect connectors.

For balanced 1-pair connecting hardware the requirements specified in Annex Q apply.

4.4.2.3 Connecting hardware for copper cabling CPs not based on Ethernet

The planner shall use the data defined in the respective installation profile according to the templates given in Table 8. Detailed specifications for M12 connectors are standardised in IEC 60512-29-100.

Table 8 – Connectors for copper cabling CPs not based on Ethernet

	IEC 60807-2 or IEC 60807-3	**IEC 61076-2-101**			**IEC 61169-8**	**ANSI/(NFPA) T3.5.29 R1-2007**		**Others**		
	Sub-D	M12-5 with A-coding	M12-5 with B-coding	M12-n with X-coding	Coaxial (BNC)	M 18	7/8-16 UN-2B THD	Open style	Terminal block	Others
CP x/y										

NOTE For M12-5 connectors, there are many applications using these connectors that are not compatible and when mixed can cause damage to the applications.

4.4.2.4 Connecting hardware for wireless installation

None.

4.4.2.5 Connecting hardware for optical fibre cabling

For optical cable connectors of an industrial network, the planner shall use the data defined in the respective installation profile according to the template given in Table 9 and the Table 10. In Table 10, the relationship between FOC and optical fibre types is expressed in terms of the optical fibre cable that applies (see 4.4.1.4).

There are several standards to help select the correct connector solution for a given environment. The planner and or the installer should consult ISO/IEC 11801-1:2017 and or IEC 61753-1 and IEC 61753-1-3 for additional information on environmental classifications of environments for connectors.

Table 9 – Optical fibre connecting hardware

	IEC 61754-2	**IEC 61754-4**	**IEC 61754-24**	**IEC 61754-20**	**IEC 61754-22**	**Others**
	BFOC/2,5	**SC**	**SC-RJ**	**LC**	**F-SMA**	
CP x/y						

NOTE IEC 61754 series defines the optical fibre connector mechanical interfaces. Performance specifications for optical fibre connectors terminated to specific fibre types are standardised in the IEC 61753 series.

Table 10 – Relationship between FOC and fibre types (CP x/y)

FOC	**Fibre type**					
	9..10/125 μm single mode silica	**50/125 μm multimode silica**	**62,5/125 μm multimode silica**	**980/1 000 μm step index POF**	**200/230 μm step index hard clad silica**	**Others**
BFOC/2,5						
SC						
SC-RJ						
LC						
F-SMA						
Others						

4.4.2.6 Specific requirements for CPs

Additional information regarding the connecting hardware requirements for a specific industrial network may be found in the respective installation profile.

4.4.2.7 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See 4.4.1.7.

4.4.3 Connections within a channel/permanent link

4.4.3.1 Common description

For the purposes of 4.4.3, the terms channel and permanent link as defined in ISO/IEC 11801-1 are modified as in 3.1.22 and 3.1.60 in order to allow them be used for CPs in accordance with IEC 61784-5 (all parts).

The planner shall request that the maximum channel lengths as defined by the specific installation profile for the specific cabling media is not exceeded. However, the quality of service depends on the length of the channel and the number of connections and splices within it (see 4.4.3.2.3).

As the number of connections and splices in the channel increases so does the insertion loss, which then decreases the signal to noise ratio of the channel.

For balanced cabling, the planner shall request that unused pairs in an active channel be terminated in accordance with 4.4.1.2.

The planner shall ensure that the impact of the number of connections within the channel is taken into account as described in 4.4.3 for 4-pair cabling. For 1-pair cabling, the requirements specified in Annex Q apply. With regard to the number of connections in a channel, the reference implementations as described in ISO/IEC 11801-3 have a limited number of connections (e.g., 4 for 4-pair and 10 for 1-pair). If the planning requires more connections than the corresponding reference implementation, then additional analysis may be required. Channel performance measurements may be required to assure that the channel meets the requirements of the application.

The planner shall ensure that an appropriate maintenance system is in place to maintain channel performance during the operational life of the cabling.

4.4.3.2 Balanced cabling connections and splices for CPs based on Ethernet

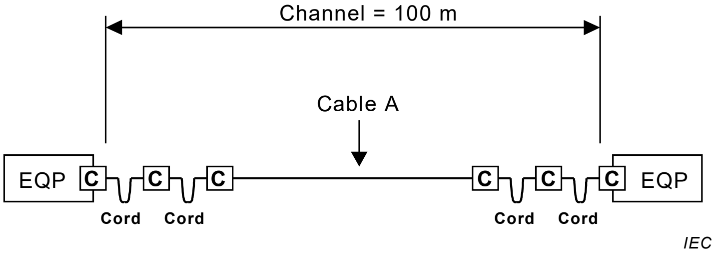
4.4.3.2.1 Common description

Ethernet-based networks shall comply with the following rules.

- The reference implementations as described in ISO/IEC 11801-3 (with specified structure, components and performance).
- The transmission performance shall be in accordance with the relevant class requirements as defined in ISO/IEC 11801-3. It shall be noted that these classes include requirements for TCL, ELTCTL and coupling attenuation with respect to MICE classification (E1, E2 or E3).
- Configurations beyond the reference implementations that are supported for a CP shall be fully described in the CP installation profile.

a) 4-pair basic reference implementation

Figure 11 shows the model used to correlate cabling dimensions specified in 4.4.3 with the channel specifications in ISO/IEC 11801-3. The cabling channel shown contains two connections at each end and two cords at each end of the channel. For the purposes of 4.4.3, jumpers are treated as cords.



Key

C = connection

EQP = equipment

Figure 11 – Basic reference implementation model

The basic reference implementation approach of Table 11 allows the length of the fixed cable A to be adjusted to compensate for variable cord lengths and channel operating temperature.

Table 11 – Basic reference implementation formulas

Category	Component		
	Class D	Class E	Class F
5	$C = (113 - 2 \times N - F \times Y) / X$ [a]	-	-
6	$C = (115 - N - F \times Y) / X$	$C = (106 - N - F \times Y) / X$	-
7	$C = (119 - N - F \times Y) / X$	$C = (109 - N - F \times Y) / X$	$C = (106 - N - F \times Y) / X$

For operating temperatures above 20 °C, the cable length C should be reduced by 0,2 % per °C for shielded cables and 0,4 % per °C (20 °C to 40 °C) and 0,6 % per °C (> 40 °C to 60 °C) for unshielded cables. Where the operating temperature exceeds 60 °C, then manufacturers' information shall be consulted regarding the required reductions in cable length.

NOTE The required channel performance is provided using the formulas provided in this table and based upon a statistical approach of performance modelling.

[a] where

C is the length of the fixed cable A (m);

N is the number of connections (subject to maximum of 4, otherwise NEXT, Return Loss and ELFEXT performance should be verified);

F is the combined length of cords and jumpers (m);

X is the ratio of the insertion loss of the fixed cable A (dB/m) to the insertion loss of the relevant category of cable (dB/m);

Y is the ratio of insertion loss of the cords/jumpers (dB/m) to the insertion loss of the relevant category of cable (dB/m).

In Table 11, it is assumed that

- the maximum channel length is 100 m;
- the fixed cable A may have a different insertion loss specification than the relevant category of cable specified in IEC 61156 (all parts);
- the flexible cable within the cords may have a different insertion loss specification than that used in the fixed cable;
- the cables within all the cords in the channel have a common insertion loss specification;
- all cables and cords are subject to the same temperature conditions;

- cable A may be constructed using the same cable types that are used in cords. In this case the proper de-rating shall be used (see Table 13).

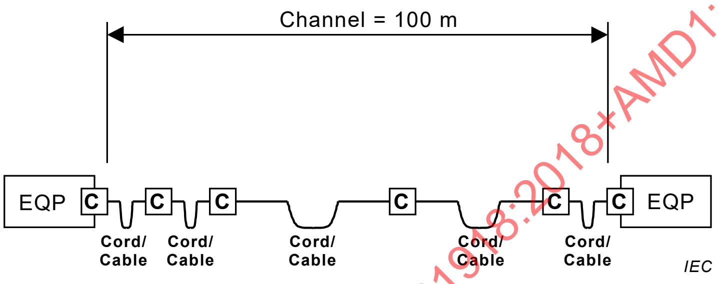
The length of the cable A shall be determined by the formulas defined in Table 11.

When four connections are used in a channel, the length of the fixed cable A should be at least 15 m. The maximum length of the fixed cable A will depend on the total length of cords to be supported within a channel. The maximum lengths of cords shall be fixed and during the operation of the installed cabling, a management system should be implemented to ensure that the cords used to create the channel conform to these design limits.

b) **4-pair enhanced reference implementation**

Figure 12 shows the model used to correlate cabling dimensions specified in 4.4.3 with the channel specifications in ISO/IEC 11801-3. The channel cabling shown contains four connections. For the purposes of 4.4.3, jumpers are equivalent to cords.

A channel may be assembled with cords and cables in any order.



Key

C = connection

EQP = equipment

Figure 12 – Enhanced reference implementation model

In Table 12, it is assumed that

a) the maximum channel length is 100 m;

b) all the cables may have a different insertion loss specification than the relevant category of cable specified in IEC 61156 (all parts);

c) each of the cables may have different insertion loss specifications;

d) each of the cables may be subject to different temperature conditions.

The length of the cords used within a channel of a given class shall be determined by the formulas defined in Table 12 and Table 13.

Where a proposed implementation would result in a cable separating two pair of connections within the channel with a length less than 15/Y (m), then validation shall be performed to confirm channel performance.

NOTE Y_i is defined in Table 12.

The planner shall require that, during the operation of the installed cabling, the maintenance organisation ensure that the cords used to construct, update or repair the channel conform to the design rules of the channel.

Table 12 – Enhanced reference implementation formulas

Category	Component		
	Class D	Class E	Class F
5	$\Sigma_{(i=1\ to\ j)}\ F_i \times Y_i \times Z_i \leq 113 - 2 \times N$ [a]	-	-
6	$\Sigma_{(i=1\ to\ j)}\ F_i \times Y_i \times Z_i \leq 115 - N$	$\Sigma_{(i=1\ to\ j)}\ F_i \times Y_i \times Z_i \leq 106 - N$	
7	$\Sigma_{(i=1\ to\ j)}\ F_i \times Y_i \times Z_i \leq 119 - N$	$\Sigma_{(i=1\ to\ j)}\ F_i \times Y_i \times Z_i \leq 109 - N$	$\Sigma_{(i=1\ to\ j)}\ F_i \times Y_i \times Z_i \leq 106 - N$

NOTE The required channel performance is defined using the formulas provided in this table and based upon a statistical approach of performance modelling.

[a] where

I is the cable section from 1 to j (subject to a minimum of 1 and a maximum of 5);

N is the number of connections (subject to maximum of 4, otherwise NEXT, Return Loss and ELFEXT performance should be verified);

F_i is the length of the cable (m);

Y_i is the ratio of the insertion loss of the cable (dB/m) to the insertion loss of the relevant category of cable (dB/m);

Z_i is the derating of insertion loss of the cords (dB/m) for operating temperatures above 20 °C, defined in Table 13.

Table 13 – Correction factor Z for operating temperature above 20 °C

Cable construction	Correction factor Z	
	20 °C < *T* < 40 °C	40 °C < *T* < 60 °C
Shielded	1 + 0,002 × (*T* – 20)	1 + 0,002 × (*T* – 20)
Unshielded	1 + 0,004 × (*T* – 20)	1 + 0,006 × (*T* – 20)

Where the operating temperature exceeds 60 °C, then manufacturers' information shall be consulted regarding the appropriate factors.

In the case where end connections differ from those specified for the standard channel, the planner shall request that the test equipment is calibrated in accordance with the equipment manufacturer's instructions and the proper test heads.

c) End-to-end link

End-to-end link is as described in Annex O.

d) Balanced 1-pair reference implementation and cabling

For 1-pair reference implementation and cabling, the requirements specified in Annex Q apply.

4.4.3.2.2 Connections minimum distance

Any requirements within the specific CP installation profile for minimum distance between connections shall be applied.

4.4.3.2.3 Balanced cabling splices

Splices shall only be used as a means of temporary repair. Splices shall be done by means that maintain channel performance and environmental integrity. The number of connections shall be taken into account. The recommended solution is to use a plug and jack combination with appropriate environmental integrity. The repaired cable segment should be tested with the appropriate field tester.

4.4.3.2.4 Balanced cabling bulkhead connections

A bulkhead connection that does not have the transmission performance of a single connection shall be counted as two connections.

When the bulkhead connection supports 4 pair to 2 pair conversion (e.g. 8-way modular to M12), accommodations shall be made to terminate the unused pairs differentially. Connection to earth is not allowed either through a capacitor or direct.

NOTE Additional information on bulkhead connection is provided in Annex J. The content of Annex J differs from that of ISO/IEC 11801-3.

A bulkhead cable gland may be used instead of a bulkhead connection when the use of the bulkhead connection is not compatible with the limit of connections in the channel.

4.4.3.2.5 Balanced cabling J-J coupler (J-J adaptor)

A J-J coupler connection that does not have the transmission performance of a single connection shall be counted as two connections in the channel.

J-J couplers are suitable to connect fixed cabling and flexible cabling, for example, for rolling c-track within a machine. J-J couplers are also suitable to provide the connections in a conveyor belt composed of several modules that are plugged together when they are put into operation. Connections in support of replacement of high flex segments shall be counted in the overall channel limits for the number of allowed connections.

4.4.3.3 Copper cabling connections and splices for CPs not based on Ethernet

4.4.3.3.1 Common description

The number of allowed connections versus the fieldbus length shall be as described in the relevant CP.

4.4.3.3.2 Connections minimum distance

See 4.4.3.2.2.

4.4.3.3.3 Copper cabling splices

See 4.4.3.2.3.

4.4.3.3.4 Copper cabling bulkhead connections

See 4.4.3.2.4.

4.4.3.3.5 Copper cabling J-J couplers (J-J adaptors)

See 4.4.3.2.5.

4.4.3.4 Optical fibre cabling connections and splices for CPs based on Ethernet

4.4.3.4.1 Common description

The maximum channel insertion loss specified for the CP (by reference to the ISO/IEC/IEEE 8802-3:2021) defines the possible configurations of the cabling at the specified wavelength as in formula (1).

$$L = 1000 \times \left[A - \sum_{i=1}^{J} M_i - \sum_{i=1}^{K} S_i \right] / C \qquad (1)$$

where

L is the channel length (m);

A is the maximum channel insertion loss/optical power budget (dB);

M_i is the insertion loss specification of each connection (dB);

S_i is the insertion loss specification of each splice (dB);

J is the number of connections in the channel;

K is the number of splices in the channel;

C is the cable attenuation coefficient (dB/km).

The planner shall apply any requirements concerning maximum channel lengths together with numbers of, or specification of, component within the specific CP. Reference should be made to the relevant installation profile (IEC 61784-5 (all parts)) to determine if additional requirements exist.

The optical fibre cable used in the channel should be long enough for the intended installation to prevent having connections and splices. The planner shall instruct the installer to take measures to ensure that the bending of the optical fibre cable does not fall below the minimum bending radius specified for the cable (see 5.2.1.2 and 5.2.1.6).

Further details of bulkhead connections are given in 4.4.3.4.3.

4.4.3.4.2 Optical fibre splices

There are two methods for performing optical splices: mechanical and fusion. They both provide for different losses that have an impact on the insertion loss of the channel. The number of splices allowed is based on the optical power budget of the system and shall be accounted for in the channel loss budget.

4.4.3.4.3 Optical fibre bulkhead connections

The insertion loss of an optical fibre bulkhead connection typically is equivalent to that of one connection.

4.4.3.4.4 Optical fibre J-J couplers (or adaptors)

The insertion loss of an optical fibre J-J coupler or adaptor typically is equivalent to that of one connection. Where it is not, the additional connections shall be considered in the applied formula (see Table 11 and Table 12).

4.4.3.5 Optical fibre cabling connections and splices for CPs not based on Ethernet

The number of allowed connections and splices is limited by the maximum allowable channel attenuation and/or power budget.

The number of allowed connections and splices versus the fieldbus length shall be as described in the relevant CP installation profile.

4.4.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

No additional requirements.

4.4.4 Terminators

4.4.4.1 Common description

Terminators reduce reflections and help to reduce radiations and noise susceptibility in a cabling system. The planner shall consult the CP for the requirements for terminators and their values.

See 4.4.1.2 for additional requirements regarding the termination of all un-used pairs.

4.4.4.2 Specific requirements for CPs

Additional information regarding the terminator requirements for a specific industrial network may be found in the respective installation profile.

4.4.4.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

No additional requirements.

4.4.5 Device location and connection

4.4.5.1 Common description

The devices should be located to provide adequate access for maintenance and troubleshooting consistent with the required channel performance. In addition environmental conditions, routing of the cable and connectivity considerations shall be given (see 4.4.11.1).

4.4.5.2 Specific requirements for CPs

Additional information regarding the device location and connection requirements for a specific industrial network may be found in the respective installation profile.

4.4.5.3 Specific requirements for wireless installation

None.

4.4.5.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

Generic cabling shall only be installed in areas where critical applications will not be subject to environmental conditions typical of the automation islands.

Generic cabling installed in automation islands shall only serve applications (voice, video, etc.) that are not dangerously affected by the environmental conditions typical of the automation islands.

4.4.6 Coding and labelling

4.4.6.1 Common description

Coding or labelling should be used in the plant (and referred to in the as-implemented cabling documentation) in such a way to facilitate the work of inspection and replacement of the network components. Colour coding provides easy identification between optical fibre cabling and balanced cabling.

NOTE See Clause 7 for additional information.

4.4.6.2 Additional requirements for CPs

Cables and AOs should be labelled in accordance with the system drawings. Labelling of connectors and/or cables (balanced and optical fibre) should be used for easy identification. Security shall be taken into account when deciding coding and labelling.

Means for identifying optical fibre polarity shall be provided.

4.4.6.3 Specific requirements for CPs

Additional information regarding coding and labelling requirements for a specific industrial network may be found in the respective installation profile.

4.4.6.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.7 Earthing and bonding of equipment and devices and shielded cabling

4.4.7.1 Common description

4.4.7.1.1 Basic requirements

When portions of generic cabling are used to support communication for a given CP, those portions of generic cabling shall conform to the requirements of the CP.

The earthing and bonding of equipment and the use of shielded cabling are very important aspects of the cabling installation.

Earth potential differences between cabling end points will induce noise in the cabling system. This is especially true in shielded cabling systems. Controlling earth currents is extremely important in reducing interference caused by earth offsets. Shield currents shall be mitigated by using a proper earthing system and or proper shield earthing techniques as defined in this document and the relevant CPs. If this requirement cannot be met, then alternate media, such as unshielded cables, optical fibre cables, or wireless, shall be considered.

Building and plant earthing wiring systems are implemented according to local, national or international regulations and standards (such as IEC 60364-4-41 and IEC 60364-5-54). If conformance is required, then the network planner/installer and verifier shall obtain confirmation that the facility conforms to the applicable standards and the relevant CP.

4.4.7.1.2 Planner tasks

The planner shall perform the following tasks.

- **Requirement 1**
  – The planner shall check with the owner of the building and plant the implemented configuration of the earthing system of the building and plant and the value of the earth resistance.
- **Requirement 2**

  For the connections to the existing building and plant earthing system, the network installation planner shall specify the following requirements for proper connection.

  – A quality of the earthing connections requirement as defined in 5.7.1.

  A common bonding network (CBN) with the required earth impedance and high current carrying capacity formed by all metallic constructional components shall be available.

  – In order to insure long-term reliability, appropriate measures shall be performed to protect earthing cables and connections against corrosion.

Methods for controlling potential differences in an earth system and selection of the earthing and bonding systems shall be as described in 4.4.7.1.3.

4.4.7.1.3 Methods for controlling potential differences in the earth system

The planner shall design the earthing of the industrial communication network in accordance with this document and the relevant installation profile. IEC TR 61000-5-2 gives additional guidance.

There are two proven earthing methods: equipotential and star (see 4.4.7.3). The planner shall use one of these to reduce the effects of earth offsets.

If this is not possible, then alternate transmission media shall be used (such as unshielded cables, optical fibre cables, or wireless).

4.4.7.1.4 Selection of the earthing and bonding systems

The planner should have a complete understanding of the condition of the existing earthing and bonding system of the building/plant in the network coverage area. If there is an adequate earthing and bonding system present, the complete system can be handled without division into earth sub-systems. If this is not the case, then the system should be split into earthing sub-systems. Each earthing sub-system may then use any of the proven earthing and bonding methods as required by the applicable CP installation profile. The planner should provide advice to the machine tool builder regarding the earthing scheme implemented in the facility and to design the earthing of the machine according to the scheme in the facility and the specific installation profile. The flowchart in Figure 14 is provided to help the planner in determining how to proceed.

