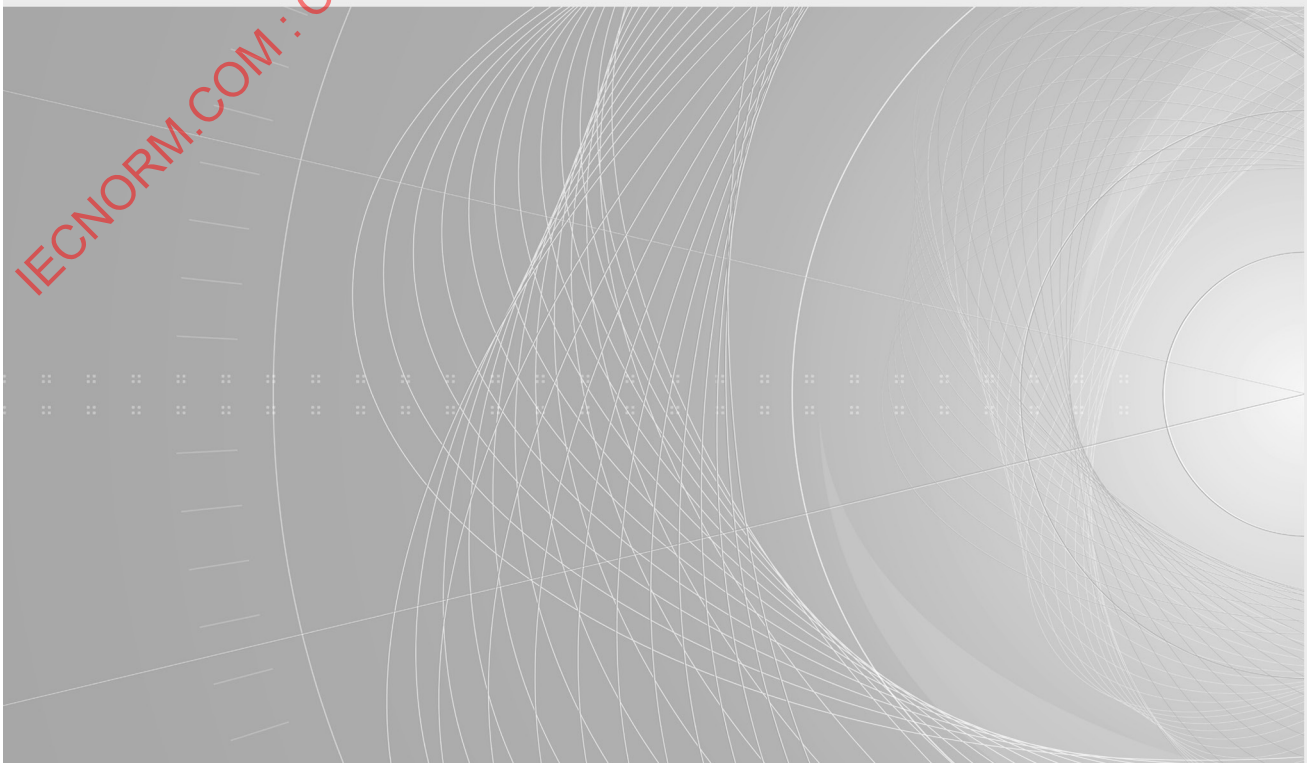


# INTERNATIONAL STANDARD



**Industrial communication networks – Profiles –  
Part 5-2: Installation of fieldbuses – Installation profiles for CPF 2**

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# INTERNATIONAL STANDARD



Industrial communication networks – Profiles –  
Part 5-2: Installation of fieldbuses – Installation profiles for CPF 2

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**IEC 61784-5-2 edition 4.1 contains the fourth edition (2018-08) [documents 65C/924/FDIS and 65C/925/RVD] and its amendment 1 (2024-03) [documents 65C/1283/FDIS and 65C/1297/RVD].**

**In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. 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 61784-5-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This document is to be used in conjunction with IEC 61918:2018, IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024.

This fourth edition cancels and replaces the third edition published in 2013. This edition constitutes a technical revision.

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

- a) references to ISO/IEC 24702 have been replaced with references to ISO/IEC 11801-3 in Table B.1;
- b) errors have been corrected;
- c) Tables B11 and B13 have been added in support of 1,000 Mb/s 4 Pair Ethernet;
- d) Clarification of dual power supplies for Annex C.

~~This standard is to be used in conjunction with IEC 61918:2018.~~

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

A list of all parts of IEC 61784-5 series, under the general title *Industrial communication networks – Profiles – Installation of fieldbuses*, can be found on the IEC website.

The committee has decided that the contents of this document and its amendment will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

- reconfirmed,
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## INTRODUCTION

This ~~International Standard~~ document is one of a series produced to facilitate the use of communication networks in industrial control systems.

IEC 61918:2018, IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024 provides the common requirements for the installation of communication networks in industrial control systems. This installation profile standard provides the installation profiles of the communication profiles (CP) of a specific communication profile family (CPF) by stating which requirements of IEC 61918 fully apply and, where necessary, by supplementing, modifying, or replacing the other requirements (see Figure 1).

For general background on fieldbuses, their profiles, and relationship between the installation profiles specified in this document, see IEC 61158-1.

Each CP installation profile is specified in a separate annex of this document. Each annex is structured exactly as the reference standard IEC 61918 for the benefit of the persons representing the roles in the fieldbus installation process as defined in IEC 61918 (planner, installer, verification personnel, validation personnel, maintenance personnel, administration personnel). By reading the installation profile in conjunction with IEC 61918, these persons immediately know which requirements are common for the installation of all CPs and which are modified or replaced. The conventions used to draft this document are defined in Clause 5.

The provision of the installation profiles in one standard for each CPF (for example IEC 61784-5-2 for CPF 2) allows readers to work with standards of a convenient size.