The earthing and bonding system shall be constructed by cables, bus bars, and other components in accordance with EN 50310 and shall not consist of pathways and building steel. Pathways and building system shall be bonded to the earthing and bonding system.

The planner shall document the chosen earthing system (mesh earthing or star earthing) for the complete communication network. Annex E recalls the reasons for using a specific system for power network.

4.4.7.2 Bonding and earthing of enclosures and pathways

4.4.7.2.1 Equalisation and earthing conductor sizing and length

The equalisation conductors and earthing conductors shall have a resistance $< 1\ \Omega$ (see 5.7.1).

The planner should require that the length of all equalization conductors and earthing conductors be cut to minimum lengths. Coiling of excess grounding and equalization conductors is not permitted as this decreases the effectiveness of the grounding and equalization conductors. Figure 13 shows the relationship between the cross-sectional area and the maximum length of the conductor.

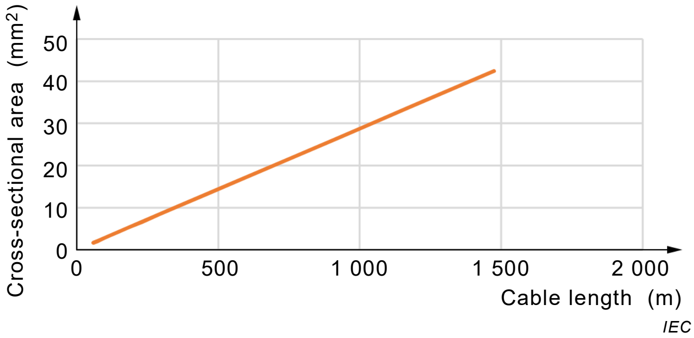


Figure 13 – Equalisation and earthing conductor cross-sectional versus maximum length

Table 14 shows maximum length values that correspond to typical standard cross-sectional areas expressed in mm^2 (see Annex F for the complete list of IEC 60228 and AWG values). These maximum length values are based on providing a maximum resistance of 0,6 Ω in order to ensure that the maximum resistance value of 1 Ω is not exceeded between the enclosure and the pre-existing earthing and bonding point.

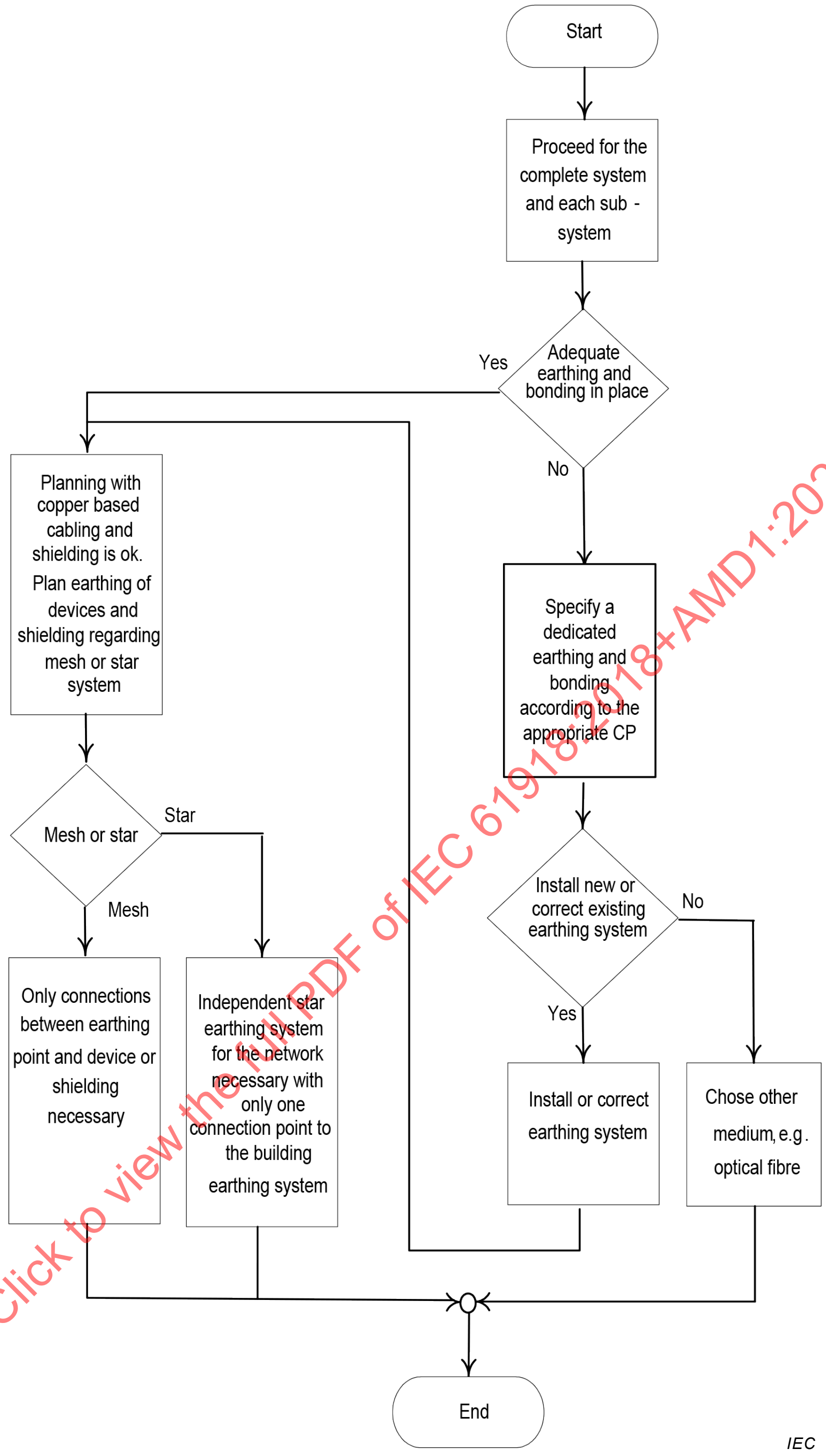


Figure 14 – Selection of the earthing and bonding systems

NOTE Long earthing conductors could increase earth impedance, rendering the earthing ineffective in lightning events.

For needed length equalization, conductors and earthing conductors shall have a cross-sectional area with a value not less than the value shown in Table 14 for a maximum lengths that is higher than the one requested. The length of earth straps should be no less than 25 mm (1 inch). Local regulations may require additional earthing conductor requirements.

Table 14 – Equalisation and earthing conductor sizing and length

Cross-sectional areas mm^2		Maximum length m
IEC 60228	AWG	[a]
	8,36 (8 AWG)	291
10		349
	10,5 (7 AWG)	368
	13,3 (6 AWG)	461
16		556
	16,8 (5 AWG)	582
	21,1 (4 AWG)	736
25		870

[a] Length of a conductor having a resistance R = 0,6 Ω.

4.4.7.2.2 Bonding straps and sizing

Bonding straps shall be constructed of copper or zinc plated steel (see Table 15 which provides data taken from IEC 60364-5-54).

The bonding straps should preferably be stranded to ensure that the connection is also effective at high frequencies as a result of the large surface area.

Table 15 – Bonding straps cross-section

Material	Minimum cross-section mm^2
Copper	6
Zinc plated steel	50

Table 16 (with data taken from IEC 60364-5-54) provides requirements for bonding plate's surface protection.

Table 16 – Bonding plates surface protection

Material	Surface protection	Thickness µm
Copper	Bare	None
	Tin-coated	1 to 5
	Zinc-coated	20 to 40

4.4.7.2.3 Surface preparation and methods

The cabling planning documentation shall require that all connections to metallic surfaces be prepared in a way to provide a low resistance of the connection and enduring protection against corrosion. Subclause 5.7.2.3 provides additional guidance to the installers on making good connections to metallic surfaces.

4.4.7.2.4 Bonding and earthing

The planner shall require the following.

a) Earthing connections for the cabinets shall not be daisy chained.

b) Where two independently moving metallic pathways are separated, a flexible bonding strap shall be used to bond the two metallic sub pathways together (see Figure 31).

c) Where two metallic pathways are mechanically connected using solid metal straps, a separate flexible bonding strap may be used.

d) Expansion joints and joint connections shall be bridged by flexible bonding straps (see Figure 31).

e) All inactive metal parts, particularly in the immediate vicinity of automation components and communication cables, shall be bonded to the earthing system. This includes all metal parts of cabinets, construction and machine parts, etc., that do not have any electrical conducting function in the automation system.

f) If an equipotential system is required, metallic conductive cable pathways shall be included in the equipotential bonding of the system and between the individual system sections. The planner shall specify how often the pathways shall be connected to the equipotential bonding system.

g) The individual segments of the cable pathways shall be connected at low impedance with each other.

h) Earthing conductors shall be kept as short as possible.

i) Excess lengths of earthing and bonding conductors shall not be coiled.

j) Earthing conductors and equalisation conductors shall be placed nearest to the metallic pathway where they are installed, to reduce the impedance of the earth circuit (Figure 15). Attention shall be paid to the fact that the noise changes the impedance of the earthing conductors and equalisation conductors in function of its frequency. The graph in Figure 16 shows the consequences of increasing the length of the earthing and or the equalizations conductor without increasing the wire gauge.

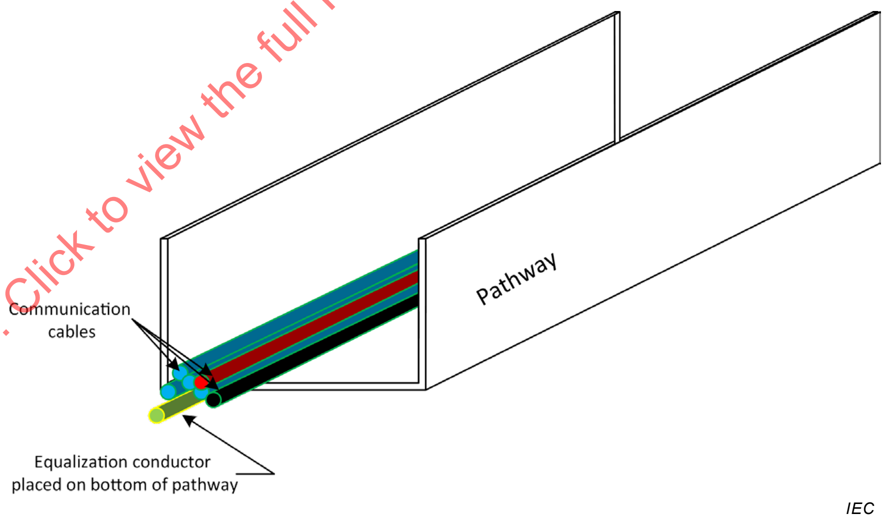


Figure 15 – Placement of equalisation conductors

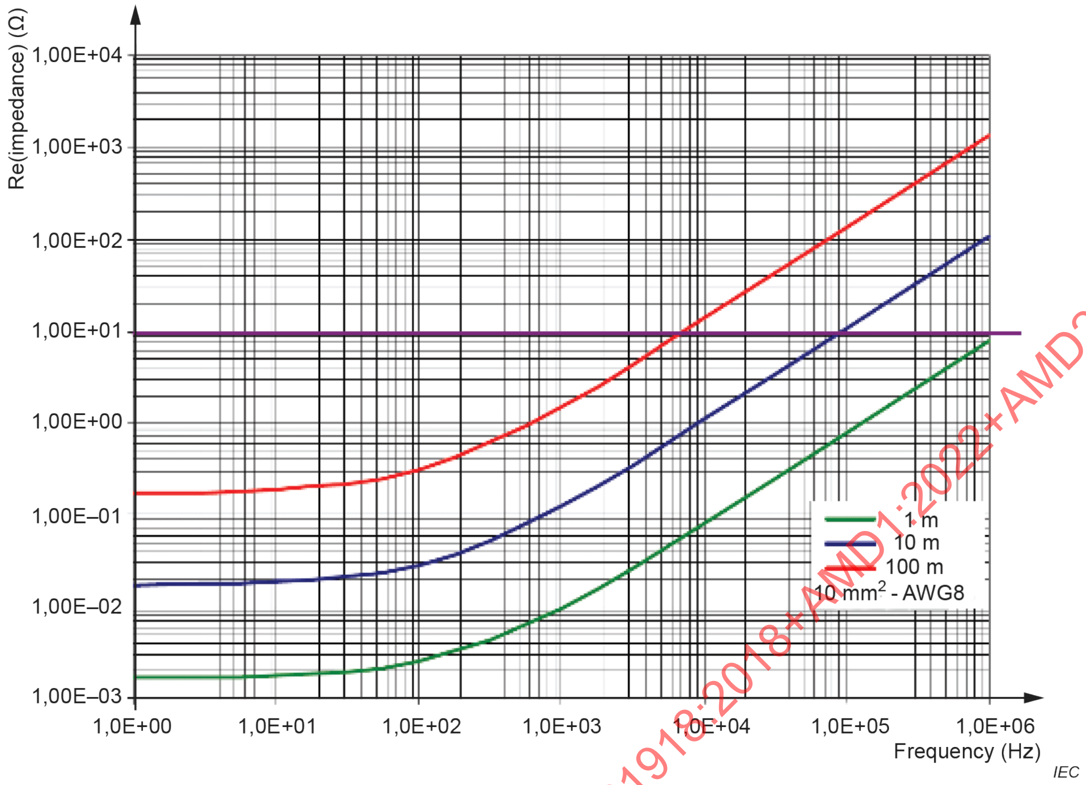


Figure 16 – Impedance of the earthing conductors and equalisation conductors versus noise frequency

4.4.7.3 Earthing methods

4.4.7.3.1 Mesh

Figure 17 shows an example of wiring for bonding enclosures, pathways and wiring of the earths arranged as a mesh to implement an equipotential earthing configuration.

The potential equalization cables shall be specified in accordance with 4.4.7.2.

If earth current cannot be controlled, this may cause component failure or communications faults. In this case, alternate media should be considered.

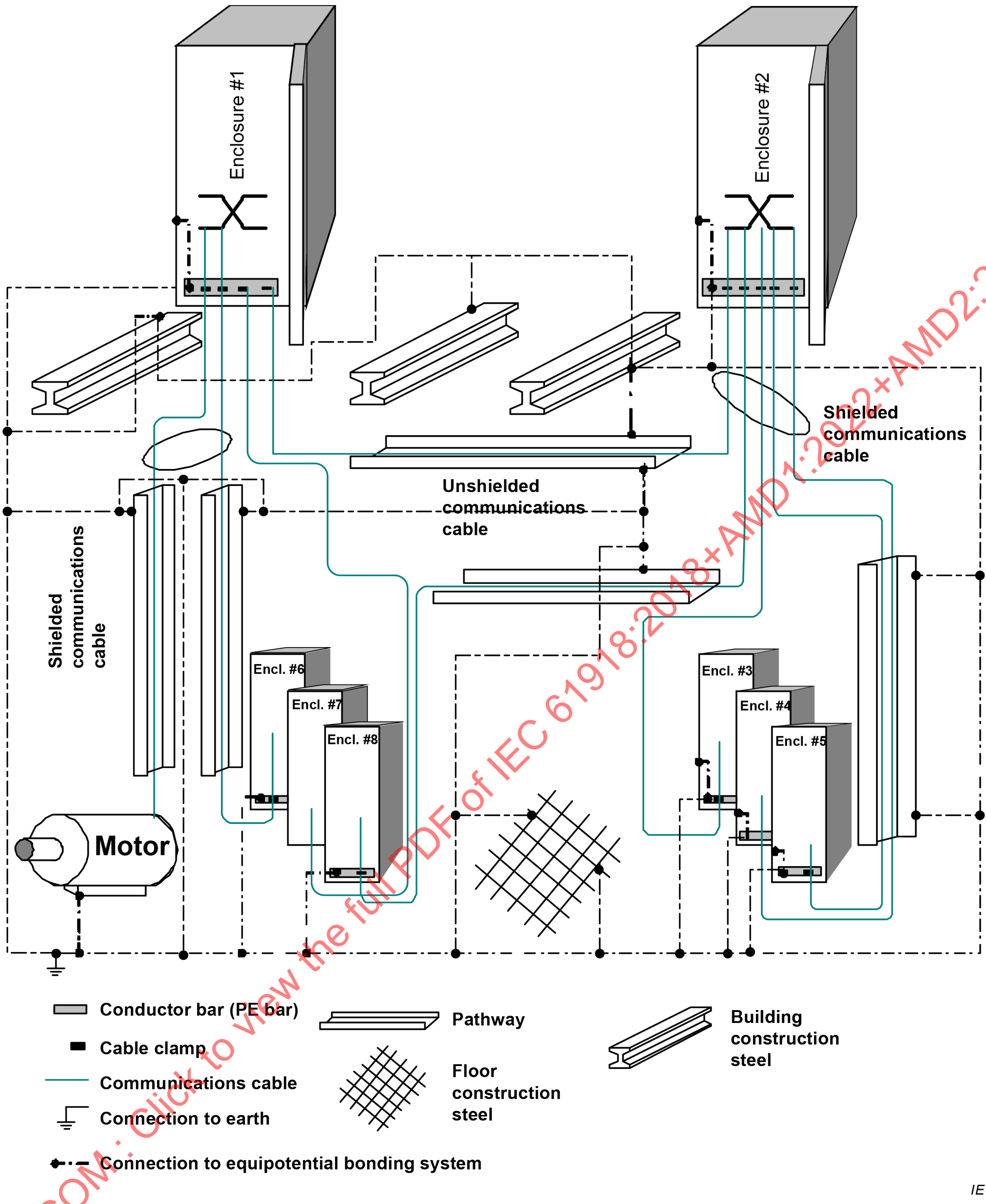


Figure 17 – Wiring for bonding and earthing in a mesh configuration

Local, national or international safety earthing standards shall be applied.

NOTE Safety always takes precedence over EMC.

4.4.7.3.2 Star

Currents in earth paths generated by high currents can be controlled by the means of a star earthing system and by isolating the signal earth from the equipment earth. This is accomplished by providing two star earths, one for the equipment and a second for the communication equipment. Shields for the communication equipment shall be referenced only to the signal earth and no equipment shall be referenced to the signal earth. Each of the star earths of the two systems shall converge to one point within the building, as shown in Figure 18.

When the devices are required to be connected to a functional earth system that is isolated from the protective earth system at the enclosures, the planner shall specify the method to be used for the isolation. Isolated bus bars can be used to create a signal earth or functional earth (see Figure 33).

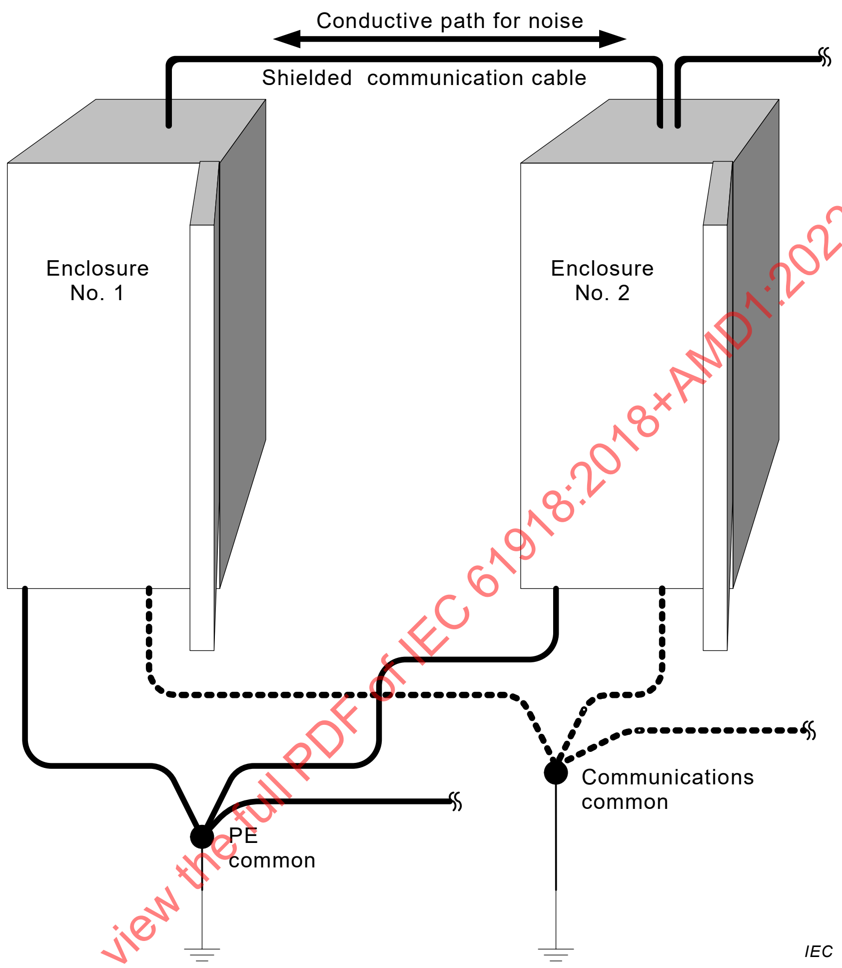


Figure 18 – Wiring of the earths in a star earthing configuration

4.4.7.3.3 Earthing of equipment (devices)

Equipment is normally earth connected, whereby the equipment's functional earth (M) is connected to the protective earth (PE) over a large area (see Figure 19). In exceptional circumstances, equipment can be arranged as a non-earthed system. This may be necessary if high short-circuit currents can occur (induction furnaces, etc.). In a non-earthed system, it is necessary to provide an insulation-monitoring device with a voltage limiter as shown in Figure 20. The term "non-earthed" is also used if a parallel RC circuit is fitted between the communication shield and earth. Many devices are fitted with a parallel RC circuit of this type to improve the interference immunity. This should be considered when choosing an earth-leakage monitor. In addition, the non-earthed arrangement ensures that uncontrolled equalisation currents do not damage or disrupt communication devices on the bus. The relevant safety regulations shall be observed.

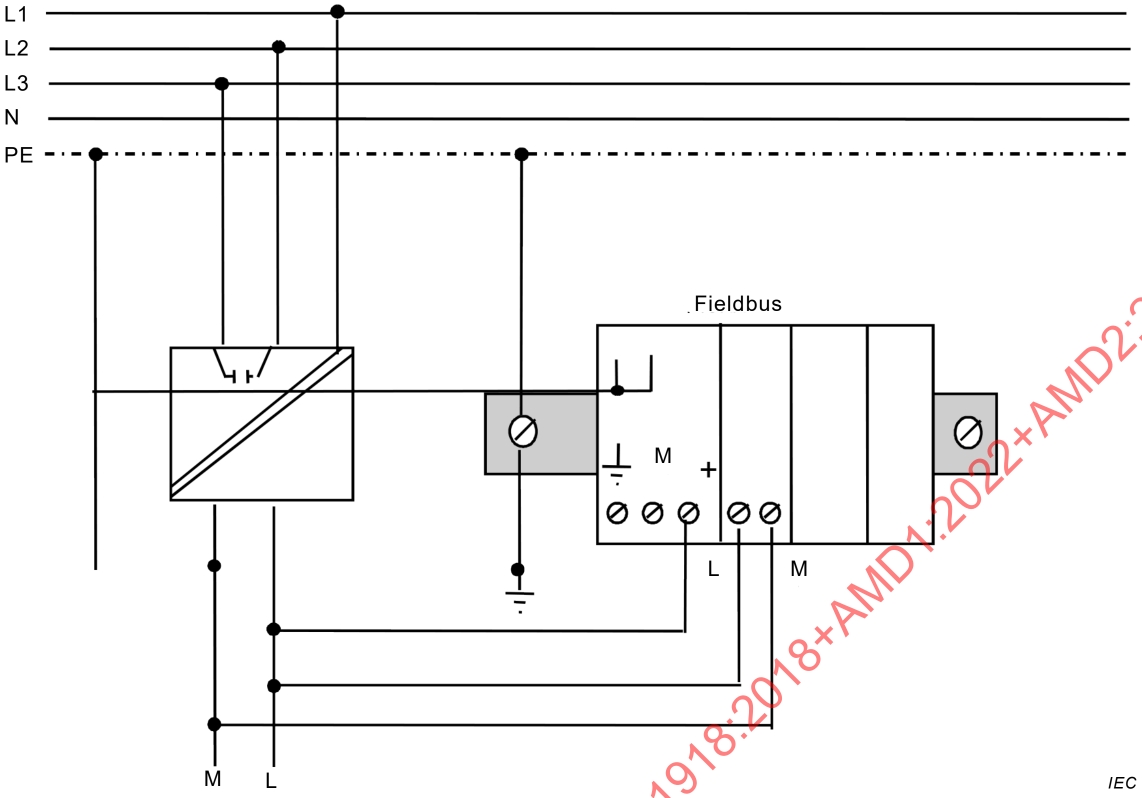


Figure 19 – Schematic diagram of a field device with direct earthing

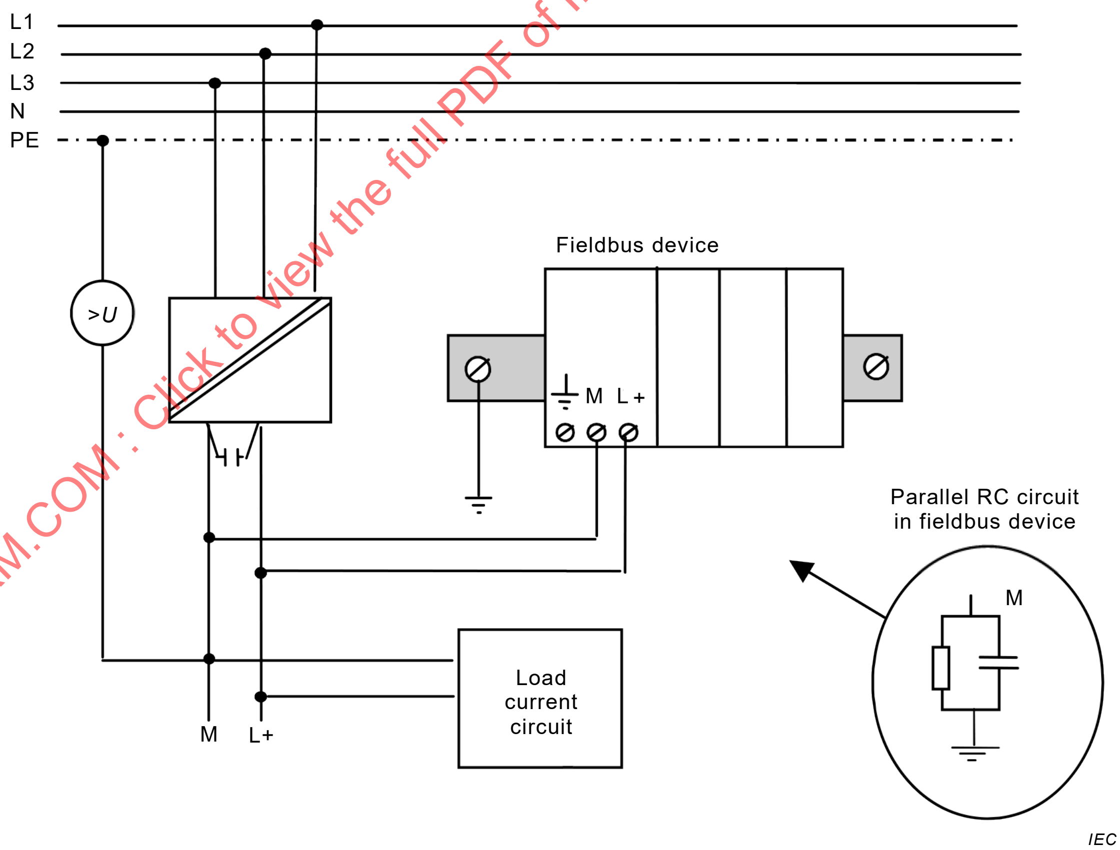


Figure 20 – Schematic diagram of a field device with parallel RC circuit earthing

4.4.7.3.4 Copper bus bars

Bus bars shall be used for the interconnection of earthing conductors.

Bus bars shall be selected and interconnected in accordance with local, national and international regulations and standards.

Bus bars shall be constructed of copper or copper alloys having a minimum conductivity of $5{,}52 \times 10^7$ S/m (95 % IACS) when annealed as specified by International Annealed Copper Standard and shall be finished with either tin coated surfaces or galvanically stabilized surfaces.

The bus bar shall be sized to carry noise currents and fault currents, which are anticipated in the installation environment, and to provide the mechanical capability for connection of the earthing conductors.

The bus bar impedance is seen in series to all earthing conductors connected to it. For fault current capability, the bus bar cross sectional area shall be at least five times the cross sectional area of the earthing conductor connected to the bus bar; considering the largest earthing conductor listed in Table 14 it shall be at least 125 mm^2. A maximum useful thickness of 9,25 mm is determined by the skin effect at 60 Hz. The minimum thickness value shall be 5 mm for mechanical capability; in this case, the minimum width shall be 25 mm. The bus bar width shall provide full coverage of the connecting hardware.

The bus bar length shall be as needed to support the number of connection of all the earthing conductors, with the maximum length given by formula (2).

$$L_{ma}x = Z_{max} \times P \times \partial \times 10^{-6} / \rho \qquad (2)$$

where

L_{max} is the maximum length in m;

Z_{max} is the maximum impedance in Ω;

P is the perimeter of the cross section of the bus bar, in mm;

∂ is the skin depth in mm at a given frequency; for copper, its value is 65,4 mm/$\sqrt{v}$ where v is the unit less value of the frequency in Hz and for copper alloy annealed as specified above is 67,6 mm/$\sqrt{v}$;

ρ is the resistivity of the conductor. For copper, its value is $1{,}68\ 10^{-8}\ \Omega \times$ m (at 20 °C) and for copper alloy annealed as specified above is $1{,}81\ 10^{-8}\ \Omega \times$ m (at 20 °C).

EXAMPLE 1 L_{max} = 3,6 m, with Z_{max}= 0,1 Ω at 50 MHz for a copper bus bar having a sectional perimeter of 60 mm.

EXAMPLE 2 L_{max} = 0,7 m, with Z_{max}= 0,1 Ω at 1 GHz for a copper bus bar having a sectional perimeter of 60 mm.

Bus bars should be supplied with pre-punched holes for use with cable terminating lugs.

The bus bar shall be used in accordance with 5.7.2.3. When it is necessary to isolate a copper bus bar, the isolation to the local earth shall be > 2 MΩ.

4.4.7.4 Shield earthing

4.4.7.4.1 Non-earthing or parallel RC

The planner shall specify if the installer shall use shield termination earthed with a parallel RC circuit (see Figure 35). In addition, the planner shall make aware the installer of the fact that non-earthed shield termination could affect the integrity of the shield due to the dangerous noise currents caused by the earth offset.

When the communication shields are required to be earthed directly at both ends, then the bonding method shown in Figure 17 shall be used.

4.4.7.4.2 Direct

The planner shall specify if the installer shall use the direct shield earthing, as represented in 5.7.4.3.

If the voltage offset between two communicating devices, which are directly connected to earth, exceeds 1 V at 50/60 Hz, then an equalization conductor shall be added to mitigate the voltage offsets that might otherwise create current through communication shields (see Figure 38). The cross-sectional area shall be in accordance with 4.4.7.2.1, 4.4.7.2.4 and 5.7.2.1. The planner shall document the requirements for this conductor in the cabling planning documentation.

4.4.7.4.3 Derivatives of direct and parallel RC

The planner shall specify which derivatives of direct and of parallel RC shield earthing shall be used by the installer. Examples of derivatives are provided in 5.7.4.4.

4.4.7.5 Specific requirements for CPs

Additional information regarding earthing and shielding requirements for a specific industrial network may be found in the respective installation profile.

4.4.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.8 Storage and transportation of cables

4.4.8.1 Common description

The planner shall require that manufacturer's handling and storage requirements be met during transportation, storage and installing in accordance with the specified local environmental conditions. To protect cable ends from corrosion, the cables should be kept sealed at both ends until installed and terminated.

4.4.8.2 Specific requirements for CPs

Additional information regarding storage and transportation requirements for a specific industrial network may be found in the respective installation profile.

4.4.8.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.9 Routing of cables

4.4.9.1 Common description

Subclause 4.4.9 describes the requirements for CPs cable routing inside buildings and enclosures and outside buildings and provides guidance on the routing of earthing conductors, communication cables and pathways.

NOTE 1 The requirements for routing of cables as they relate to generic cabling are provided in ISO/IEC 14673-2.

- Cable routes shall be selected to minimize noise coupling and crosstalk.
- Excess cables shall be dressed to minimise noise coupling from adjacent radiators, i.e. shaped like an 8 with a length of 0,3 m to 0,5 m and maintaining correct bending radius.

- Cables (optical fibre and balanced) shall be routed in such a way that they are protected from damage.
- Cables shall be grouped according to the circuit types as defined in Table 17.
- Cable routes for networks supporting functional safety systems should be implemented in accordance with the specified precautions. It could help using unique labelling and colouring to uniquely identify this cabling.

In addition the planner shall request not to bundle cables, because this may lead to heat build-up.

For the placement and protection of cables other than pre-manufactured assemblies (see 4.4.9.2) the planner shall require the use of cable pathways. Cable pathways shall be in accordance with ISO/IEC 14763-2:2012. The selection of the cable pathway system shall take into account the environmental conditions. The cable supplier's instructions shall be consulted to confirm that the selected pathway system is appropriate for the cable to be installed.

The planner shall request that the pathway systems used for EMC purposes are installed in accordance with the following rules (see Figure 31).

- A solid metallic wall construction shall be used. Meshed grating structures are only allowed if they provide the required level of EMC protection. Wire pathways and pathways with vents shall be avoided.
- Pathways shall be connected by using rigid metal straps with maximum coverage of the gap.
- The connection with braided straps is only allowed when the connected two parts of the pathway system are expected to move independently from each other.

The planner should request that a single braided strap between two parts of the pathway system is not used due to degraded electromagnetic performance caused by high local impedance.

NOTE 2 From frequencies of a few MHz upwards, a 10 cm braided strap between the two parts of the cable management system would degrade the impedance by more than a factor of 10.

Appropriate cable pathways and pathway systems shall be specified to ensure that cables are protected from damage and that suppliers' specifications for bending radius, tensile strength, crush resistance and temperature range are complied with during installation and operation.

Information technology cables containing flammable material (for example polyethylene sheaths) shall either be

a) terminated inside the building, within 2 m (or an alternative distance if defined by national or local regulations) of the point of internal penetration of the fire barrier (for example, floor/ceiling/wall), or
b) installed within trunking or conduit that is considered as fire barrier in accordance with local fire regulations.

4.4.9.2 Cable routing of assemblies

The planner shall not define cable routes that require installing cables near the following:

- lights,
- motors,
- drive controllers,
- arc welders,
- induction heaters,
- RF fields (transmitters),

- antennas.

The planner shall assure that pre-manufactured subassemblies of an automation system shall be designed in accordance with 4.4.10.

The appropriate high flex cable shall be used in a rolling "C" track application. Cables shall be rated appropriately for use in applications requiring constant movement of cables such as robotic applications where the cable is moved in a bending flex fashion (see 4.4.1.5).

4.4.9.3 Requirements for cable routing inside enclosures

The planner shall specify:

a) the requirements for the pathways to be used (for example, continuous metallic, non-continuous metallic, non-metallic);

b) that the cables shall be separated into individual bundles according to the circuit type as defined in Table 17 of 4.4.10;

c) that the cable shield shall be continuous and terminated in accordance with the manufactures instructions and CP installation profile.

4.4.9.4 Cable routing inside buildings

In addition to the requirements specified in 4.4.9.1, the planner shall require the following.

a) Communication cables routed inside buildings shall be separated from other cable circuits as specified in Table 17.

b) When installed in metallic pathways, the pathways shall be earthed and bonded in accordance with Figure 16.

c) If communication cables share the same pathway with other cable circuits, they may require isolation by means of metallic partitions. The metallic partition shall be selected in accordance with the behaviour needed from an EMC point of view (see Figure B.5).

d) If only one metallic pathway is available for the several cable circuit types, communication cables and low-voltage power cables or the individual cable circuit types shall be isolated from each other by a metallic partition. The partition shall be directly connected to the pathway.

4.4.9.5 Cable routing outside and between buildings

The rules described in 4.4.9.4 also apply for installing cabling outside buildings. Cables installed between buildings shall be segregated for physical protection (e.g. by using a plastic pipe).

Copper cabling installed above earth shall be protected from lightning where appropriate.

The planner should consider the use of optical fibre cables for connections between buildings and between buildings and external facilities where lightning is a problem and/or where there is a large potential earth offset between the buildings and external facilities.

4.4.9.6 Installing redundant communication cables

Redundant cables should always be installed in separate cable routes in order to prevent simultaneous damage. Labels and distinctive cable/conduit colouring should be used as a means of distinguishing between redundant cables (see 4.4.6). The planner may require additional measures in accordance with IEC 62439.

4.4.10 Separation of circuits

Table 17 defines the minimum distances between circuit types inside and outside buildings.

Requirements in Table 17 apply to all cabling.

Table 17 – Cable circuit types and minimum distances

Circuit type	Cables for	Distance for routing outside enclosure	Distance for routing inside enclosure or metallic pathway
AC power lines of greater than 100 kVA High-power digital AC I/O High-power digital DC I/O Power connections (conductors) from motion drives to motors	Motors Motor drives Secondary spark welders, power mains	0,6 m (24 in)	0,3 m (12 in)
Analog I/O lines and analog circuits Low-power digital AC/DC I/O lines Communication cables for control AC power lines of 20 A or more, but only up to 100 kVA	Switched I/O Solenoid Contactors	0,3 m (12 in)	0,15 m (6 in)
Low-voltage DC power lines Communication cables to connect between system components within the same enclosure Process signals (≤25 V) Unscreened DC voltages (≤60 V) Unscreened AC voltages (≤25 V) Conductors of less than 20 A	DC power supplies Low-voltage DC I/O	0,15 m (6 in)	0,08 m (3 in)
Electric light and power	Minimum distance: 8 cm (3 in): 0 V to 100 V: 8 cm (3 in) 101 V to 200 V: 11 cm (4 in) 201 V to 300 V: 13 cm (5 in) 301 V to 400 V: 16 cm (6 in)		

4.4.11 Mechanical protection of cabling components

4.4.11.1 Common description

Install cabling components in areas that provide protection from damage from machine movement including tow motors.

Additional protection may be required to prevent damage from falling objects, liquid, heat and sparks.

The connectors specified in the installation profile shall be used in the bulkhead connection assemblies.

4.4.11.2 Specific requirements for CPs

Additional information regarding mechanical protection of cabling components requirements for a specific industrial network may be found in the respective installation profile.

4.4.11.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.4.12 Installation in special areas

4.4.12.1 Common description

Cable construction or protection shall be selected based on characteristics of the area or application. For example, weld-spatter applications require weld-spatter cabling or protective sheathes over the cabling.

Documents for installation implementation shall be provided.

4.4.12.2 Specific requirements for CPs

Additional information regarding installation on special areas requirements for a specific industrial network may be found in the respective installation profile.

4.4.12.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.5 Cabling planning documentation

4.5.1 Common description

Cabling planning documentation shall be produced based upon the requirements of 4.1, 4.2, 4.3, and 4.4 and shall contain the elements listed in 4.5.2, 4.5.3, and 4.5.4 as appropriate, that shall be collected in documents organised and named in accordance with IEC 62708.

4.5.2 Cabling planning documentation for CPs

The cabling planning documentation should contain the following information:

- specified environment;
- location of each AO;
- location of interconnections;
- location of connection for device;
- topology;
- earthing, bonding, and shielding requirements;
- cable type (shielded, unshielded, optical fibre, etc.);
- additional cable requirements to meet the specified environment (flex, liquid or dust ingress rating, temp, etc.);
- length of cable section;
- pathways type (cable tray, conduit, duct, metallic rack, etc.);
- placement instructions for the cables (routing);
- labelling instructions for AO and cables;
- type of connector, including sealing requirements, for the specified environment, and pin pair assignment;
- connector installation requirements;
- required mitigation;
- required channel/ permanent link performance;
- life cycle of cabling;
- designation of the areas containing optical fibre cabling in accordance with IEC 60825-2;
- list of tests required;

- a table for comparison of nominal and actual network performance values;
- list of spare parts;
- planner's compliance statement (see 4.1.3).

4.5.3 Network certification documentation

If electrical safety certification is required, then the planner shall define the required documents and the list of actions to be taken to obtain the certification and the required documents.

4.5.4 Cabling planning documentation for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

4.6 Verification of cabling planning specification

The planner shall verify that the cabling planning work is fully and correctly documented as described in 4.1.3 and specifically shall verify the following:

- components for the design match the specified environment;
- adequate plant/building earthing system exists to support the required communication performance.

5 Installation implementation

5.1 General requirements

5.1.1 Common description

The installation shall be performed in accordance with the cabling planning documentation (see 4.5). The installer shall consult with the planner before deviating from the installation specification. All agreed deviations shall be recorded in the cabling planning documentation.

The requirements specified in this Clause 5 for the CPs also apply for the installation implementation of balanced 1-pair networks specified in Annex Q.

Additional requirements are specified in Clause Q.3.

5.1.2 Installation of CPs

For cabling in support of CPs specified in IEC 61784 (all parts), the installation personnel (termed "the installer" in this document) shall be familiar with the appropriate installation profile of IEC 61784-5 (all parts).