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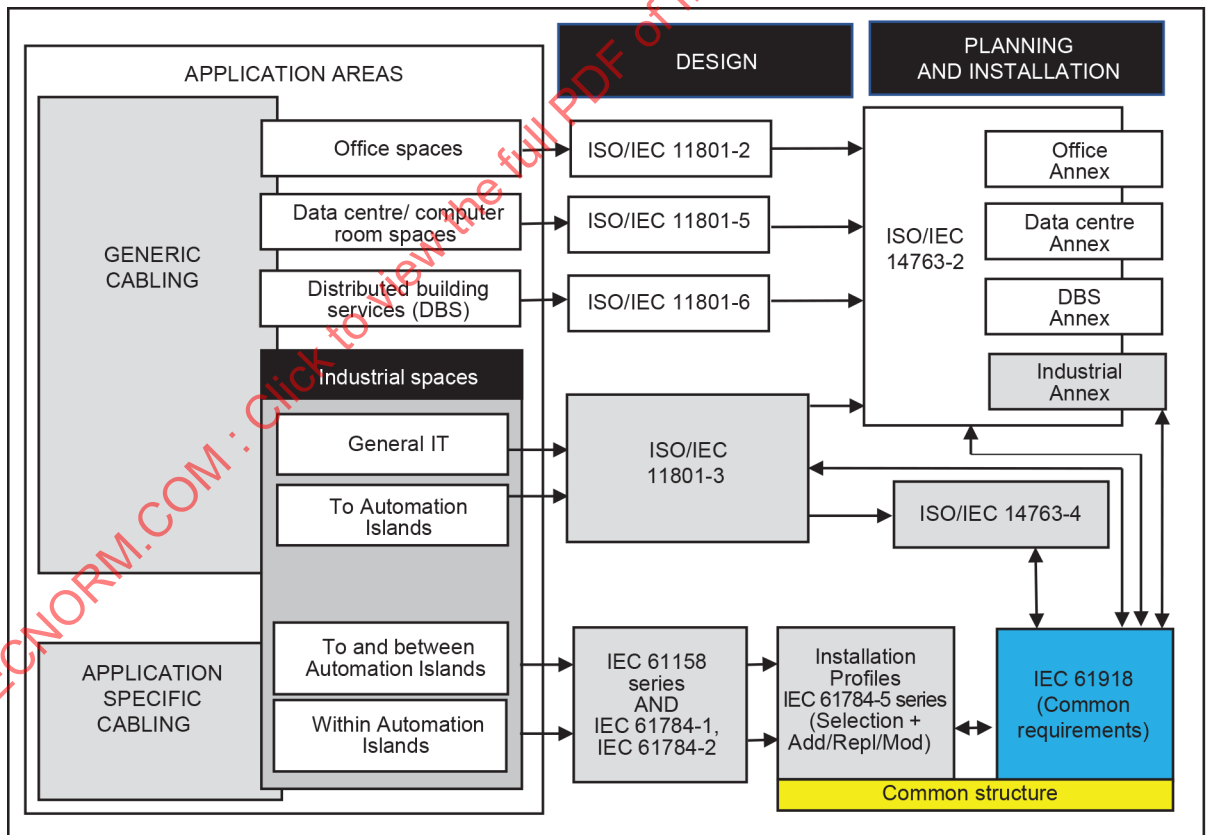
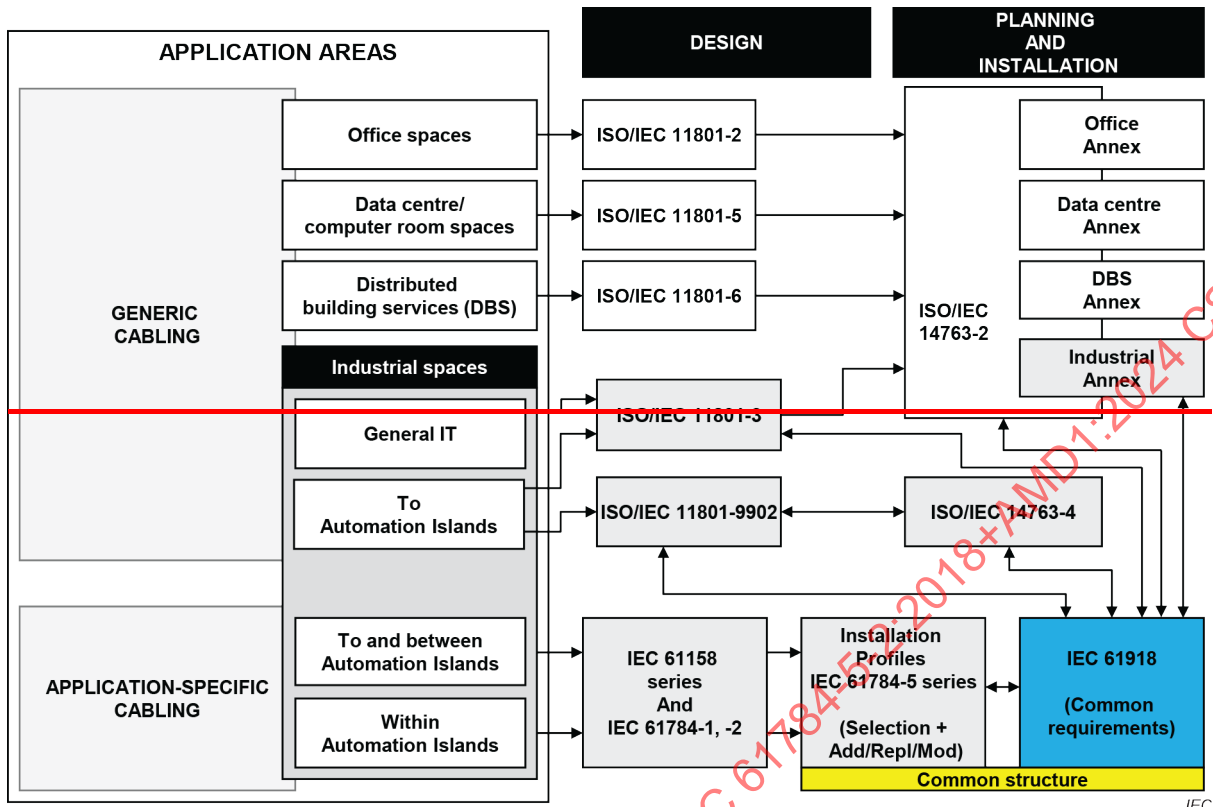


Figure 1 – Standards relationships

## INTRODUCTION to Amendment 1

This Amendment 1 includes the following significant technical changes with respect to IEC 61784-5-2:2018:

- a) Updated references of IEC 61918:2018 to include additions of IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024,
- b) Added references for consideration of security to Subclause B.4.2.2,
- c) Updated optical fiber specifications and references in Subclauses B.4.3.3.2 and B.4.4.1.4,
- d) Added definition of electromagnetic compatibility options for conformance to Subclause B.4.4.1.2.1,
- e) Added support of mesh bonding systems to Subclause B.4.4 and Clause B.5,
- f) Added acceptance of end-to-end link verification and certification testing to Clause B.6.