5.1.3 Installation of generic cabling in industrial premises

For generic cabling in accordance with ISO/IEC 11801-3, the requirements and recommendations for installation shall be in accordance with ISO/IEC 14763-2.

5.2 Cable installation

5.2.1 General requirements for all cabling types

5.2.1.1 Storage and installation

The cabling components shall be transported, stored, and installed in accordance with the manufacturer's guidelines and 4.4.8.

In addition, requirements in the cabling planning documentation (4.4.8) shall be applied.

5.2.1.2 Protecting communication cables against potential mechanical damage

Communication cables shall not be subject to mechanical loads that exceed the manufacturer's specifications and the values or range of values defined in the installation profile according to the templates given in Table 18, Table 19, Table 20, and Table 21. Cable pathways and pathway systems specified by the planner shall be installed in such a way to ensure that cables are protected from damage and that suppliers' specifications for bending radius, tensile strength, crush resistance and temperature range are complied with during installation.

NOTE Examples of values or of range of values are provided in the installation profiles of CPs.

Table 18 – Parameters for balanced cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Table 19 – Parameters for silica optical fibre cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Table 20 – Parameters for POF optical fibre cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Table 21 – Parameters for hard clad silica optical fibre cables

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	
	Bending radius, multiple bending (mm)	
	Pull forces (N)	
	Permanent tensile forces (N)	
	Maximum lateral forces (N/cm)	
	Temperature range during installation (°C)	

Communication cables should be protected by a continuous enclosed metallic conduit or by a steel cable tunnel in pathway areas of building and machine sections as well in the region of transport routes and throughways.

The cable supplier's instructions shall be consulted to confirm that the selected pathway system is appropriate for the cable to be installed.

Pathway systems shall be as specified by the planner and installed to eliminate the risk of damage from sharp edges or corners. Edge protection should be used as shown in Figure 21. Where required, the installer shall install pathways which provide protection from water or other contaminant liquids.

Pathways shall be kept clean and free from obstruction with all separators and bridging pieces in place before the installation of cabling. Access points shall not be obstructed.

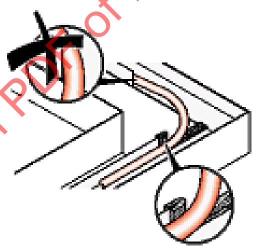


Figure 21 – Insert edge protector

Where the cable is to be pulled within shared pathways, the installer shall take precautions to prevent damage to both new and existing cables or structures.

Redundant cables should always be installed in separate cable routes in order to prevent simultaneous damage through the occurrence of the same event (see 4.4.9.6).

5.2.1.3 Avoid forming loops

When pulling cables into pathways, the installer shall use a suitable cable spool management method to prevent damage caused by torsion and looping (see Figure 22).

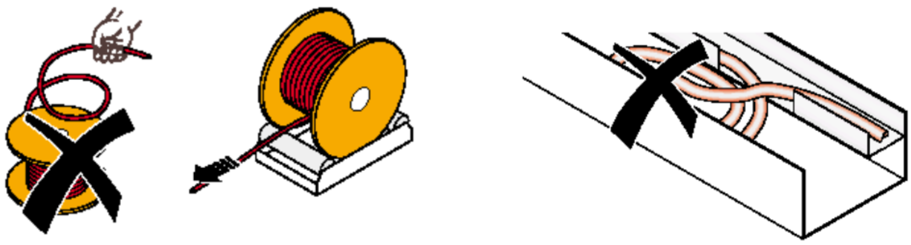


Figure 22 – Use an uncoiling device and avoid forming loop

5.2.1.4 Torsion (twisting)

Torsional stress can result in shifting individual cable construction elements and therefore may have a negative influence on the electrical properties of the cable. For this reason, communication cables shall not be twisted as shown in Figure 23, unless they are specially designed cables for torsional strain (for example in robotic applications).

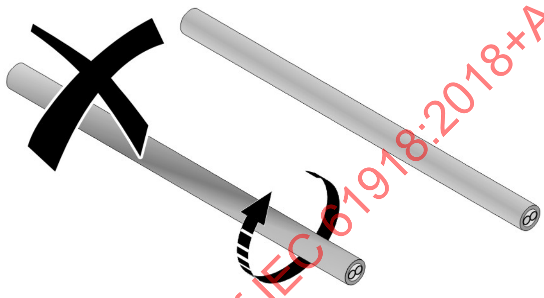


Figure 23 – Avoid torsion

5.2.1.5 Tensile strength (on installed cables)

When installing additional cables in pathways, the installer shall use installation methods that ensure that the tensile strength limits of the installed cables are not exceeded.

5.2.1.6 Bending radius

The minimum-bending radius of a cable is as specified in 5.2.1.2, in accordance with the manufacturer's data sheet. The bending radius shall not fall below the specification at any time.

NOTE 1 Failure to observe this requirement could result in permanent degradation in the cable's electrical or optical performance.

NOTE 2 The bending radius of a cable is affected by the following.

- Bending radius is greater while pulling it under tensile load than in a resting, installed state.
- Bending radius only applies for the flat side when bending flattened cables. Bending over the rounded side requires much greater radii.

It is recommended to secure cables with cable clamps when installed at a right angle and with proper strain relief as shown in Figure 24.

NOTE 3 Over-tightening the clamps could crush the cable.

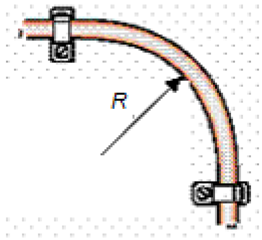


Figure 24 – Maintain minimum bending radius

5.2.1.7 Pull force

The permitted pull force of a cable is as specified in 5.2.1.2, in accordance with the manufacturer's data sheet. The pull force acting on the cable shall not exceed the maximum tensile strength of the cable during handling (for example rewinding) or when installed. Cables shall not be pulled by the individual wires or optical fibres as shown in Figure 25.

Install a pulling grip to the end of the cable to be pulled. This helps to reduce the strain on the cable while pulling into pathways. Wire rollers should be used to reduce the strain on the cable while pulling into the pathway.

Figure 25 – Do not pull by the individual wires

5.2.1.8 Fitting strain relief

A strain relief component shall be fitted at a distance of about 1 m from the connecting point of all cables subject to tensile forces (see Figure 26).

NOTE 1 Cable clamps attached to shielding sheaths are not sufficient as strain relief.

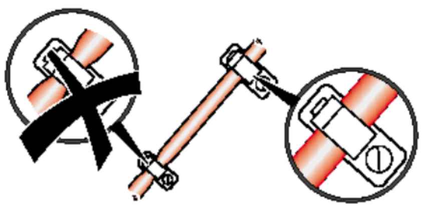


Figure 26 – Use cable clamps with a large (wide) surface

Cables shall be properly strain relieved when hanging from ceilings in pendant applications.

Cable clamps shall be used to secure cables in place within control cabinets.

NOTE 2 Over-tightening the clamps could crush the cable.

Cables shall be secured using fabric hook-and-loop or plastic fastening elements with a large surface to avoid deforming the cables. The fastening elements should have a width of at least 5 mm (0,197 in) and should be fastened without power tools.

5.2.1.9 Installing cables in cabinet and enclosures

Cable wire glands with bending protection or other suitable methods shall be used to prevent cable damage due to exceeding the minimum bending radius of the cable (see Figure 27).

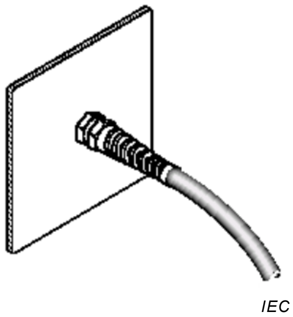


Figure 27 – Cable gland with bending protection

5.2.1.10 Installation on moving parts

Where cables are installed on or between moving parts (for example doors in industrial enclosures/control cabinets), they shall be protected by appropriate fittings to prevent the specified bending radius being compromised (see Figure 28).

5.2.1.11 Cable crush

Cables shall be protected from being crushed. Proper placement of cables or mechanical protection shall be used.

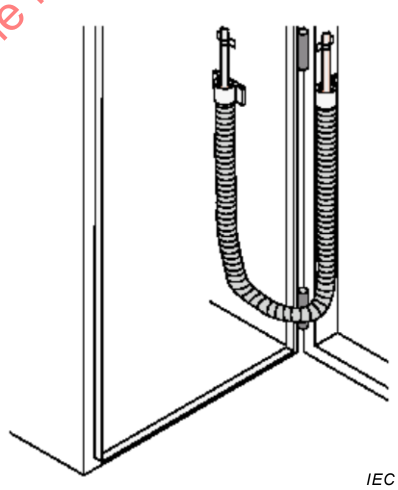


Figure 28 – Spiral tube

5.2.1.12 Installation of continuous flexing cables

Where cables are installed on rolling “C tracks” they shall be laid straight and parallel to the movement of the track. In addition, the separation rules from other circuits shall be observed. The appropriate high flex cable shall be used in a rolling "C" track application. Continuous flexing cables shall be installed in accordance with 4.4.1.5.

5.2.1.13 Additional instructions for the installation of optical fibre cables

5.2.1.13.1 Use cable pulling tools

Cable pulling tools shall only be used if

- specified in the cables suppliers instructions;
- it is applied to the constructional elements of the cables as specified in the cable supplier's instructions.

5.2.1.13.2 Cautions for handling optical fibre cables

The installation of optical fibre cabling shall be performed in accordance with the safety requirement of IEC 60825-2 or local regulations.

Open accessible optical fibre ends shall be kept away from skin and eyes.

It is good practice to follow the following recommendations:

a) installers and maintenance personnel should never look directly into optical fibre ends with either non-protected eye or microscope;
b) when viewing the optical fibre connector, the installer should be sure that the opposite optical fibre end is disconnected from the transceiver or light source.

5.2.1.13.3 Keeping plugs clean

Protective caps shall be applied to all exposed optical fibre plugs and adaptors to prevent contamination and damage to optical fibre end-faces.

5.2.1.13.4 Attenuation change under load

When mixing optical cables with other cable types, care should be taken as to the order of the cable installation to protect the cables from damage.

NOTE This is to protect optical fibre cables against increased bending and tensile loads as, for example, when balanced cables are replaced in the shared cable pathway.

5.2.1.13.5 Strain relief

Strain relief devices shall be used to reduce mechanical strain on the cable connector interface.

5.2.1.13.6 EMC ruggedness

Optical fibre cables, even if without metallic sheathing or amour, are resistant to electromagnetic influences. If permissible under local regulations, optical fibre cables may be directly mixed with other circuits (for example 230/400 V supply).

5.2.1.13.7 Crush resistance

Metallic sheathing or armour provides mechanical protection for fibre optic cables. When conductive protection is used on optical fibre cables, care shall be used in mixing with other circuits of high voltage.

5.2.2 Installation and routing

5.2.2.1 Common description

The installer shall ensure that the cables are compatible with the environmental conditions of the proposed route. For help in classifying the environment, see 4.2.3 and Annex B.

Particular attention is drawn to the following:

- when routing cables in extreme temperature areas, the cables being installed shall be suitable for both the installation temperature and operational temperature of the local environments;
- when routing cables through wet areas, the cables installed shall be suitable for wet locations;
- when routing cables in aggressive chemicals or gaseous areas, the cables installed shall be suitable for the specific chemicals in the environment.

The routing of cables shall take into account the presence, or potential presence, of electromagnetic interference. Unless appropriate components are selected or mitigation techniques are applied:

- cables shall be routed away from high EMI sources such as motors, motor drives, arc welders, induction heaters, etc.;
- cables shall not be routed in parallel with other noise carrying conductors including mains power.

The installer shall take measures to prevent any flammable materials that are present within cables (for example petroleum gel) leaking in pathways, closures or at any point of termination.

Where cables contain liquid or gel filling materials it is advisable to use protective caps (or equivalent) over exposed ends of the cable. This is particularly important where there may be considerable delays between installation of the cable and final termination.

When cabling with remote powering is used, the effects of heat on the cabling shall be considered as specified in Annex P.

The installer shall make every attempt to place earthing and equalization conductors as close to the metallic pathway as possible. Copper communications conductors should be located above the earthing and equalization conductors.

As for the optical fibre cables, the installer shall observe the minimum cabling path loss requirements (cables and connectors) to insure proper functioning channel. In addition, the instructions of the cable, plug connector and device manufacturer shall be observed.

The installer should place fibre cables either in a separate pathway or in such a way that they will not be damaged by cable loading or during maintenance (e.g. as in Figure 29).

Labels shall be applied in accordance with the cabling planning documentation.

5.2.2.2 Separation of circuits

To avoid negative effects on communication due to EMI, minimum separation distances shall be observed between cables of different circuits as defined by the planner according to requirements given in 4.4.10.

Communication cables should be installed in a separate pathway away from other circuits to reduce the effects of EMI on the communication cables. In shared pathways, communication cables shall be isolated from other circuits by means of metallic barriers as specified by the planner (see Figure B.5).

Figure 29 provides an example of separation for optical fibre cables.

NOTE Separation provides a number of advantages:

- improvement of the EMC;

- protection of existing cables from damage caused by pulling additional cables in the pathway;
- easier localisation if troubleshooting becomes necessary.

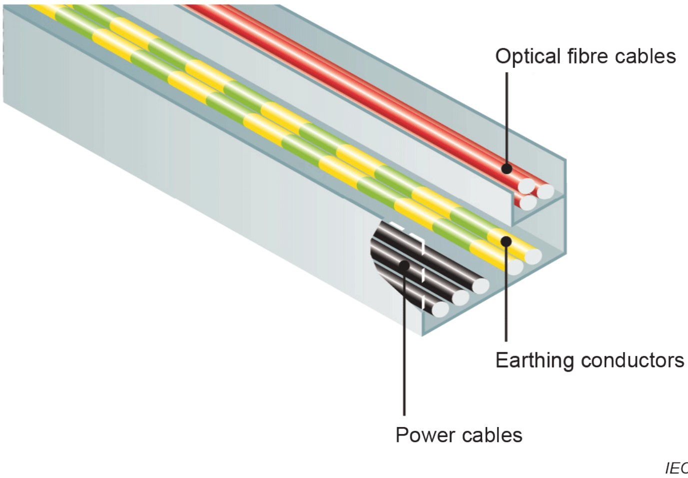


Figure 29 – Separate cable pathways

5.2.3 Specific requirements for CPs

Additional information regarding the cable installation requirements for a specific industrial network may be found in the respective installation profile.

5.2.4 Specific requirements for wireless installation

None.

5.2.5 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

5.3 Connector installation

5.3.1 Common description

Cables shall be terminated in accordance with the instructions provided by the manufacturer/supplier of the connecting hardware. If special tools are required for the termination, then only those recommended by the manufacturer shall be used.

Following termination, the cable elements shall be arranged in a manner that allows access to individual connectors, joints and cable elements with minimal disruption to neighbouring components during subsequent repair, expansion or extension of the installed cabling.

The connector pin-pair designation shall be in accordance with the cabling planning documentation.

When making cables or cord sets, the installer shall refer to Annex H for the appropriate connector and connector wiring.

The following common mistakes shall be avoided:

a) cutting the insulation of the wire, when stripping the cable. If the installer damages the insulation, he/she shall cut off the end of the cable and start over;
b) failure to put the connector shell or boot on in the correct order of the connector installation;

c) un-twisting the pairs of symmetrical multi-core cables too far back. This is important for maintaining system performance in balanced cabling systems;

d) incorrect placement of conductors into the connector.

In addition, for terminating unshielded and shielded twisted pairs cable ends, the following recommendations and the basic rules described in 5.3.2 and 5.3.3 should be applied.

Trim conductors before installing into the connector body as short as possible. The length of the jacket shall be long enough to fit inside the connector back end.

Labels shall be applied in accordance with the cabling planning documentation.

5.3.2 Shielded connectors

The cable shield shall provide a 360 degree shield around the cable along its entire length (a shielding contact applied only through the drain wire has little effect at high frequencies). Cable shields shall be terminated at all termination points.

At each termination point:

a) special attention shall be paid to the assembly of connection elements. The shield contact shall be applied over 360° according to the Faraday cage principle. The shield shall be terminated to provide a low impedance termination;

b) the shielding shall continue through an appropriate shield connection; normal pin contacts alone shall not be used;

c) discontinuities in the shielding shall be avoided, such as even small holes in the shield, pigtails, loops;

d) shield connections shall be firmly fixed, for instance by strapping or clamping;

e) shields shall not be used as a strain relief;

f) shields shall be earthed in accordance with the cabling planning documentation and the relevant CPs requirements.

Shielded connectors shall be installed in accordance with connector and cordset termination procedures given in Annex H and Annex I.

5.3.3 Unshielded connectors

Install connectors according to planner's recommendations and manufacturer's information.

Unshielded connectors shall be installed in accordance with connector and cordset termination procedures given in Annex H and Annex I.

5.3.4 Specific requirements for CPs

Additional information regarding the connector installation requirements for a specific industrial network may be found in the respective installation profile.

5.3.5 Specific requirements for wireless installation

None.

5.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

5.4 Terminator installation

5.4.1 Common description

The installation of terminators shall be in accordance with the cabling planning documentation.

NOTE Improper termination of any balanced cable element or shield can degrade transmission performance, increase emissions and reduce immunity (taken from 10.1.6 of ISO/IEC 11801-1:2017).

5.4.2 Specific requirements for CPs

Additional information regarding the terminator installation requirements for a specific industrial network may be found in the respective installation profile.

5.5 Device installation

5.5.1 Common description

The installer, once agreed with the planner, shall make a note on the as-implemented cabling documentation regarding placement of devices that deviates from the cabling planning documentation.

5.5.2 Specific requirements for CPs

Additional information regarding the device installation requirements for a specific industrial network may be found in the respective installation profile.

5.6 Coding and labelling

5.6.1 Common description

Coding and labelling shall be applied in accordance with planner's requirements.

5.6.2 Specific requirements for CPs

Additional information regarding the coding and labelling installation requirements for a specific industrial network may be found in the respective installation profile.

5.7 Earthing and bonding of equipment and devices and shield cabling

5.7.1 Common description

The installer shall perform the earthing of the installation (including equipment, pathways, devices and cable shields) in accordance with the cabling planning documentation, as detailed in 5.7, and should apply the recommendations of IEC TR 61000-5-2.

Where required by the cabling planning documentation, the installer shall ensure that earthing conductors meet the following specifications.

- The resistive earth impedance should be less than 0,6 Ω and shall be less than 1 Ω. The resistive earth is measured between any two points at which communication devices or cable shields are earthed.

NOTE 1 Inductive factors of the earth conductors will raise the effective earth impedance during high frequency events (see Annex B).

NOTE 2 A low resistance is not a sufficient condition to guarantee functional performance with respect to communication errors.

The installer shall also ensure that connection resistance to the earth bus is < 0,005 Ω (see 5.7.2.3).

Labels shall be applied in accordance with the cabling planning documentation.

5.7.2 Bonding and earthing of enclosures and pathways

5.7.2.1 Equalisation and earthing conductor sizing and length

Placement of the grounding and equalization conductors shall be in accordance with the planner's instructions. If conductor-sizing requirements are not defined in the cabling planning documentation, then the installer shall use the cable cross-section values defined in 4.4.7.2.1.

The earthing conductor length shall be cut to minimum length to complete the connection.

Excess earthing and bonding conductors shall be cut and shall not be coiled. In fact coiling increases their inductance and impedance and decreases the effectiveness of the grounding circuit.

The graphs in Figure 30 show the consequences to the impedance as a result of increasing the spacing between the earthing conductor and the metallic pathway. The installer shall take into account the fact that the equalization and earthing circuit become less effective as the impedance raises with the spacing changing from 1 mm to 10 mm or to 100 mm, etc..