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## INDUSTRIAL COMMUNICATION NETWORKS – PROFILES –

### Part 5-2: Installation of fieldbuses – Installation profiles for CPF 2

#### 1 Scope

This part of IEC 61784-5 specifies the installation profiles for CPF 2 (CIP™<sup>1</sup>).

The installation profiles are specified in the annexes. These annexes are read in conjunction with IEC 61918:2018, IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024.

#### 2 Normative references

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

IEC 61918:2018<sup>2</sup>, *Industrial communication networks – Installation of communication networks in industrial premises*  
IEC 61918:2018/AMD1:2022  
IEC 61918:2018/AMD2:2024

~~The normative references of IEC 61918:2018, Clause 2, apply.~~

NOTE For profile specific normative references, see Clauses A.2, B.2, and C.2.

#### 3 Terms, definitions and abbreviated terms

For the purpose of this document, the terms, definitions and abbreviated terms given in IEC 61918:2018 Clause 3, IEC 61918:2018/AMD1:2022, Clause 3, and Clauses A.3, B.3, C.3 of this document, 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>

~~NOTE For profile specific terms, definitions and abbreviated terms, see Clauses A.3, B.3, and C.3.~~

<sup>1</sup> CIP™ (Common Industrial Protocol) is a trade name of ODVA, Inc. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this document does not require use of the trade name CIP™. Use of the trade name CIP™ requires permission of ODVA, Inc.

<sup>2</sup> The normative references of IEC 61918:2018, Clause 2, IEC 61918:2018/AMD1:2022, Clause 2 and IEC 61918:2018/AMD2:2024, Clause 2, apply.

## 4 CPF 2: Overview of installation profiles

CPF 2 consists of three basic communication profiles as specified in IEC 61784-1 and IEC 61784-2. These profiles share a common upper layers protocol named CIP™ (Common Industrial Protocol).

The installation requirements for CP 2/1 (ControlNet™<sup>3</sup>) are specified in Annex A.

The installation requirements for CP 2/2 (EtherNet/IP™<sup>4</sup>) are specified in Annex B.

The installation requirements for CP 2/3 (DeviceNet™<sup>5</sup>) are specified in Annex C.

## 5 Installation profile conventions

The numbering of the clauses and subclauses in the annexes of this document corresponds to the numbering of IEC 61918 main clauses and subclauses.

The annex clauses and subclauses of this document supplement, modify, or replace the respective clauses and subclauses in IEC 61918.

Where there is no corresponding subclause of IEC 61918 in the normative annexes in this document, the subclause of IEC 61918 applies without modification.

The annex heading letter represents the installation profile assigned in Clause 4. The annex (sub)clause numbering following the annex letter shall represent the corresponding (sub)clause numbering of IEC 61918.

EXAMPLE "Subclause B.4.4" in IEC 61784-5-2 means that CP 2/2 specifies the Subclause 4.4 of IEC 61918:2018.

All main clauses of IEC 61918 are cited and apply in full unless otherwise stated in each normative installation profile annex.

If all subclauses of a (sub)clause are omitted, then the corresponding IEC 61918 (sub)clause applies.

If in a (sub)clause it is written "Not applicable.", then the corresponding IEC 61918 (sub)clause does not apply.

If in a (sub)clause it is written "*Addition*:", then the corresponding IEC 61918 (sub)clause applies with the additions written in the profile.

If in a (sub)clause it is written "*Replacement*:", then the text provided in the profile replaces the text of the corresponding IEC 61918 (sub)clause.

<sup>3</sup> ControlNet™ is a trade name 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 to this profile does not require use of the trade name ControlNet™. Use of the trade name ControlNet™ requires the permission of ODVA, Inc.

<sup>4</sup> EtherNet/IP™ is a trade name 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 to this profile does not require use of the trade name EtherNet/IP™. Use of the trade name EtherNet/IP™ requires the permission of ODVA, Inc.

<sup>5</sup> DeviceNet™ is a trade name 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 to this document does not require use of the trade name DeviceNet™. Use of the trade name DeviceNet™ requires the permission of ODVA, Inc.

NOTE A replacement can also comprise additions.

If in a (sub)clause it is written "*Modification*:", then the corresponding IEC 61918 (sub)clause applies with the modifications written in the profile.

If all (sub)clauses of a (sub)clause are omitted but in this (sub)clause it is written "(Sub)clause *x* has "*addition*:" (or "*replacement*:"), or "(Sub)clause *x* is not applicable.", then (Sub)clause *x* becomes valid as declared and all the other corresponding IEC 61918 (sub)clauses apply.

## 6 Conformance to installation profiles

Each installation profile within this document includes part of IEC 61918:2018. It may also include defined additional specifications.

A statement of compliance to an installation profile of this document shall be stated<sup>6</sup> as either

Compliance ~~to~~ with IEC 61784-5-2:2018<sup>7</sup> and IEC 61784-5-2:2018/AMD1:2024 for CP 2/m <name> or

Compliance ~~to~~ with IEC 61784-5-2 (Ed. 4.04.1) for CP 2/m <name>.

where the name within the angle brackets < > is optional and the angle brackets ~~are~~ shall not ~~to~~ be included. The m within CP 2/m shall be replaced by the profile number 1 to 3.

NOTE The name ~~may~~ can be the name of the profile, e.g. ControlNet, EtherNet/IP or DeviceNet.

If the name is a trade name then the permission of the trade name holder shall be required.

Product standards shall not include any conformity assessment aspects (including quality management provisions), neither normative nor informative, other than provisions for product testing (evaluation and examination).

<sup>6</sup>~~In accordance with ISO/IEC Directives.~~

<sup>7</sup>~~The date should not be used when the edition number is used.~~

## Annex A (normative)

### CP 2/1 (ControlNet™) specific installation profile

#### A.1 Installation profile scope

*Addition:*

This annex specifies the installation profile for Communication Profile CP 2/1 (ControlNet). The CP 2/1 is specified in IEC 61784-1.

The installation profiles are specified in the annexes. These annexes are read in conjunction with IEC 61918:2018.