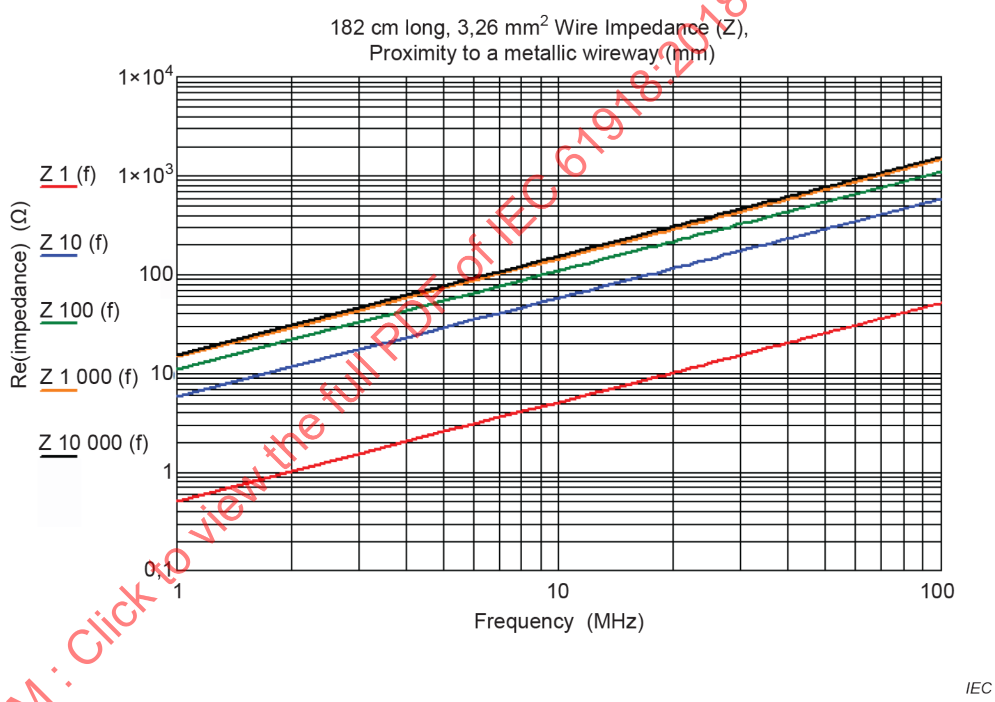


Figure 30 – Impedance of the earthing circuit as a function of distance from the metallic pathway

An earthing conductor shall not be placed into a metallic conduit unless the conductor is bonded at each end of the metallic conduit.

NOTE Omitting the bonding requirement increases the earthing conductor's impedance and defeats its effectiveness as a low impedance earth path for noise.

5.7.2.2 Bonding straps and sizing

If bonding straps requirements are not defined in the cabling planning documentation, then the installer shall use the bonding strap sizes defined in Figure 31.

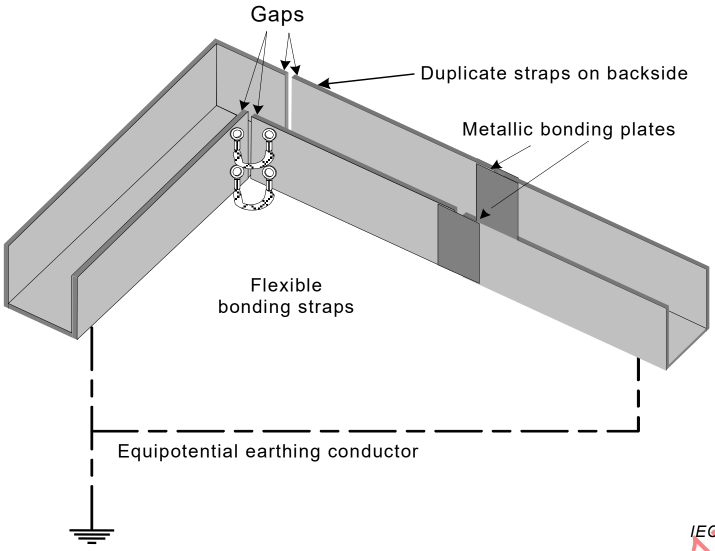


Figure 31 – Use of flexible bonding straps at movable metallic pathways

Figure 31 clarifies how the installer shall use the flexible bonding straps and the metallic bonding straps in accordance with the planner requirements specified in 4.4.7.2.4.

5.7.2.3 Surface preparation and methods

Figure 32 shows examples of proper mechanical implementation of earthing connections.

Figure 32 a) shows how to connect a sub plate to a back plate; Figure 32 b) shows how to connect an earthing conductor to a bus bar or to a sub plate; Figure 32 c) shows how to connect an earth bus bar to a back panel; Figure 32 d) shows how to connect an isolated earth bus bar to a back panel.

The installer shall perform the following, when installing earthing hardware:

- clean any paint and oxidation from all contacts and mating surfaces before affixing the earthing conductors;
- use either internal tooth star washers or flat washer as shown in Figure 32.

The connections to earth shall be protected against corrosion to ensure long-term stability.

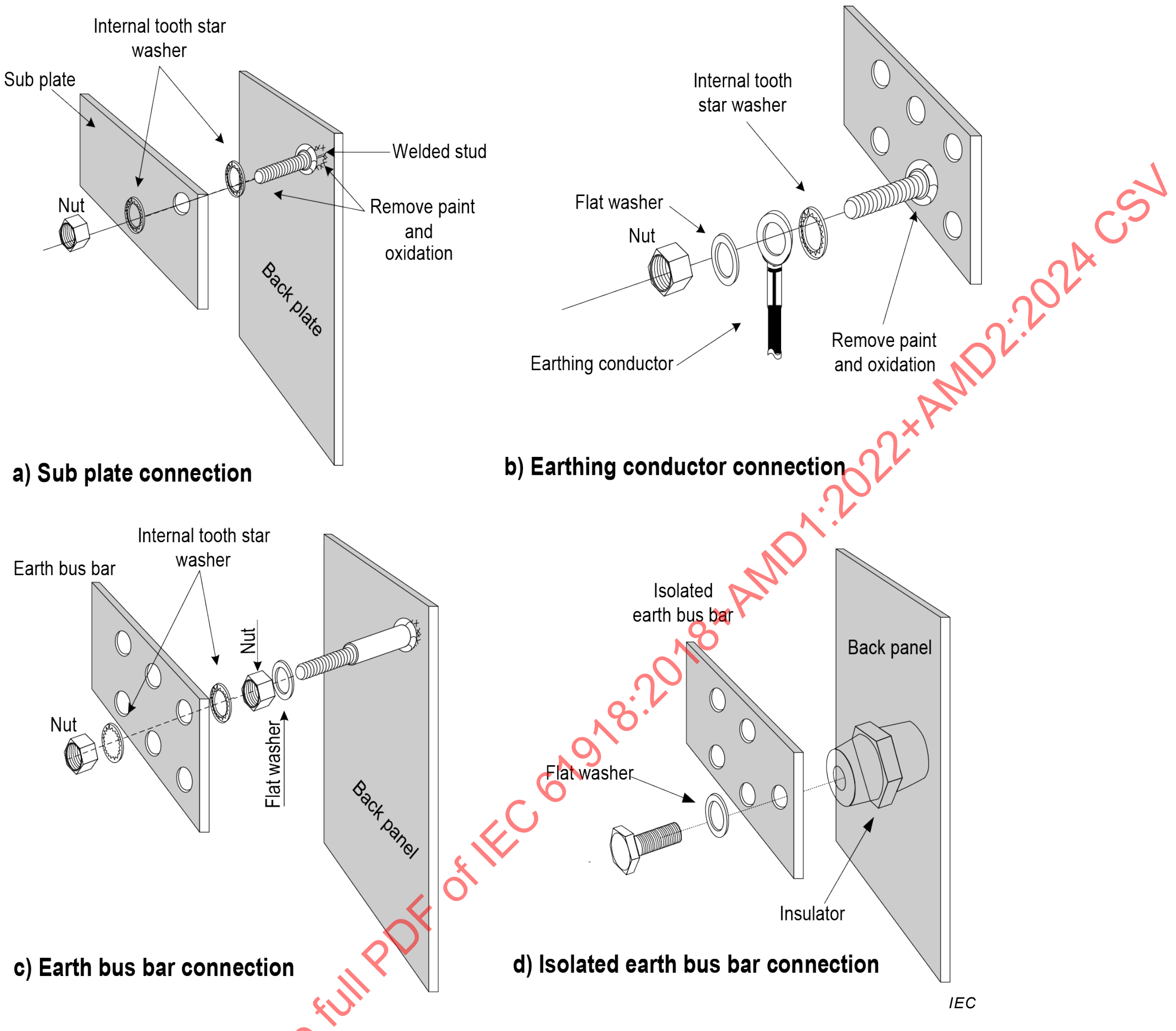


Figure 32 – Surface preparation for earthing and bonding electromechanical connections

5.7.3 Earthing methods

5.7.3.1 Equipotential

When installing enclosures and communication devices, in addition to what is defined by the planner, the installer shall ensure the following as well as what is specified in 5.7.2.2.

a) The potential equalization rail is earthed in each industrial enclosure/control cabinet and connected to the potential equalization rails of the other control cabinets.

b) Each part of the installed network and devices shall be electrically connected to the potential equalization system/functional earth at as many places as possible, as defined by the planner. The earthing conductor, trays, parts of machines or supporting structures, and any additional equipotential bonding conductors should be integrated in the potential equalization system.

5.7.3.2 Star

Where the cabling planning documentation specifies a star earthing system, and the devices are required to be connected to a functional earth system that is isolated from the protective earth system, the method specified by the planner shall be used with the addition of the following specifications: bus bars provide a convenient star earthing point for star earthing systems.

A method to reduce the length of the earthing conductors in a star earthing system requires connecting a work cell to a common star connection and then connecting this common star connection to the building earthing system, thus helping to eliminate earth offsets within a local work cell. If shielded communication cables travel from one work area to another, then the associated earths shall be part of the star earth system.

5.7.3.3 Earthing of equipment (devices)

5.7.3.3.1 Non-earthing or parallel RC

When the cabling planning documentation requires that devices are isolated from earth, then the leakage current shall be in accordance with the relevant installation profile.

If a parallel RC circuit is used between earth and the device, it shall be installed in accordance with the cabling planning documentation and the relevant communication profile. The value of the RC shall be in accordance with the relevant communications profile. The installer shall confirm the presence of the parallel RC circuit to ensure that the device is properly isolated. The isolated standoff shown in Figure 33 may be required to prevent shorting of the RC circuit.

5.7.3.3.2 Direct

The direct connection to earth shall be established in accordance with specifications provided in 5.7.1.

5.7.3.3.3 Installing copper bus bars

Where the cabling planning documentation specifies the use of isolated bus bars, the requirements specified by the planner shall be used with the addition of the following specifications.

- Figure 33 shows an example of the connection points provided by isolated bus bars.
- If the communication components are DIN rail mounted, then insulators for the DIN rails shall be used (see the example in Figure 34).

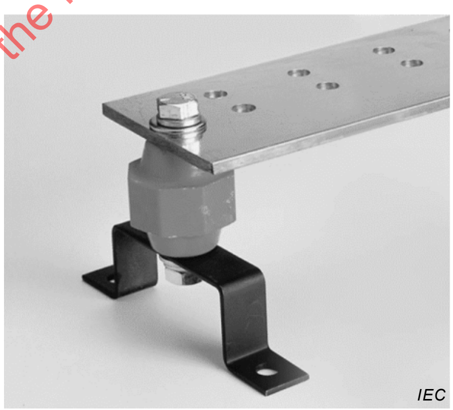


Figure 33 – Example of isolated bus bar

Figure 34 – Example of isolator for mounting DIN rails

5.7.4 Shield earthing methods

5.7.4.1 General

When shielded cables are used, the housing of the device, and also the control cabinet in which the fieldbus device is mounted, shall have the same earth potential by providing a large-area metallic contact to earth (use, for example, copper to ensure a good connection).

It is important that communication cabling shields do not conduct noise currents due to earth offset and improper earthing of devices and enclosures. Noise currents in the cabling shield would cause disruptions in the communication network.

Subclauses 5.7.4.2 to 5.7.4.4 provide a description of earthing techniques that have been proved to help reduce communication faults due to earth offsets where shields might be terminated. The reader is encouraged to consider other standards such as IEC 60364 with regards to the proper termination of screened cables and exposed metallic structures.

5.7.4.2 Parallel RC

Parallel RC earthing of a shield is done by using a combination of R and C as represented in Figure 35.

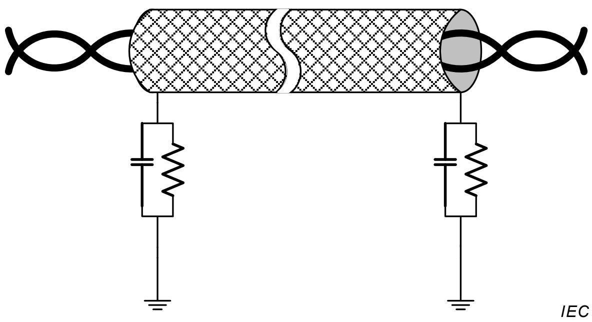


Figure 35 – Parallel RC shield earthing

5.7.4.3 Direct

Direct earthing of shield is as represented in Figure 36.

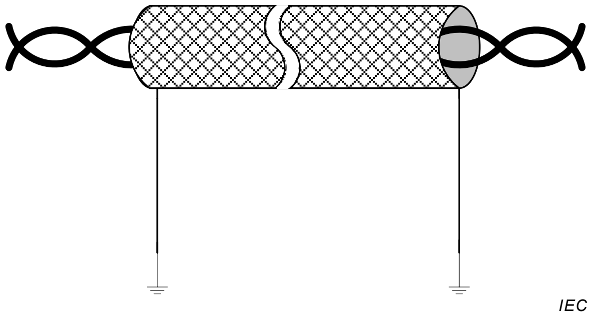


Figure 36 – Direct shield earthing

In addition, the installer shall observe the following points.

a) Do not damage the cable shielding foils and braids while stripping the outer sheath of the cable.

b) Cable contacts may only be established to the copper braided shielding sheaths, not to the aluminium foil-shielding sheaths, which are often also present. The foil-shielding sheath is usually fastened on one side to a plastic film to increase its tear resistance; therefore it is non-conductive.

c) Metallic cable clips for fasten braided shielding shall be selected to match the dimension of the cable (see Figure 37). The installer shall be aware of the following:

   1) this connection, if it is too tight, permanently damages the cable by degrading the transmission performance; and,

   2) if it is too loose, introduces noise in the system.

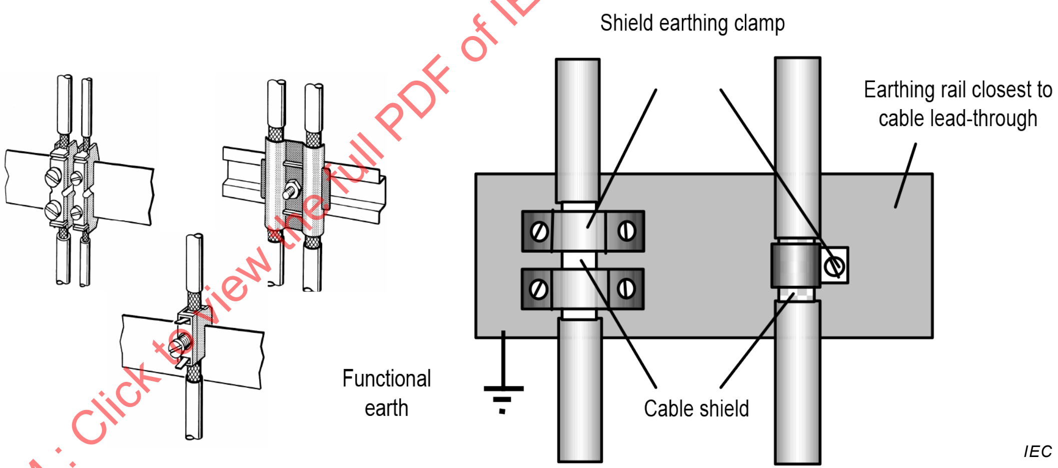


Figure 37 – Examples for shielding application

d) Tin plated or galvanically stabilized surfaces are ideal for establishing a good contact. With galvanized surfaces, the necessary contact shall be established by using a suitable screw connection. Contact points with painted surfaces are not suitable.

e) Shielding sheath clamps/contacts should not be used as strain relief, unless explicitly designed for such purpose. The contact could come loose or tear off.

Figure 38 shows how the installer shall use the equalization conductor to mitigate voltage offsets, as required by the planner (see 4.4.7.4.2).

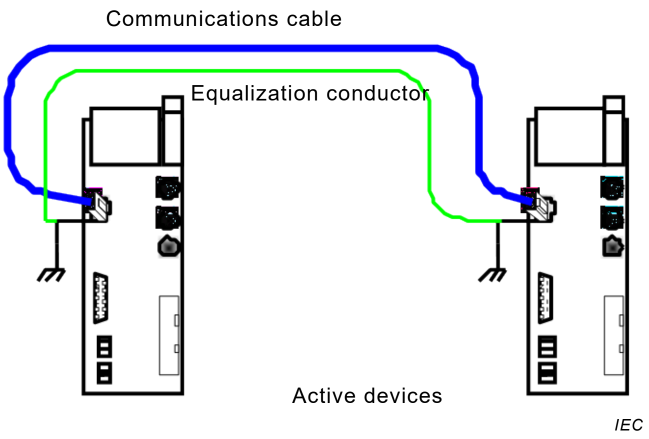


Figure 38 – Voltage offset mitigation

5.7.4.4 Derivatives of direct and parallel RC

Examples of derivative of direct and parallel RC earthing of shield are provided in Figure 39 and Figure 40.

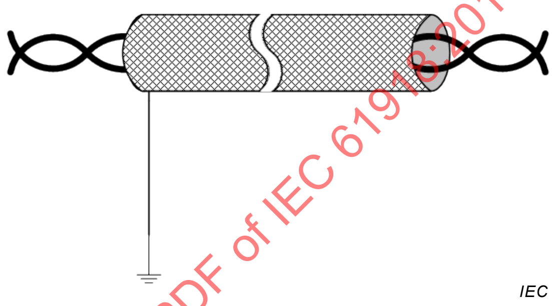


Figure 39 – First example of derivatives of shield earthing

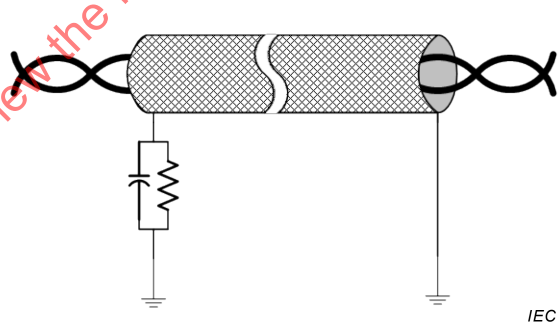


Figure 40 – Second example of derivatives of shield earthing

5.7.5 Specific requirements for CPs

Additional information regarding the earthing and shielding installation requirements for a specific industrial network may be found in the respective installation profile.

5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

See ISO/IEC 14763-2.

5.8 As-implemented cabling documentation

The installer shall document the result of the network installation. The as-implemented cabling documentation should include at least the following items, to be collected in documents organised and named in accordance with IEC 62708:

a) inventory of installed components;
b) cable routing;
c) used labelling;
d) location for the devices to connect to the network;
e) implemented channels.

6 Installation verification and installation acceptance test

6.1 General

Clause 6 addresses the verification and installation acceptance test of an installed cabling infrastructure.

Installation verification comprises the inspection of the cabling infrastructure and the testing of related aspects such as earthing systems against the following verification requirements:

a) the cabling planning documentation including deviations and additions as agreed by the planner;
b) the appropriate installation profile of IEC 61784-5 (all parts) or ISO/IEC 11801-3 (in the case of generic cabling);
c) the requirements of Clause 5.

Acceptance testing ensures that the installation is capable of supporting the required application and includes

- inspection of the installed cabling;
- cabling transmission performance tests against the cabling planning documentation and any recorded deviations.

For cabling in support of CPs within IEC 61784 (all parts), the personnel performing the testing shall be familiar with the appropriate CP installation profile or ISO/IEC 11801-3 (in the case of generic cabling).

The requirements specified in this Clause 6 for the CPs also apply for the installation implementation of balanced 1-pair networks specified in Annex Q.

Additional requirements for balanced 1-pair network are specified in Clause Q.4.

6.2 Installation verification

6.2.1 General

The verifier shall check (with a visual inspection and some simple measurements) that the entire network is installed in full accordance with the cabling planning documentation and that the as-implemented cabling documentation is complete and correct as required.

Verification is also done after each additional connection is made or after adds, maintenance, changes and moves.

NOTE The work of the verifier is usually done by the installer himself at the end of the installation.

Items to be verified according to cabling planning documentation are listed in the subclauses of 6.2.

These verification action items are aimed to ensure the network is installed in accordance with the cabling planning documentation and supports future maintenance and/or troubleshooting activities.

The schematic in Figure 41 is provided to guide the installation verification process.

Test tools should be selected based on the needs and the requirements of the specific CP. Commercial test tools may be available.

6.2.2 Verification according to cabling planning documentation

Each installed cabling should be verified, against the requirements provided in 6.2.3 and the checklists in Annex G, for proper installation.

Additional information regarding the installation verification requirements for a specific industrial network may be found in the respective installation profile.