#### A.2 Normative references

*Addition:*

IEC 60096-2:1961<sup>8</sup>, *Radio-frequency cables – Part 2: Relevant cable specifications*

#### A.3 Installation profile terms, definitions, and abbreviated terms

##### A.3.1 Terms and definitions

##### A.3.2 Abbreviated terms

*Addition:*

DVM	Digital voltmeter
HMI	Human machine interface
I/O	Input/Output
IS	Intrinsic safety
MM	Multi mode
NAP	Network access port (local access to a device, i.e. not via the bus)
OTDR	Optical time domain reflectometer
PLC	Programmable logic controller
PVC	Polyvinyl chloride
RG6	Coaxial cable
SM	Single mode
TDR	Time domain reflectometer

##### A.3.3 Conventions for installation profiles

Not applicable.

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<sup>8</sup> This document has been withdrawn but for the purposes of this document, the edition cited is applicable.

## A.4 Installation planning

### A.4.1 General

#### A.4.1.1 Objective

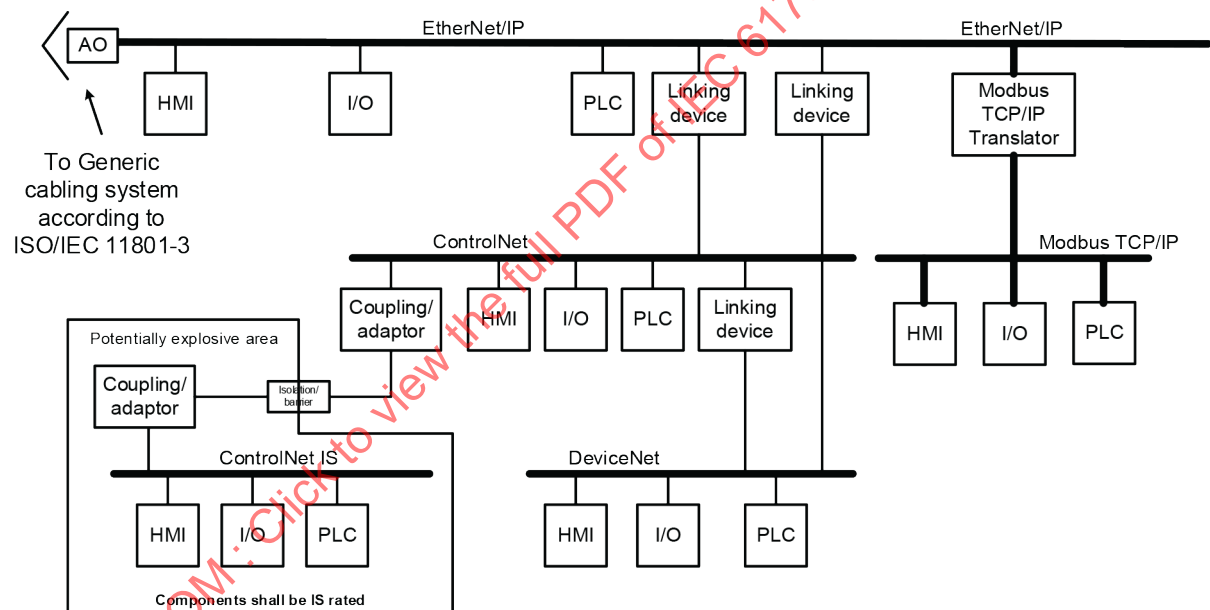
#### A.4.1.2 Cabling in industrial premises

*Addition:*

CP 2/1 networks can be connected to generic cabling via a converter/adaptor as mentioned in IEC 61918:2018, 4.1. Connection to the generic cabling system can also be facilitated through EtherNet/IP and the AO as shown in Figure A.1.

CP 2/1 is designed to be deployed within the automation island and between automation islands as detailed in IEC 61918:2018, 4.1.2, Figure 4, Figure 5 and Figure 6. The network is constructed of passive Taps **[T]** and Repeaters **[R]** interconnected by coaxial cable. Links are connected by Bridges **[B]**. The network can span an entire factory floor.

The interconnection of CP 2/1 with CP 2/2 and CP 2/3 can be accomplished through an appropriate converter/adaptor (linking device) as shown in Figure A.1.



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**Figure A.1 – Interconnection of CPF 2 networks**

The CP 2/1 coaxial media system is made up of the components found in Figure A.2. These parts are as follows:

- coaxial cable and associated connectors (BNC/TNC);
- passive taps (non-sealed and sealed) with fixed 1 m drop cable BNC/TNC connector on the end of the drop cable, which shall not be extended under any circumstances;
- trunk line terminators BNC/TNC;
- repeaters (linear, ring and star) fibre and copper;
- various coaxial couplers, bulkhead, jack-to-jack and plug-to-plug (BNC/TNC).

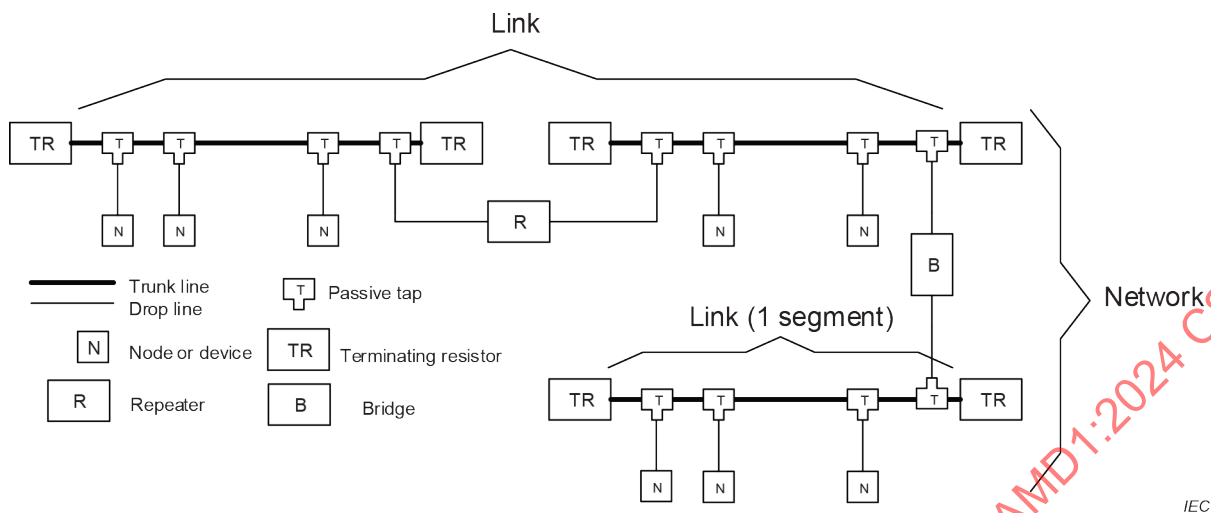


Figure A.2 – Overview of CPF 2/1 networks

## A.4.2 Planning requirements

### A.4.2.1 Safety

#### A.4.2.1.1 General

#### A.4.2.1.2 Electrical safety

#### A.4.2.1.3 Functional safety

Not applicable.

#### A.4.2.1.4 Intrinsic safety

Not applicable.

#### A.4.2.1.5 Safety of optical fibre communication systems

### A.4.2.2 Security

### A.4.2.3 Environmental considerations and EMC

#### A.4.2.3.1 Description methodology

*Addition:*

The configuration of the low-voltage power distribution system shall comply with local regulations. In some cases and geographical areas, additional earthing and bonding is necessary to control noise currents and provide a low noise functional earth for the low signal communications devices. This may be achieved through methods described in IEC 61918:2018, 4.4.7 and A.4.4.7.3 of this document.

This network uses a parallel RC between earth and the shield of the coaxial cable. The shields shall not directly reference to earth at any point in the system, as doing so will allow noise currents to flow in the shields causing high error rates in the network.

**A.4.2.3.2 Use of the described environment to produce a bill of material**

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

Not applicable.

**A.4.3 Network capabilities**

**A.4.3.1 Network topology**

**A.4.3.1.1 Common description**

**A.4.3.1.2 Basic physical topologies for passive networks**

*Modification:*

ControlNet supports passive bus topologies. Passive star topologies are not supported.

**A.4.3.1.3 Basic physical topologies for active networks**

*Modification:*

ControlNet supports active linear, star and ring topologies.

**A.4.3.1.4 Combination of basic topologies**

*Addition:*

ControlNet supports both series connected and parallel connected linear passive bus topologies. In addition, ControlNet supports network redundancy using both series connected and parallel connected linear passive bus topologies. Both networks shall have the same number of active nodes in the same order on the network.

**A.4.3.1.5 Specific requirements for CPs**

*Addition:*

**A.4.3.1.5.1 General**

CP 2/1 supports both coaxial and fibre media in the trunk segments. Drop cables shall be coaxial. The network is an amplitude and delay limited network. In general, for the coaxial variant, amplitude is the limiting factor. Fibre trunk segments have much less loss, so delay limits can be readily exceeded. In either case, the amplitude and delay limits shall be observed. The maximum delay for any network construction (cabling and repeaters) shall be limited to 242  $\mu$ s round trip or 121  $\mu$ s each way.

ControlNet can be configured as a redundant network for both active star and active linear topologies in copper and fibre. See A.4.4.9.6 for specific design considerations. When configured as a redundant network, the number of nodes and addressing shall be the same for both networks.

The following Subclauses A.4.3.1.5.2 to A.4.3.1.5.8 describe the various components and topology constructions possible.

**A.4.3.1.5.2 Taps (coaxial media)**

Taps connect each node on a network to the coax media system via a fixed 1 m drop cable as shown in Figure A.3.

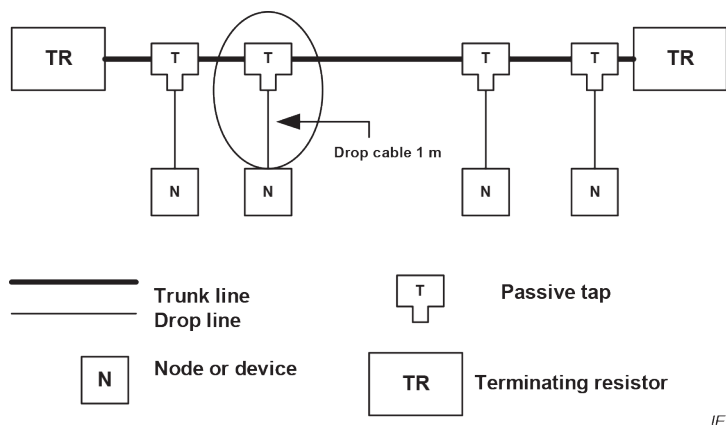


Figure A.3 – Drop cable requirements

**A.4.3.1.5.3 Trunk cable**

The trunk cable is the bus or central part of the CP 2/1 coax media system. The trunk cable is composed of multiple sections of cable. The standard cable that can be used to construct trunk cable sections is defined in A.4.4.1.2.1.

**A.4.3.1.5.4 Trunk line connectors**

BNC/TNC plugs are used to connect the coaxial cables to the taps. Devices are connected to the tap through a 1 m cable attached to the tap with the appropriate BNC/TNC plug. Each trunk cable section shall have a BNC or TNC plug installed on each end as shown in Figure A.4.

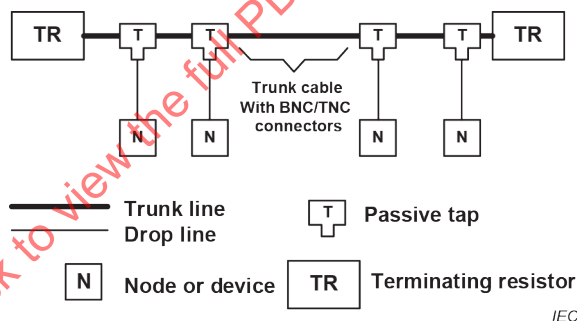
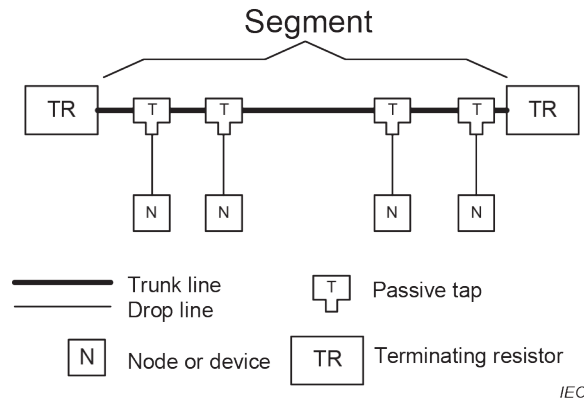


Figure A.4 – Placement of BNC/TNC plugs

**A.4.3.1.5.5 Terminators**

To minimize reflections, the network segment(s) shall be terminated with the appropriate 75 Ω coaxial terminators (see A.4.4.4.2).