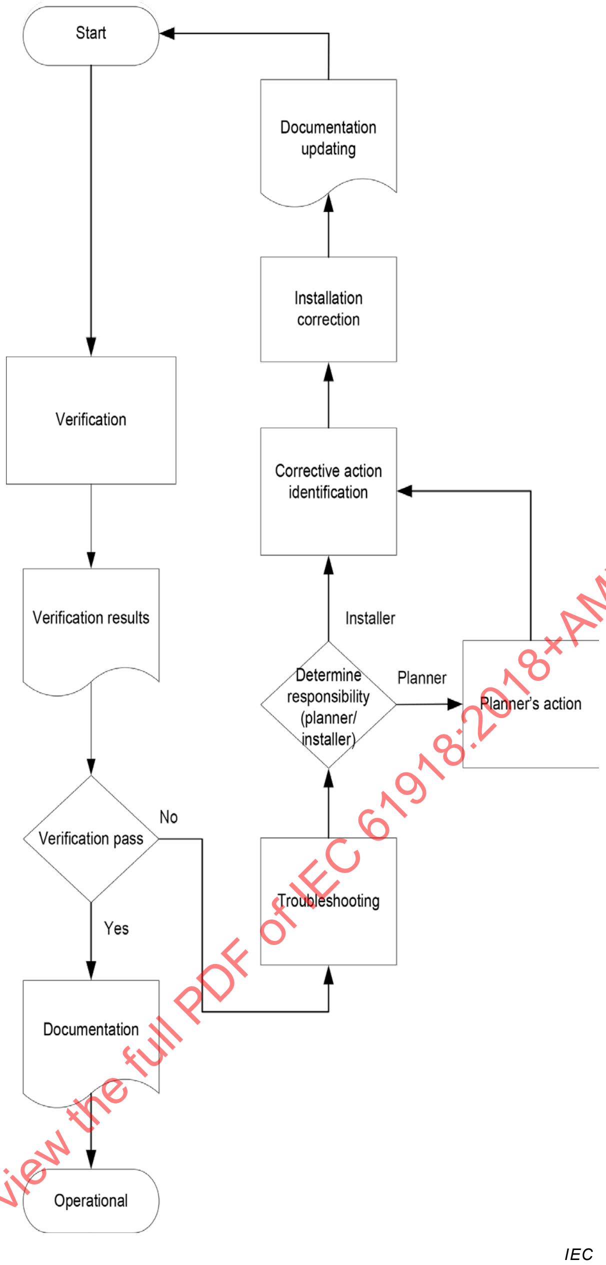


Figure 41 – Installation verification process

6.2.3 Verification of earthing and bonding

6.2.3.1 General

All earthing and bonding connections shall be in accordance with the cabling planning documentation and shall be verified to meet the minimum resistance requirements specified in 6.2.3.

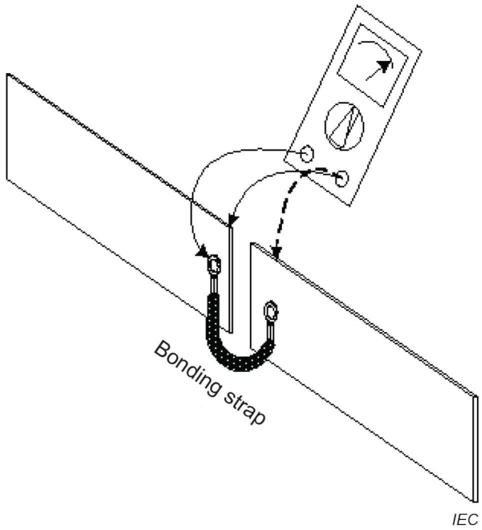


Figure 42 – Test of earthing connections

Test (see Figure 42), with the use of a suitable voltmeter (or oscilloscope), that the resistance or voltage offset between any installed earthing and bonding connection and one pre-existing earthing and bonding point is in accordance with requirements in 5.7.1 and 5.7.2 with communications cables connected or 1 V respectively without communications cables connected. The mechanical connection between a bonding or earthing conductor and any metal surface shall have a resistance less than 0,005 Ω. If distance prohibits this test, then visual verification of earthing requirements should be used in conjunction with verification of resistance measurements at the connection points. Visual verification should include verification of proper conductor size of earth and bonding conductors in accordance with the cabling planning documentation. If the above conditions cannot be met, then the earthing system should be corrected or alternate media shall be considered (unshielded cables, optical fibre cables, or wireless).

The requirements specified in 6.2 apply to all equipment, equipment enclosures and telecommunications rooms.

Proper installation of copper bus bars shall be verified. If isolated from building steel at point of mounting, verify that isolation resistance is > 2 MΩ between the bus bar and the point of mounting. If directly mounted to building steel, verify that resistance is $< 0,005$ Ω between the bus bar and the building steel.

Verify that conductor connecting the bus bars together is in accordance with the planner's requirement defined in line with 4.4.7.3.4 in particular. Verify proper conductor size and that bonding resistance is $\leq 0,005$ Ω between wire and bus bar.

Verify correct implementation of the star configuration or the equipotential configuration.

Verify that excess earthing and bonding conductors have been removed and not coiled.

6.2.3.2 Specific requirements for earthing and bonding

Additional information regarding the earthing and bonding verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.4 Verification of shield earthing

Subclause 6.2.4 applies when shielded cables or cables with shielded elements or units are used. Only basic guidance is provided.

The procedures necessary to provide adequate earthing for both electrical safety and EMC are subject to national and local regulations, are dependent on proper workmanship, and are at times only accomplished with installation-specific engineering.

Note that improper termination of shields may degrade safety and/or performance.

When shields shall be earthed they shall be verified according to the requirements of the appropriate CP installation profile. In the absence of specific guidance, the connection shall be verified to be ≤ 0,005 Ω between the shield and the point where it is bonded to earth.

6.2.5 Verification of cabling system

6.2.5.1 Verification of cable routing

Visual inspection should verify that the cable routing is in accordance with the planner's requirement and routing techniques.

NOTE Depending on the CP or network being installed there are specific topology limits (see Clause 4 and the respective CP installation profile for supported topologies). The cabling planning documentation defines the topology for the network to be installed.

Visual inspection of the network should include verification that

- the cabling has been installed with the proper isolation and separation from circuits as defined by this document and the local regulations (see 4.4.10), and
- excess communications cable is in accordance with 4.4.9.1.

6.2.5.2 Verification of cable protection and proper strain relief

Verify that cables entering and exiting enclosures maintain seal, proper strain relief, and drip loops, where appropriate.

6.2.6 Cable selection verification

6.2.6.1 Common description

Verification should include verifying that the installed components are in accordance with the cabling planning documentation and as-implemented documentation.

6.2.6.2 Specific requirements for CPs

Additional information regarding the cable selection verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.6.3 Specific requirements for wireless installation

None.

6.2.7 Connector verification

6.2.7.1 Common description

Connector verification includes the following two requirements:

- the connectors are in accordance with the cabling planning documentation;
- the connector has been installed in accordance with the installation profile and the manufacturer's data sheet.

6.2.7.2 Specific requirements for CPs

Additional information regarding the connector verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.7.3 Specific requirements for wireless installation

None.

6.2.8 Connection verification

6.2.8.1 Common description

The verifier shall verify proper number of connections, connectors used and wire mapping.

6.2.8.2 Number of connections and connectors

Verify proper number of connections and connectors used, as specified in the cabling planning documentation, especially the number of permitted connections.

6.2.8.3 Wire mapping

The verifier shall verify that the wire mapping is in accordance with the cabling planning documentation. Test method is given in 5.3.3.2 of IEC 61935-1:2019.

Wire mapping is intended to verify pin-to-pin termination at each end and check for installation connectivity errors. For each of the conductors in the cable, the wire map indicates:

- continuity to the remote end;
- shorts between any two or more conductors;
- reverse pairs;
- split pairs;
- transposed pairs;
- any other incorrect wiring.

Figure 43 and Figure 44 provide examples of pin and pair grouping assignments. Incorrect pairings are represented in Figure 45.

A reverse pair occurs when the polarity of one wire pair is reversed at one end of the permanent link (also called a tip/ring reversal).

A transposed pair occurs when the two conductors in a wire pair are connected to the position for a different pair at the remote connection.

NOTE 1 Pair transpositions are sometimes referred to as crossed pairs.

Split pairs occur when pin-to-pin continuity is maintained, but physical pairs are separated.

NOTE 2 When testing 2 pair systems, a connector conversion for the cable tester can be needed to support the M12 connector. In addition, this hardware will need to support 2 pair cables with the correct wiring configuration.

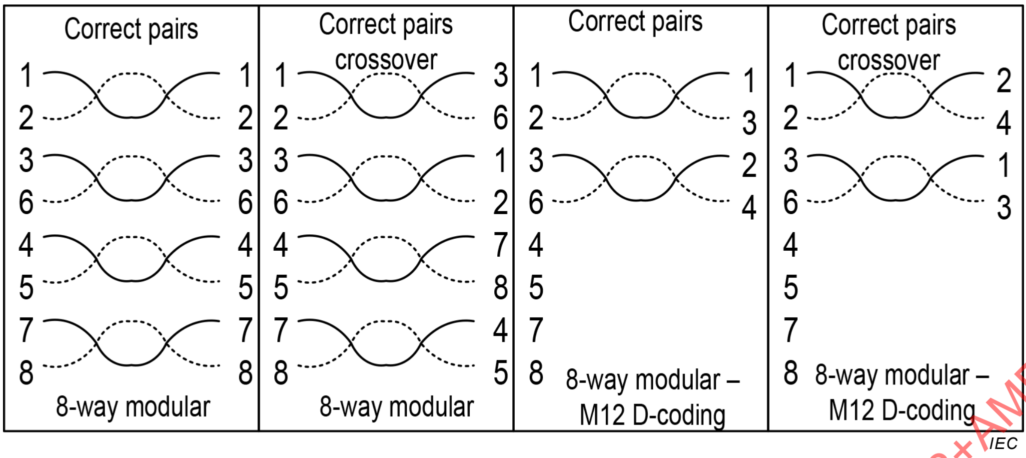


Figure 43 – Pin and pair grouping assignments for two eight position IEC 60603-7 subparts and four position IEC 60603-7 series to IEC 61076-2-101 connectors

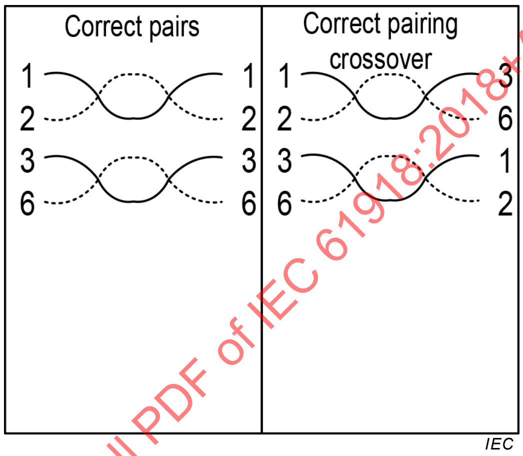


Figure 44 – Two pair 8-way modular connector

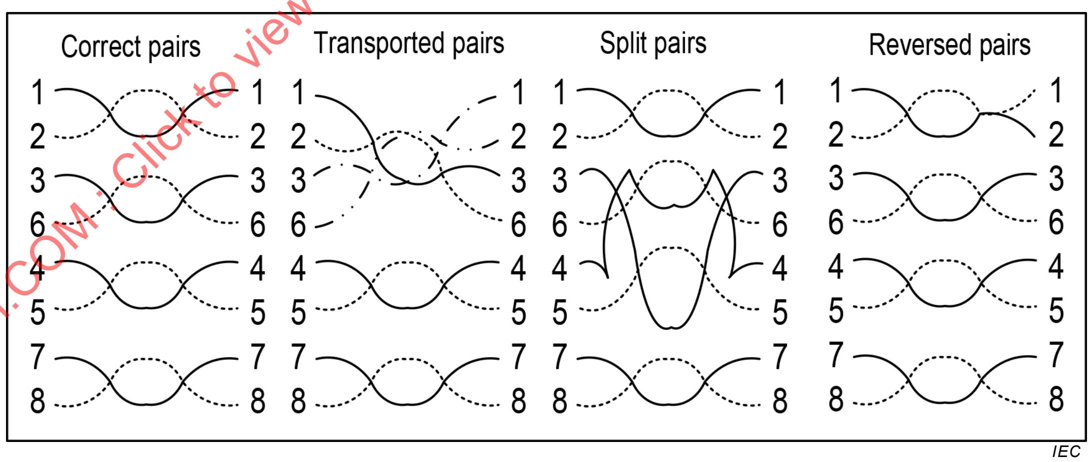


Figure 45 – Transposed pairs, split pairs and reversed pair

For balanced 1-pair applications, the requirements specified in Q.4.2 apply.

6.2.9 Terminator verification

6.2.9.1 Common description

The verification process shall include visual and electrical verification, (i.e. terminator values, placement and protection) in accordance with cabling planning documentation.

6.2.9.2 Specific requirements for CPs

Additional information regarding the terminator verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.10 Coding and labelling verification

6.2.10.1 Common description

The verifier shall verify the presence of the label and that the label contains the text required in the cabling planning documentation. Where required, the verifier shall verify that the label is constructed of durable material with permanent readable text.

6.2.10.2 Specific coding and labelling verification requirements

Additional information regarding the coding and labelling verification requirements for a specific industrial network may be found in the respective installation profile.

6.2.11 Verification report

Successful completion of verification shall be documented in a final verification report. The report shall include copy of the checklists (see Annex G) filled in by the verifier.

6.3 Installation acceptance test

6.3.1 General

The organisation in charge of the acceptance testing shall assess the network ability to support the required applications. “Acceptance test” is a process meant to ensure that the implementation conforms to the standard as detailed in the cabling planning documentation (see 4.5).

The acceptance test personnel shall

a) check that the cabling planning documentation, with recorded deviations and additions, is complete and correct as required;

b) include a visual inspection of the network installation to ensure that the network is properly installed (see 6.2.4, 6.2.5, 6.2.6, 6.2.6.3, 6.2.9, 6.2.10);

c) perform the validation of the network through a defined list of measurements and provide the documentation of the results of the measurements.

NOTE 1 The record of positive test results is an important point of reference for the maintenance and troubleshooting work.

NOTE 2 The term “validation” in this document has the specific meaning described in 3.1.84.

There are many commercially available tools to help validate the performance of the cabling system. Test tools should be selected based on fieldbus, test coverage and precision desired.

The tester shall perform network testing in accordance with the acceptance test requirements as detailed in 6.3.2 (Ethernet-based cabling) and 6.3.3 (non-Ethernet-based cabling).

The resulting test records provide a documented network validation.

The flowchart in Figure 46 is provided to guide the validation process.

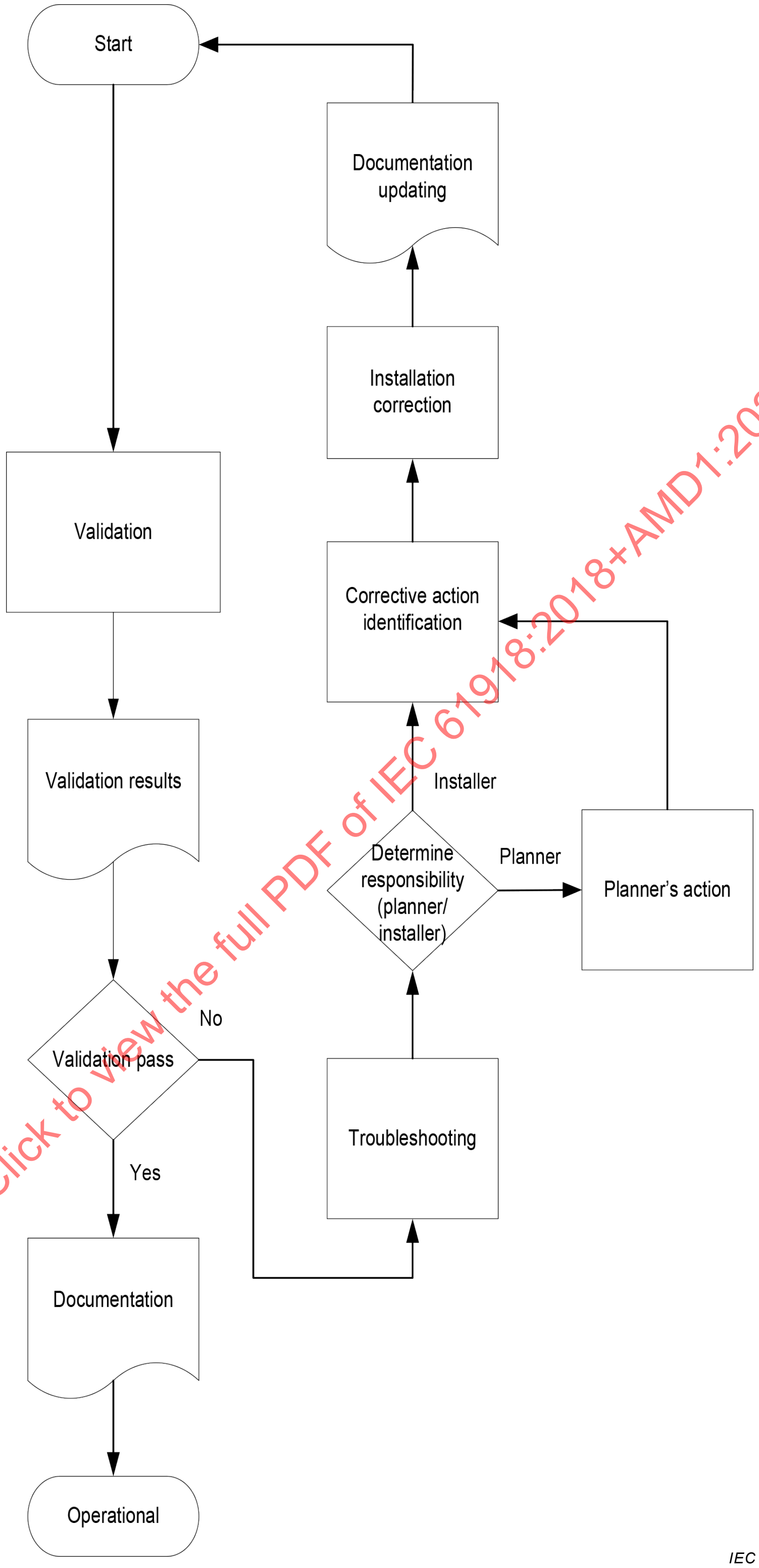


Figure 46 – Validation process

6.3.2 Acceptance test of Ethernet-based cabling

6.3.2.1 Validation of balanced cabling for CPs based on Ethernet

6.3.2.1.1 Common description

The transmission performance of cabling channels (see Figure 47) as described in Clause 4 can only be determined if the cables or cords connecting the installed cabling to the devices are present. The type of connecting hardware that terminates these cables or cords may influence the selection of test equipment.

The transmission performance of permanent links (see Figure 48) can only be determined using specific test cords. The type of connecting hardware that terminates these cables or cords may influence the selection of test cords and equipment.

Where the CP is specified to be supported by a transmission performance class as defined in ISO/IEC 11801-3, the test methods of ISO/IEC 11801-3 may be applied to the channel.

A permanent link test, against the applicable requirements of the appropriate transmission class of ISO/IEC 11801-3, should only be applied where the cabling components subsequently attached to the permanent link to form the transmission channel have been proven to maintain the required channel performance class of ISO/IEC 11801-3.

The requirements for test equipment to perform testing in accordance with ISO/IEC 11801-3 are specified in IEC 61935-1 and ISO/IEC 14763-4 for End-to-end link (see Figure 49). This equipment is required to produce specific documentation covering both transmission performance and conductor mapping.

NOTE Test equipment in accordance with IEC 61935-1 may require modification to allow effective testing of 2-pair balanced cabling.

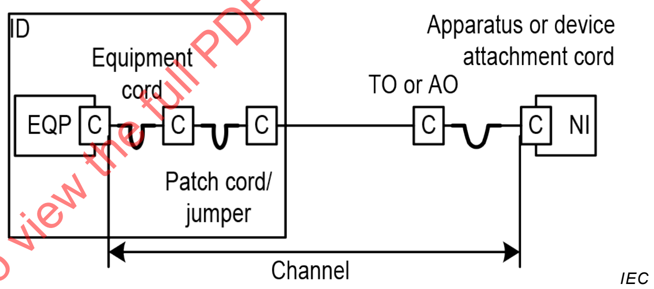


Figure 47 – Schematic representation of the channel

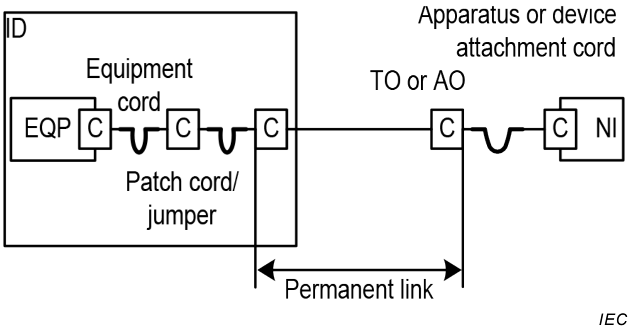


Figure 48 – Schematic representation of the permanent link

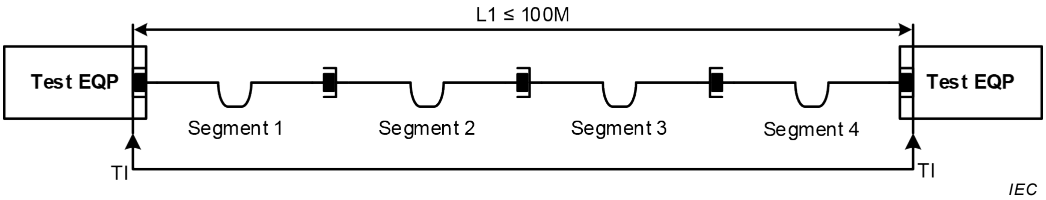


Figure 49 – Schematic representation of an E2E link

Equipment in accordance with IEC 61935-1 may be applicable for testing of channels and permanent links against other Ethernet performance criteria (such as those stipulated in other standards). However, also in these cases, a permanent link test against the applicable requirements should be applied, only where the cabling components subsequently attached to the permanent link to form the transmission channel have been proven to maintain the required channel performance.