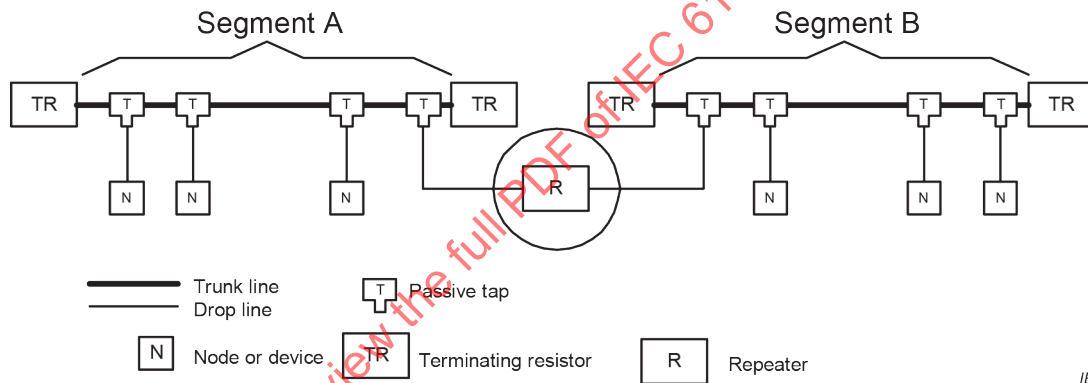
Figure A.5 details the location of the 75 Ω coaxial terminators. The designer shall specify the placement of the 75 Ω coaxial terminators in the design documentation. The terminators are generally installed on the outside port of the tap located at each end of a segment. The terminator is fully described in A.4.4.4.



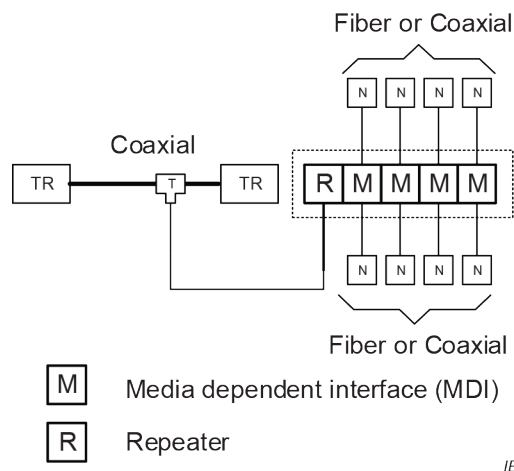
**Figure A.5 – Placement of terminators**

**A.4.3.1.5.6 Repeaters**

Repeater adapters shall be used to increase the number of taps, extend the total length of the network (see Figure A.6), or create an active star configuration as shown in Figure A.7. The number of repeaters and cable length total is limited depending on the network topology. See A.4.4.3.3.2 for information on limitations of length and number of nodes per segment. A repeater creates a new segment allowing additional cable or taps or both.



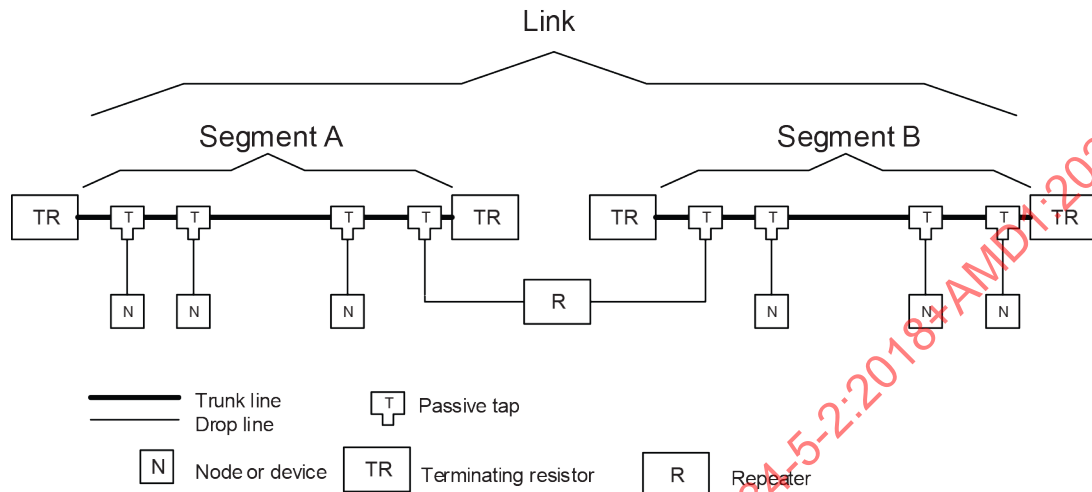
**Figure A.6 – Extending a network using repeaters**



**Figure A.7 – Extending a network using active star topology**

**A.4.3.1.5.7 Links**

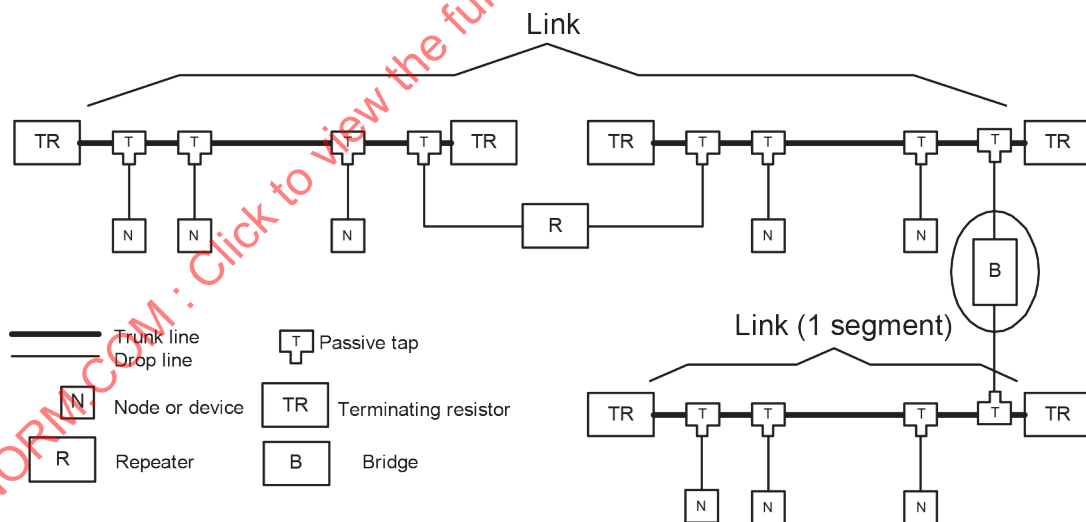
A link is formed by connecting multiple segments together through repeaters (see Figure A.8). A link may consist of only one segment. Each node in a link shall have a unique address in the range of 0 to 99. Node address 0 shall be reserved for devices that are auto address nodes or nodes without address switches.



**Figure A.8 – Links**

**A.4.3.1.5.8 Bridges**

Bridges may be used to connect links together and to extend the network addressing beyond 99 nodes. A bridge connects links together as shown in Figure A.9.



**Figure A.9 – Extending the network beyond 99 nodes**

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

**A.4.3.2 Network characteristics**

**A.4.3.2.1 General**

**A.4.3.2.2 Network characteristics for balanced cabling not based on Ethernet**

*Replacement:*

ControlNet is a coaxial based system, balanced cabling is not supported.

Table A.1 provides values based on the template given in IEC 61918:2018, Table 1.

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

Characteristics	CP 2/1
<b>Basic transmission technology</b>	Linear bus
<b>Length / transmission speed</b>	
Transmission speed	Segment length m
5 Mbit/s	Segment: 1 000 m maximum (see Figure A.10) Link: 20 km maximum <sup>a</sup>
<b>Maximum capacity</b>	<b>Max. no.</b>
Devices / segment	48
Devices / link	99
Devices / network	Unlimited
<sup>a</sup> The total link length is limited to 20 km due to delay limitations of 242 μs round trip (121 μs one-way trip).	

**A.4.3.2.3 Network characteristics for balanced cabling based on Ethernet**

Not applicable.

**A.4.3.2.4 Network characteristics for optical fibre cabling**

*Replacement:*

The allowable fibre segment lengths and wavelengths are detailed in Table A.2 for CP 2/1 based on the template given in IEC 61918:2018, Table 3.

**Table A.2 – Network characteristics for optical fibre cabling**

CP 2/1		
Optical fibre type	Description	
Single mode silica	Bandwidth (MHz) or equivalent at $\lambda$ (nm)	20 MHz 1 310 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	20 000 <sup>b</sup>
	Maximum channel Insertion loss/optical power budget (dB)	10,5
	Connecting hardware	See A.4.4.2.5
Multimode silica	Modal bandwidth (MHz × km) at $\lambda$ (nm)	20 MHz 1 300 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	M = 3 000 <sup>c</sup> L = 10 000 <sup>c</sup> XL = 10 000 <sup>c</sup>
	Maximum channel Insertion loss/optical power budget (dB)	M = 13,3 L = 15 XL = 10,5
	Connecting HW	See A.4.4.2.5
POF	Modal bandwidth (MHz × km) at $\lambda$ (nm)	–
	Minimum length (m)	–
	Maximum length <sup>a</sup> (m)	–
	Maximum channel Insertion loss/optical power budget (dB)	–
	Connecting HW	–
Hard clad silica	Modal bandwidth (MHz × km) at $\lambda$ (nm)	20 MHz 650 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	300
	Maximum channel Insertion loss/optical power budget (dB)	4,2 <sup>d</sup>
	Connecting HW	See A.4.4.2.5
<sup>a</sup> This value is reduced by connections, splices and bends in accordance with Formula (1) in 4.4.3.4.1 of IEC 61918:2018. <sup>b</sup> Extra Long Repeaters Only. <sup>c</sup> M = Medium distance capable modules, L = Long distance capable modules and XL = Extra long distance capable modules. <sup>d</sup> Short distance modules only.		

**A.4.3.2.5 Specific network characteristics***Addition:*

CP 2/1 supports active fibre rings, active line and active star topologies.

Fibre redundancy is only available for active linear and active star topologies, see A.4.4.9.6 for the design and limitations of redundant networks.

Fibre ring is inherently redundant and does not require duplicate hardware.

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

**A.4.4 Selection and use of cabling components**

**A.4.4.1 Cable selection**

**A.4.4.1.1 Common description**

**A.4.4.1.2 Copper cables**

**A.4.4.1.2.1 Balanced cables for Ethernet-based CPs**

Not applicable.

**A.4.4.1.2.2 Copper cables for non-Ethernet-based CPs**

*Replacement:*

The selection of connector and installation tools shall be compatible with coaxial cable (referred to as RG6). If these are not properly matched, network failures may result.

The coaxial cable electrical requirements, on which the standard topology is based, can be found in Table A.3. The mechanical properties for the standard coaxial cable are described in Table A.4. These parameters (electrical and mechanical) can be used to procure the proper cable for standard installations. Speciality cables as described in Table A.5 may require different mechanical and/or electrical properties and therefore shall be accounted for in the network length limits and tools used for connector installation. Since the network is designed to be a 75  $\Omega$  system, substitution of the cable impedance is not allowed.

The electrical parameters detailed in Table A.3 shall be met in order to maintain standard network configurations as described in this installation profile.

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**Table A.3 – RG6 coaxial electrical properties**

Specification	Limits/Characteristics
Shielding	Quad shield
Impedance	$(75 \pm 3) \Omega$
Delay	$(4,1 \pm 0,1) \text{ ns/m}$
Frequency	Attenuation (dB/100 m)
1 MHz	1,15
2 MHz	1,25
5 MHz	1,48
10 MHz	1,94
20 MHz	2,82
50 MHz	4,49
Structural return loss	23 dB minimum from 5 MHz to 50 MHz
Conductor DC resistance	92 $\Omega$ /km nominal
Shield DC resistance	24 $\Omega$ /km nominal
Capacitance	53,2 pF/m

The physical parameters listed in Table A.4 shall be met in order to maintain noise immunity and connector compatibility.