Figure 49 shows the schematic representation of a four segments, five connections E2E link. The keys of this figure are described in Annex O where other configurations of E2E links are specified.

The test of E2E link shall be performed in accordance with ISO/IEC 14763-4. Annex O describes how to test E2E link.

Other channel or permanent link performance requirements shall be applied as detailed in the relevant CP installation profile.

Field test equipment for Ethernet-based networks including connection adapters shall meet the appropriate channel and accuracy level as defined in IEC 61935-1.

6.3.2.1.2 Transmission performance test parameters

The parameters for which field tests are specified in ISO/IEC 11801-3 and for which support exists in IEC 61935-1:2019 and IEC 61935-1-1:2019 are as follows:

a) return loss;
b) insertion loss;
c) near-end crosstalk loss (NEXT);
d) far-end crosstalk loss (FEXT);
e) power sum near-end crosstalk loss (PSNEXT);
f) attenuation crosstalk ratio (ACR);
g) power sum attenuation crosstalk ratio (PSACR);
h) equal-level far-end crosstalk loss (ELFEXT);
i) power sum equal-level far-end crosstalk loss (PSELFEXT);
j) DC loop resistance;
k) propagation delay skew;
l) delay skew;
m) unbalance attenuation, near-end (TCL);
n) unbalance attenuation, far-end (ELTCTL).

Items m) and n) above apply where requirements are given in the relevant CP.

NOTE 1 This list assumes that wire map and length have been successfully verified since:

- errors in pair-pin mapping would result in identified failures of transmission performance;

- channel/permanent link length is not a transmission performance test parameter (but may be important for maintaining accurate installation documentation).

NOTE 2 Continuity is not included since errors in pair-pin mapping would result in identified failures of transmission performance.

NOTE 3 This list can be amended in subsequent editions of the above standards.

The results of the tests shall be recorded into the acceptance test report.

6.3.2.1.3 Specific requirements for CPs based on Ethernet

Additional information regarding validation requirements for a specific CP may be found in the respective installation profile.

6.3.2.2 Validation of optical fibre cabling for CPs based on Ethernet

6.3.2.2.1 Common description

The transmission performance of cabling channels as described in Clause 4 can only be determined if the cables or cords connecting the installed cabling to the devices are present. The type of connecting hardware that terminates these cables or cords may influence the selection of test cords and test equipment.

The transmission performance of permanent links can only be determined using specific test cords. The type of connecting hardware that terminates these cables or cords may influence the selection of test cords and equipment.

Channel or permanent link performance requirements shall be applied as detailed, and at the wavelengths specified, in the relevant CP.

As a minimum, the following parameters shall be measured:

- optical fibre polarity;
- permanent link or channel insertion loss;
- length.

The test methods of ISO/IEC 14763-3 shall be applied. Cabling lengths may be determined using test equipment that operates in the time-domain or from cable markings.

Permanent link tests, against the applicable requirements should only be applied where the cabling components subsequently attached to the permanent link to form the transmission channel have been proven to maintain the required channel performance.

6.3.2.2.2 Specific requirements for optical fibre cabling CPs

Additional information regarding the optical fibre cabling validation requirements for a specific CP may be found in the respective installation profile.

6.3.2.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

The installed generic cabling for industrial premises shall be tested in accordance with the methods specified in ISO/IEC 11801-3 against requirements of the relevant transmission performance class of ISO/IEC 11801-3.

6.3.3 Acceptance test of non-Ethernet-based cabling

6.3.3.1 Copper cabling for non-Ethernet-based CPs

6.3.3.1.1 Common description

The measurements for cabling validation are required in the relevant CP installation profile. Hereafter is a list of measurements that may be required in the CP installation profiles:

a) loop resistance (see cabling specifications);
b) DCR of data line (see cabling specifications);
c) DCR of shield (see cabling specifications);
d) DCR between data lines (result shall be "open");
e) DCR between data lines and shield (result shall be "open");
f) cable length by a tester or inspection;
g) DCR between shield and the bonding surface (result is dependent on shield earthing method implemented);
h) terminator value (see the CP installation profile).

Annex N provides a procedure applicable for DCR measurements of the installed cabling to validate:

- loop resistance;
- DCR of data line;
- DCR of shield;
- absence of shorts between wires;
- absence of shorts between wire and shield.

6.3.3.1.2 Specific requirements for copper cabling for non-Ethernet-based CPs

Additional information regarding the non-Ethernet-based balanced cabling validation requirements for a specific industrial network may be found in the respective installation profile.

6.3.3.2 Optical fibre cabling for non-Ethernet-based CPs

6.3.3.2.1 Common description

See 6.3.2.2.1.

6.3.3.2.2 Specific requirements for non-Ethernet-based CPs

Additional information regarding the non-Ethernet-based optical fibre cabling validation requirements for a specific industrial network may be found in the respective installation profile.

6.3.3.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3

The installed generic cabling for industrial premises shall be tested in accordance with the methods specified in ISO/IEC 11801-3 against requirements of the relevant transmission performance class of ISO/IEC 11801-3.

6.3.4 Specific requirements for wireless installation

None.

6.3.5 Acceptance test report

Successful completion of acceptance test shall be documented in a final report.

The report shall include a copy of all the checklists filled in by the person in charge of the acceptance test.

7 Installation administration

7.1 General

The operability of a communication network infrastructure is based on an effective administration. Each network owner shall establish and maintain administration procedures either based on company requirements or based on available standards.

Clause 7 does not recommend specific rules for the administration of the network. Clause 7 provides basic principles and examples from which a suitable administration system shall be developed and maintained.

Administration of the cabling considers the cabling along its life cycle, which includes

- adding and removing bus segments;
- adding and removing connection points including attachment cords, AOs and TOs.

NOTE Additional information on administration of networks is available in EN 50174-1 and EIA/TIA 568.

The specific requirements for the installation administration shall be provided as follows.

a) The specific requirements for the administration of generic cabling for industrial premises are specified in ISO/IEC 14763-2:2012.
b) The specific requirements for the administration of a CP cabling are provided in the relevant installation profile.

7.2 Fields covered by the administration

The administration of a network is done along the life cycle of the network. In Clause 7, the term “fieldbus infrastructure” covers the information-technical cabling as well as the applications and equipment linked to it.

The administration covers the following fields:

- basic principles for the administration system;
- working procedures;
- installation location identification;
- labelling;
- documentation.

7.3 Basic principles for the administration system

The administration system of the cabling system is established in such a way:

- to be consistent with the administration system of the other systems of the plant;
- that labelling for the cabling systems is consistent with the labelling of the other systems in the plant (for example electrical cabling of a machine);
- that suitable information of other management systems can be integrated that clearly state the place of equipment or of the cabling. Its place descriptions are to be taken over into the system of cabling management;

- that recordings of the cabling management are linked with each other and with recordings of other building services, such as lighting, power supply, heating, and building plans.

7.4 Working procedures

Working procedures are established in such a way as to guarantee that the following issues are fixed in detail.

a) The extent and the format of the documentation, which is required after the planning, the implementation of installation, the verification and validation, the operation and the maintenance of the installation.

b) The handing-over of this documentation from the contractor to the operating authority of the fieldbus infrastructure.

c) The duration of the storage of this documentation.

d) The updating of this documentation to reflect any changes or corrections of the cabling along its life cycle. Actions to be performed for the updating of the documentation are

   – invalid documentation is marked as such;

   – every time a change or correction is made, all concerned recordings are updated in such a way that multiple updates are understandable;

   – copies of these recordings are marked as “copy”;

   – copies of these recordings, or a warning notice, are included in the working procedures to update them;

   – the time of each change or correction is recorded in the documentation;

   – a defined method is applied for revision control (for example revision lettering is used in the documentation);

   – changes and corrections in the documentation of an interface are considered for possible changes and corrections of the equipment connected to the interface;

   – the labelling and marking are kept in accordance with the documentation, after each change or correction;

   – up-to-date documentation is made available to operation, maintenance and authorized personnel.

e) Required inventory of spare parts and test equipment needed to support the network.

f) The locations where support documentation can be found, if support documentation is collocated or duplicated in multiple locations.

7.5 Device location labelling

The following is usually adopted.

a) Every device location is identified with an appropriate labelling.

b) The labelling material is selected in accordance with the environment.

c) All device locations are marked at a suitable spot, for example area at the entrance.

7.6 Component cabling labelling

A consistent approach to labelling is recommended. All major components of the cabling system are usually labelled. For example the cable ends should be labelled to uniquely identify each cable, including starting and ending locations.

The following list represents good practice.

a) Labels are either, part of the component, attached to the component, or in the vicinity of the component.

b) Where required, components have more than one label (for example, cables are usually labelled at each end).

c) Labels are attached in such a manner that they are easily accessible, readable and changeable.
d) Labels remain legible during the prospective life span of the cabling.
e) The labelling materials are selected based on the environment.
f) Labelling reflects the most current configuration.
g) Documentation, labelling and network configuration are consistent.

The content and the format of the labelling are usually specified on the basis of technical and organizational criteria: the label print shall contain clear and legible information.

The labelling normally contains:

- a unique identifier (for example: sub elements of a multi-element component);
- a description of the type of the component;
- an installation location identification;
- additional information.

Information about the structure and content of the labelling is provided in the documentation.

The components to be labelled are as follows:

1) Cables
   – Every cable should have clear labelling.
   – Cables should be labelled at each of their ends.
   – All branch connections should be uniquely identified with a label.
   – For optical fibre cables with multiple optical fibres, the individual optical fibres are to be identified by either colour coding or by labelling.
2) Connection point
   – Each connection point should be labelled. For example, a terminal block should be clearly identified in the documentation and at the terminal block.
3) Earthing and potential equalization
   – Each connection of the earthing and potential equalization should have a label.
4) Active elements of a network
   – Every element should have a label.
5) Cable pathways
   – Every cable pathways should have a label.

7.7 Documentation

The documentation of the cabling usually includes the following elements to be collected in documents organised and named in accordance with IEC 62708:

a) System drawings.
b) Site plans, building layouts and location drawings, which contain the identification and location of connection points, cable routing, cables, equipment and safety equipment.
c) Schematic diagram and other information which show the electrical connections and summaries of cables, connection points, connections for equipment, earthing and potential equalization, the segment lengths, marking and location of all components.
d) Provisions for recording the incoming inspection results, including the result of a comparison between the list of material ordered and the list of material received. In addition, provisions for recording discrepancies or damaged material.
e) Installation verification and acceptance test report.

f) Details regarding the installed earthing system already in use and measurements taken as documented in cabling planning documentation.

g) Recordings about the cable routing as specified in the cabling planning documentation and in the as-implemented cabling documentation.

h) A list of components used with the order number of the manufacturer, the type designation of the field bus organization or the standardised material designations with the respective quantity and the assigned labels.

i) A list of the required spare parts, cables, cable sets, connectors, tools, measuring instruments, measuring cables, equipment, etc.

j) Recordings about date of installation date of inspections, maintenance, servicing, updates, and exchange of each component.

k) Documentation of the components provided by manufacture or supplier (such as installation manuals, etc.).

7.8 Specific requirements for administration

Additional information regarding the administration requirements for a specific industrial network may be found in the respective installation profile.

8 Installation maintenance and installation troubleshooting

8.1 General

Each network owner shall establish and maintain maintenance and troubleshooting procedures, over the full life cycle of the network, by selecting the appropriate procedures out of the options described in Clause 8 and represented in Figure 50.

Clause 8 is also applicable for high availability networks as specified in IEC 62439. Installation of high availability networks shall provide at least the following:

- maintenance documentation that explains the specific redundancy techniques used by the installed network to ensure continuity of operation during the failure and repair of any single component or cable element;
- maintenance procedures to ensure that diagnosis and restoration actions for a faulty part of a network do not affect performance of the non-faulty parts of the network which are continuing to support the user applications.

A proper maintenance procedure applied to fieldbus networks allows maximising MTBF. Proper troubleshooting procedure, repair methods, diagnostic tools and personal training allows minimising MTTR.

The owner of the network shall decide to which extent it is convenient for him to invest in diagnostic tools and the training of his maintenance and troubleshooting personnel to use these tools.

For further advice on network administration, see Clause 7. Clause 7 describes procedures for updating the documentation that supports the maintenance and troubleshooting work.

The requirements and the recommendations of Clause 8 may be applied for the generic cabling in addition to those of ISO/IEC 11801-3.

8.2 Maintenance

8.2.1 Scheduled maintenance

The scheduled maintenance is a kind of preventive maintenance performed on each component in order to discover degradation of the component before a failure occurs and to restore the component to a state in which it can perform the required function. The interval (defined in terms of time or number of actions) between the interventions is defined based on the characteristics of the component and information provided by the manufacturer. The key drawback of this method is that on each component the interventions are performed regularly, irrespective of the actual condition of the component. This results in some waste of time and money, because in many cases the component results confirm it to be working correctly.

Scheduled maintenance of the network will help in maximizing the MTBF.

There are the two following types of interventions to schedule.

a) Visual inspection and check-up.

   Visual inspection and check-up are performed by comparing the result of the inspection and of the check-up with the reference information (baseline, resulted from the acceptance tests) and performance limits recorded in the maintenance documentation.

   The documentation for the visual inspection and check-up lists includes:

   1) components to be inspected/ checked-up (for example, the cabling in use, redundant cabling, cable routing, earthing system);
   2) time interval or number of actions for the visual inspection and check-up of each component;
   3) the baseline, performance limits and pass-fail criteria for each component;
   4) tools.

   If a corrective action is needed, the process described in 8.2.3 applies.

b) Component replacement/adjustment.

   Intervention to replace/adjust the component to keep it in a defined acceptable condition (for example after the transmission of a defined number of data frames reset all active components). This maintenance intervention is specifically applicable to components that have critical behaviour (for example, limited life).

   The documentation for this maintenance intervention lists:

   1) the critical components;
   2) time interval or number of actions (for example data frames transmitted) for replacement/ adjustment of each component;
   3) procedure for replacement/adjustment of each component;
   4) tools and spare parts.

If a corrective action is needed, the process described in 8.2.3 applies.

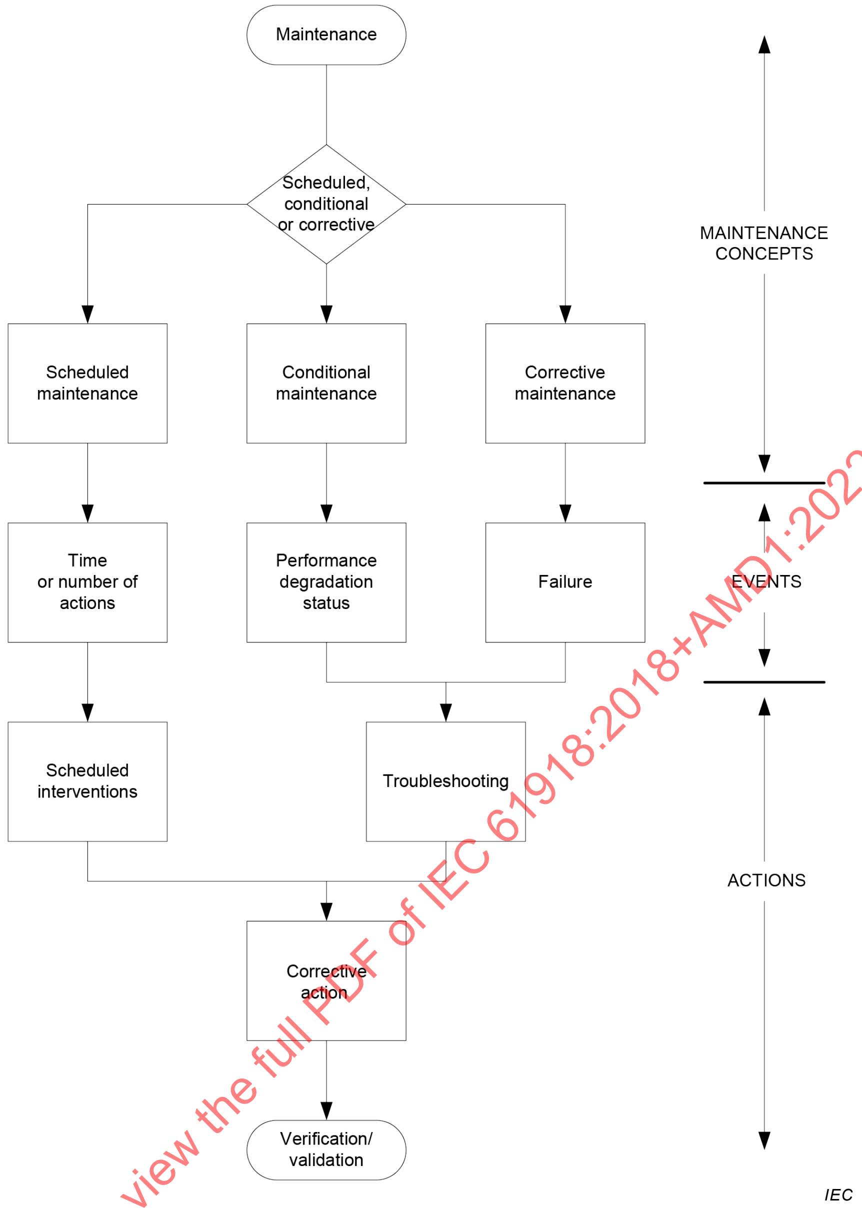


Figure 50 – Communication network maintenance

8.2.2 Condition-based maintenance

Condition-based maintenance is a kind of preventive maintenance performed on each component based on the known conditions of the components to maintain. The intervention is performed in a component only when a degradation is documented that could result in a fault of the network. If the conditions of the components are monitored on-line the degradation can be detected in real time and the intervention can be performed timely and before the degradation goes beyond the acceptable limit. Compared with scheduled maintenance, condition-based maintenance usually requires much less time and money for maintenance personnel support.

Condition-based maintenance of the network will help in maximizing the MTBF. Investment in suitable on-line diagnostic tools and training of the maintenance personnel will help to minimise the MTTR.

Examples of degradations are the following:

a) the resistance to earth exceeds a defined value (for example 1 Ω);

b) the BER between two components exceeds a defined value (for example 1×10^{-9}).

If a corrective action is needed, the process described in 8.2.3 applies.

8.2.3 Corrective maintenance

The corrective intervention on a component after a failure occurred is aimed to restore the component to a state in which it can perform the required function.

Once a failure occurs, the maintenance personnel:

- troubleshoots the network failure (see 8.3);
- performs the corrective actions described in the maintenance documentation.

The documentation for this maintenance intervention lists:

a) procedures for repairing or replacing failed components, based on documentation provided by the supplier;
b) spare parts;
c) procedures for correcting network faults;
d) procedures for the verification and validation of the network after the corrective intervention, in accordance with selected Clause 6 requirements.

The result of the intervention is usually considered for updating the maintenance specification, in accordance with Clause 7 requirements.

8.3 Troubleshooting

8.3.1 General description

Troubleshooting starts after a failure or performance degradation of a network occurs (see Figure 50).

The troubleshooting organisation begins their activity by establishing the needed documentation and by the training of the troubleshooting personnel.

The documentation for troubleshooting intervention lists:

a) guidance for systematic network troubleshooting, such as with a checklist or a flow diagram, based on documentation provided by the supplier;
b) guidance for troubleshooting components based on documentation provided by the supplier;
c) test tools for the specific network.

8.3.2 Evaluation of the problem

The answers to the following questions usually help to create a clear understanding of the problem and allow efficient troubleshooting of the network.

- Is the complete network documentation available?
- Were there any recent changes in the network infrastructure?
- How was the problem identified?
- Since when is the problem identified?
- Was the concerned application already working failure free?
- Which users/devices are affected by the problem?
- Are there certain time frames when the problem occurs?

- Is the problem reproducible?
- Have there been previous attempts to correct the problem?

8.3.3 Typical problems

Problems usually encountered by the maintenance personnel are described in Table 22 and Table 23. When troubleshooting unshielded installations, EMC influence can be quantified through field-testing of TCL and ELTCTL transmission parameters. If needed, noise impact reduction may be achieved by identification of at-risk components and selection of replacement components with superior performance.

Table 22 – Typical problems in a network with balanced cabling

Problem	Most probable cause	Corrective action
Failed communications and/or high error rates	Loose termination or bad connector (or terminal) contacts	Locate and correct intermittent connection
	EMC influence from other devices, poor grounding, improper separation from emitting devices or cables	Locate and correct grounding, identify improper separation or shielding, use optical fibre
	Corrosion of shielding contacts	Locate and replace the damaged components with either the proper protection or compatible components
	Mechanical stress in cables or connections	Install mechanical support and strain relief
Intermittent communications for a short time and/or burst error rates	EMC influence from other devices	Correlate the communication problem with physical or environmental events. Locate and take corrective actions (mitigation, etc.)
	Loose termination or bad connector (or terminal) contacts, such as vibration or temperature influence	Locate and replace the damaged components with either the proper protection or compatible components
	Corrosion of shielding contacts	Locate and replace the damaged components with either the proper protection or compatible components
	Mechanical stress in cables or connections	Install mechanical support and strain relief
	Condensing liquids between the electrical contacts	Clean the connectors. Replace the damaged components with either the proper protection or compatible components
Fault report from the balanced cabling diagnostic equipment: return loss too large	One is using cables or cords with incorrect impedance, for example different from 100 Ω for Ethernet systems	Use the proper components
Fault report from the balanced cabling diagnostic equipment: Cable length too large, attenuation or loop resistance too large	One is using cables or cords with a smaller wire size or longer length as allowed for the application. An injury is also possible	Use the proper components and cable length or replace the components
Fault report from the balanced cabling diagnostic equipment: NEXT, PSNEXT, ACR, PSACR, ELFEXT, PSELFEXT	One is using connectors, cables or cords without the expected quality. An injury is also possible	Use the proper components and cable length or replace the components

Table 23 – Typical problems in a network with optical fibre cabling

Problem	Most probable cause	Corrective action
Failed communications and/or high error rates	Loose termination or bad connector (or splice) contacts, such as vibration or temperature influence	Locate and correct intermittent connection
	Optical fibre attenuation increases (aging or dust)	Clean the end of the optical fibre using proper cleaning procedures. Replace the damaged components with either the proper protection or compatible components
	Transmitter power degradation (aging)	Replace the module

Problem	Most probable cause	Corrective action
	Liquids or condensing liquids between the optical fibre ends	Clean and protect the optical fibre ends using proper cleaning procedures. Replace the damaged components with either the proper protection or compatible components
	Mechanical stress in cables or connections	Install mechanical support and strain relief
No power is measured at an optical source	The optical source is defective	Replace the module
	The module is without electrical power	Power up the module
	A cord is defective	Replace the cord
Fault report from the optical fibre diagnostic equipment: power loss is more than expected	The optical fibres are connected to the wrong ports on the testing unit	Refer to labelling and documentation for the correct wiring scheme and correct if necessary
	The optical fibres are swapped at one end of the link	Refer to labelling and documentation for the correct wiring scheme and correct if necessary
	A cord is broken	Retest using a different set of cords
	There is one or more dirty connections in the link	Clean all optical fibre connector ends and retest
	The number of connectors, adapters or splices set in tester SETUP is too low	Correct according to the documentation of the network
	The reference power level is incorrect	Set the reference again using the same patch cords to be used for testing
	A cord or optical fibre segment has the wrong core size. For example one is using 62,5 µm patch cords to connect to a 50 µm optical fibre. Or one is using multimode patch cords or adapters to connect to single mode optical fibre	Use the proper components in the channel for the described wavelength and optical fibre size
Fault report from the optical fibre diagnostic equipment: a known length of cable measures too long or too short	The index of refraction is not set correctly for the optical fibre under test	Set the index of refraction to give the correct length for a known length of optical fibre

8.3.4 Troubleshooting procedure

The procedure in Figure 51 is an example of a generic troubleshooting procedure that could be adapted to most common networks.

The troubleshooting procedure shown in Figure 51 applies if a procedure is not available.

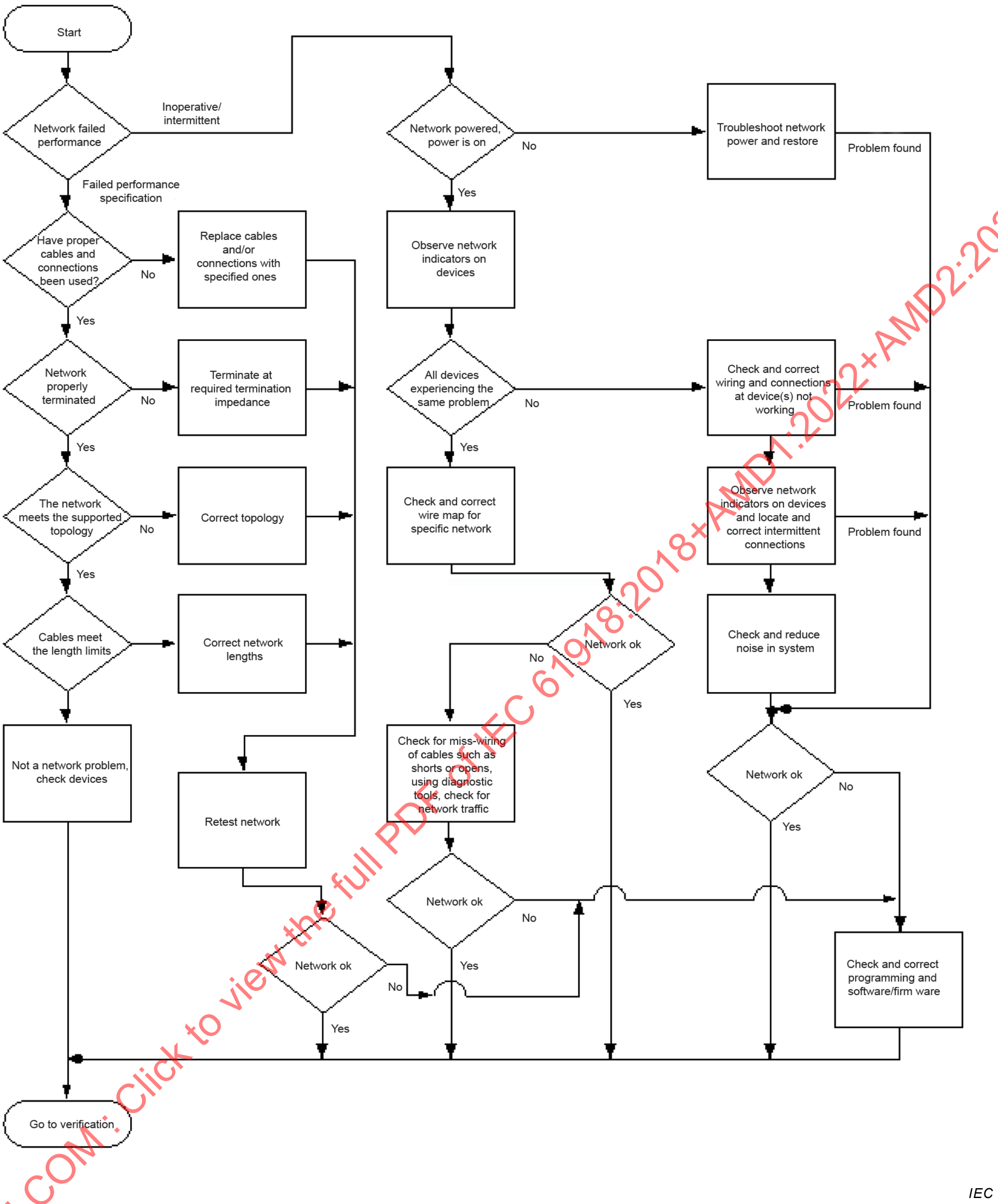


Figure 51 – Troubleshooting procedure

8.3.5 Simplified troubleshooting procedure

The procedure in Figure 52 is an example of simplified troubleshooting procedure that is sufficient in many cases. This procedure does not require the use of specific tools. It applies if a specific procedure is not established.

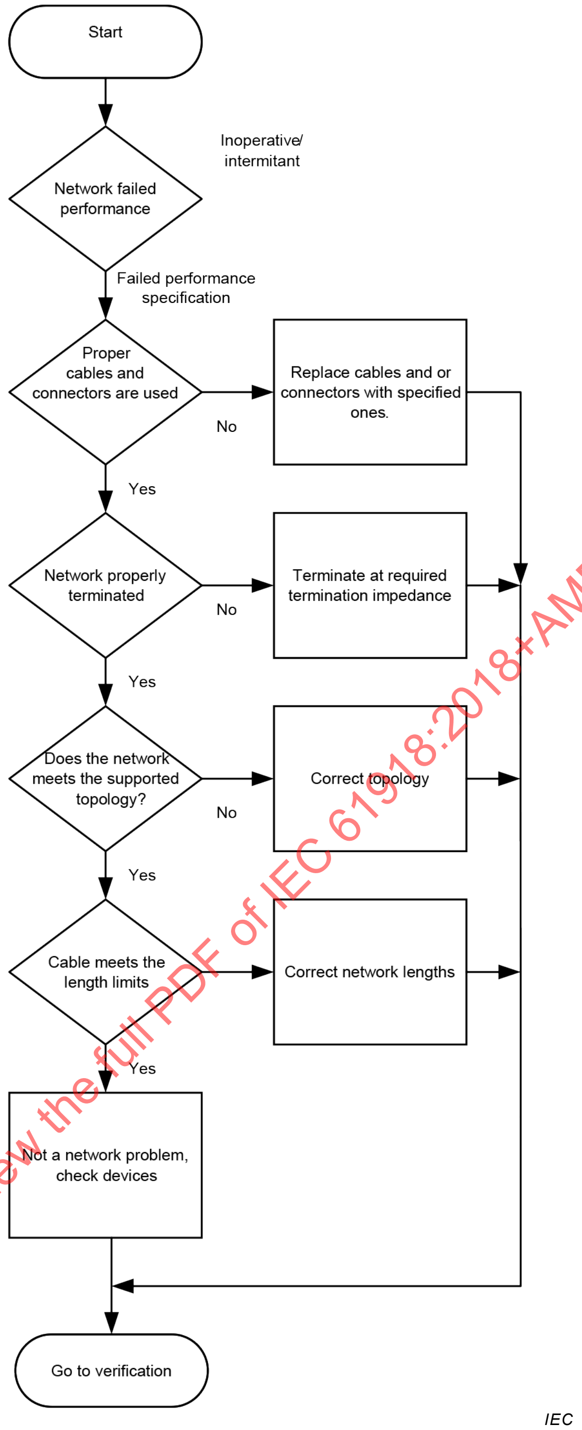


Figure 52 – Fault detection without special tools

If a corrective action is needed at the end of the troubleshooting, the process described in 8.2.3 applies.

8.4 Specific requirements for maintenance and troubleshooting

Additional information regarding the troubleshooting requirements for a specific industrial network may be found in the respective installation profile.

Annex A
(informative)

Overview of generic cabling for industrial premises

Within industrial premises, generic cabling enables a fixed cabling infrastructure to be installed to support a wide range of information technology and monitoring applications. The design of this cabling is specified in ISO/IEC 11801-3.

The generic nature of the cabling is delivered by:

- the specification of a flexible cabling structure comprising a series of cabling subsystems that can be connected together either passively, using cords, or actively using transmission equipment;
- a minimum level of transmission performance within each of the series of cabling subsystems used to distribute the applications.

The termination points of generic cabling that are distributed throughout the premises, called the TO, enables the connection of a variety of applications to the cabling. The applications supported are detailed in ISO/IEC 11801-3 and include telephony and local area networks. Where the TO is installed in locations associated with AIs, the type of applications detailed in this document may also be supported.

As generic cabling is intended to support a wide range of applications, the specification of the TO in ISO/IEC 11801-3 is restricted to specific interfaces for balanced cabling and optical fibre cabling. This restriction is intended to optimise the interoperability of cords and portable terminal equipment that may be connected to the TO.

Where a designated connection from generic cabling to specific communication cabling within an AI is desired, an AO specified within this document may replace the TO and the cabling is considered non-generic.

NOTE ISO/IEC 11801-3 also contains information in support of non-generic cabling structures that may support the implementations of specific CPF.

Annex B
(informative)

MICE description methodology

B.1 General

The MICE environmental classification is specified in ISO/IEC 11801-1:2017.

The background to the development of the approach is given in ISO/IEC TR 29106:2007/AMD1:2012.

A recommendation for the wider application of this approach by the installation planner and installer is given in Clause 4. Information provided with Annex B is intended just as a first guidance on the use of the MICE system. For the application of the MICE system, the specifications provided with the most recent versions of the above standard and technical report take precedence.

B.2 Overview of MICE

The MICE concept is a concept in which an environment within an installation can be classified in terms of environmental and EMI levels. The MICE table (see Table B.5) defines 3 levels for each component of the MICE classification: Mechanical, Ingress, Climatic and Electromagnetic (thus the name MICE). The three classifications are graphically shown in Figure B.1. These classifications begin at generally the lowest ($M_1I_1C_1E_1$) which best describes most office spaces and extends to a highest level that best describes a typical industrial space ($M_3I_3C_3E_3$).

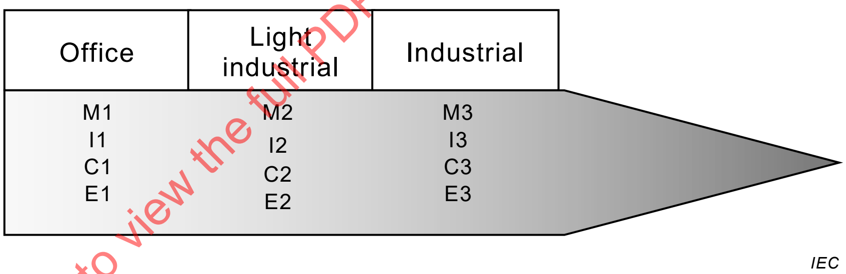


Figure B.1 – MICE classifications

Figure B.2 is an example of typical industrial areas. Further, the AI may expand to include the entire factory floor. Figure B.2 indicates typical MICE classifications for the three primary areas within a factory. Not all areas fall exclusively into one classification, for example, an AI may have mechanical shock at >150 ms^{-2} whereby it may be classified as a M_3. The environment may only have light dust consistent with the levels in I_2. The temperature where the cables and equipment are routed/installed may be 65 °C with the Climatic classification C_2 as defined by the MICE table. The machinery in the AI may consist of welding robots, in which the EMI is most likely in the E_3 classification. The MICE environment can then be summarised as M_3, I_2, C_2 and E_2.

NOTE The terms used in Figure B.2 are specific to Annex B.

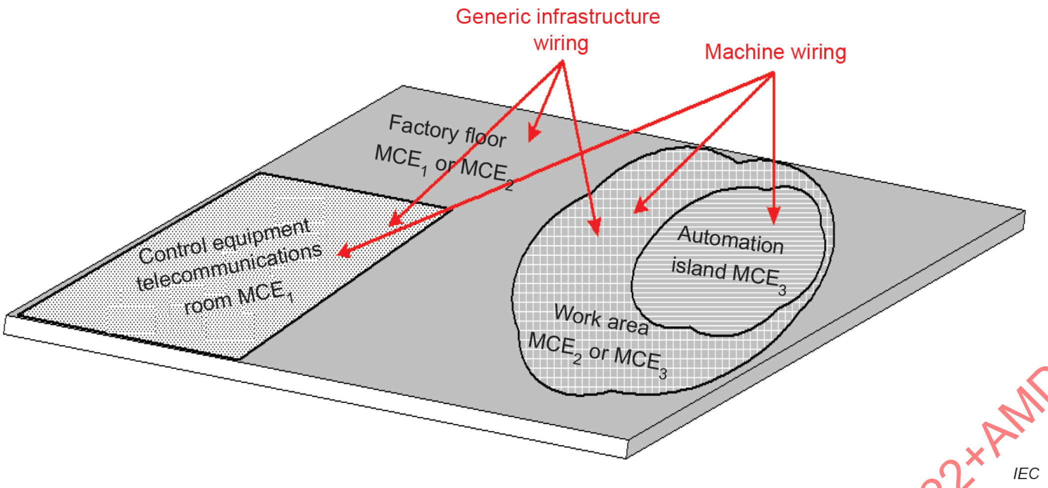


Figure B.2 – Example MICE classifications within a facility

B.3 Examples of use of the MICE concept

B.3.1 Common description

The planner should be aware of the environment and EMC levels in the areas in which the cabling and equipment will be installed. By systematically classifying the installation coverage area, decisions can be made on component selections and additional mitigation needs. Cabling systems can be designed using all enhanced components in which no mitigation is required or a combination of enhancements and mitigation may be chosen. In some cases, this may restrict flexibility or may create a cost and/or availability issue. This concept allows the designer to balance component cost (and availability) with mitigation costs thereby designing the most robust cost-effective cabling system, as shown in Figure B.3. Mitigation can be broken down into two forms, separation and isolation. The following examples will help to solidify the importance of mitigation. Mitigation simply converts one MICE area into another that is compatible with the cabling components and equipment to be installed.

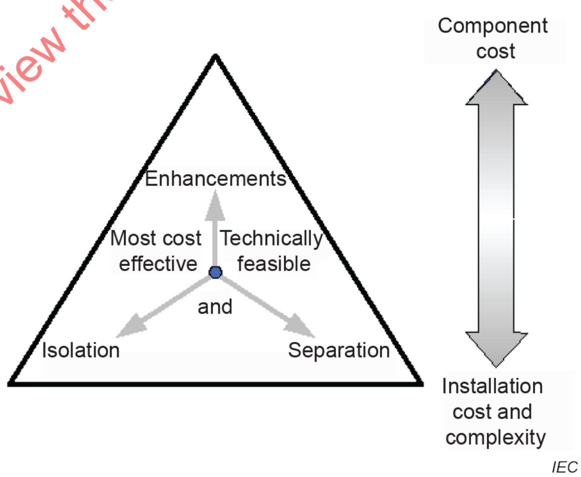


Figure B.3 – Enhancement, isolation and separation

B.3.2 Examples of mitigation

B.3.2.1 Example 1

The targeted MICE area is specified in Table B.1. The desired component has been determined to be compatible with a MICE environment as described in the left column of

Table B.1. The environment to which the component should be installed in is described in the second column of Table B.1. By inspection of the component and environment parameters “M” and “E” do not match, requiring mitigation. Parameters “I” and “C” exceed the environmental condition and therefore need action.

Table B.1 – Example 1 of targeted MICE area

Component	Environment
M_1	M_3
I_3	I_1
C_3	C_2
E_2	E_3

Since the component does not map directly in to the environment, the environment should be mitigated. The harsh M_3 environment can be converted to an M_1 local to the component by shock mounting the equipment in an enclosure. The high EMI can be reduced by using a metallic EMI, shock mounted, enclosure as indicated in Figure B.4. Both M_3 and E_3 problems are solved.

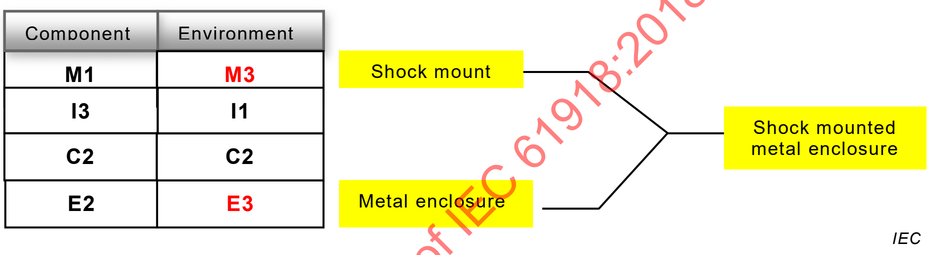


Figure B.4 – Example 1 of mitigation

B.3.2.2 Example 2

This is an example of a cable installation where the environment is described as in Table B.2. By inspection, it can be seen that the cable does not match the environmental conditions for EMI (E). Therefore, some form of mitigation is required.

Table B.2 – Example 2 of targeted MICE area

Component	Environment
M_1	M_1
I_3	I_1
C_2	C_2
E_2	E_3

Since the cable selected does not meet the EMI requirements, then some mitigation is required. Mitigation can be solved two ways, separation and/or isolation. The drawing in Figure B.5 shows how this can be done in a pathway.