**Table A.4 – RG6 coaxial physical parameters**

Specification	Characteristics
Centre conductor material and diameter	18 AWG solid bare copper covered steel $0,823 \text{ mm}^2 \pm 0,020 \text{ mm}^2$
Dielectric material and diameter	$4,65 \text{ mm} \pm 0,13 \text{ mm}$
Shield construction 4 layers	Layer 1: foil Layer 2: 60 % braid Layer 3: foil Layer 4: 40 % braid
Jacket diameter	$7,67 \text{ mm} \pm 0,13 \text{ mm}$

*Addition:*

CP 2/1 uses 75  $\Omega$  RG6 quad shield coaxial cables compliant with IEC 60096-2.

Specific cable designs shall be selected based on the application and the environment. The MICE concept can be used to help determine the environmental conditions and to select components and/or appropriate mitigation. Table A.5 provides guidance for application-specific cables.

**Table A.5 – Cable type selection**

Application type	Example cable type <sup>a</sup>
Light industrial applications	Standard – PVC CM-CL2
Industrial applications	Lay-on armoured and interlocking armour
High and low temperature application, as well as corrosive area (harsh chemicals – see manufacturing data sheets for chemical resistivity)	Plenum-FEP CMP-CL2P
Festooning or flexing applications (rolling "C" track and robotic tic-toc)	High flex
Moisture resistant applications; direct burial, with flooding compound, fungus resistant	Flood burial
<sup>a</sup> See the local cable distributor for cable availability.	

All coaxial cables used in the ControlNet system shall meet the electrical requirements of this Clause A.4. In addition, they shall be constructed with quad shields (single, dual and tri shields are not allowed). It is important that the attenuation be met over the frequencies listed in this Clause A.4. If the attenuation is greater than listed in this Clause A.4, additional length derating shall be determined by using the equations in this Clause A.4. If the segment attenuation is too high, the segment shall be divided using repeaters.

The cabling components shall be selected based on the environmental and application requirements. Highflex applications shall use cables designed to meet high flex. Cables expected to be subjected to weld splatter shall have the appropriate protection or jacket designs. Cables used in outdoor applications, shall have the appropriate UV protection or jacketing design.

**A.4.4.1.3 Cables for wireless installation**

**A.4.4.1.4 Optical fibre cables**

*Addition:*

For optical fibre, cabling shall conform to the requirements given in Table A.2. In addition the planner shall consider the following.

The planner shall define the maximum cable length allowed between any two devices. When installing optical fibre cables, this maximum cable length shall not exceed the lengths as defined in Table A.2. Using special cables or optical fibre splices can further reduce cable lengths. Reliable data transmission may be ensured up to this certified length if the cables and the connections have been installed correctly.

The properties of an optical fibre transmission system are mainly characterized by:

- the output power of the optical interface;
- the type of cable used;
- the quality of installation and the plug configuration.

Planner and installer shall observe the insertion loss requirements (cables and connectors) to insure proper functioning segment. In addition, the instructions of the cable, plug connector and device manufacturer shall be observed. For optical fibre cables of an industrial network the planner shall use the data defined in Table A.6.

Some additional information that shall be considered by the installer and maintenance personnel are given in the relevant clauses of this document.

Table A.6 provides values based on the template given in IEC 61918:2018, Table 6.

**Table A.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	OS1	OM1, OM2 or OM3 1 300 nm	OM1, OM2 or OM3 1 300 nm	–	–
Attenuation per km (650 nm)	–	–	–	–	≤ 6,0 dB
Attenuation per km (820 nm)	–	–	–	–	–
Attenuation per km (1 310 nm)	≤ 1,0 dB or OS1	≤ 2,5 dB or OM1	≤ 3,5 dB or OM1	–	–
Number of optical fibres	2	2	2	–	2
Connector type (e.g. duplex or simplex)	BFOC 2,5	BFOC 2,5	BFOC 2,5	–	V-Pin
Jacket colour requirements	User defined	User defined	User defined	–	User defined
Jacket material	Application specific	Application specific	Application specific	–	Application specific
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	Yes <sup>a</sup>	Yes <sup>a</sup>	Yes <sup>a</sup>	–	Yes <sup>a</sup>
NOTE Duplex and simplex cords/cables are supported.					
<sup>a</sup> If application requires.					

#### A.4.4.1.5 Special purpose balanced and optical fibre cables

#### A.4.4.1.6 Specific requirements for CPs

Not applicable.

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

#### A.4.4.2 Connecting hardware selection

##### A.4.4.2.1 Common description

##### A.4.4.2.2 Connecting hardware for balanced cabling CPs based on Ethernet

Not applicable.

##### A.4.4.2.3 Connecting hardware for copper cabling CPs not based on Ethernet

*Replacement:*

The connectors used in this network are limited to those shown in Table A.7.

**Table A.7 – Copper connectors for ControlNet**

CP 2/1	Coaxial IEC 61169-8	Others
Characteristics for CP 2/1 (ControlNet)	BNC	TNC RJ45 (NAP)

*Addition:*

The centre conductor contact shall be plated in conformance with one of the following specifications:

- 0,75 µm gold minimum over 1,25 µm nickel minimum over base metal;
- 0,05 µm to 0,2 µm gold flash over 1,25 µm palladium nickel minimum over 1,25 µm nickel minimum over base metal.

The connector characteristic impedance shall be 75 Ω nominal, 45 Ω minimum and 80 Ω maximum, from DC to 50 MHz.

For network reliability, the cables, connectors and installation tools shall be mechanically compatible. The cable and connector manufacturer's data sheets shall be consulted for compatibility and installation tool requirements.

Passive taps are used to connect the trunk sections together and provide a connection point for each node. A tap is required for each active device connected to the network. There are two variants of the taps available:

- sealed meeting IP67 minimum, using TNC connectors;
- non-sealed meeting IP65 maximum, using BNC connectors.

For reliability reasons, the number of connections in a segment shall be minimized.

The cabling components shall be selected based on the environmental and application requirements.

**A.4.4.2.4 Connecting hardware for wireless installation**

**A.4.4.2.5 Connecting hardware for optical fibre cabling**

*Replacement:*

Table A.8 provides values based on the template given in IEC 61918:2018, Table 9.

**Table A.8 – 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	VPIN
<b>CP 2/1 (ControlNet)</b>	Yes	No	No	No	No	Yes
NOTE The 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.						

To minimize noise coupling into the sensitive receiver, connectors with plastic or ceramic ferrules are recommended.

Table A.9 provides values based on the template given in IEC 61918:2018, Table 10.

**Table A.9 – Relationship between FOC and fibre types (CP 2/1)**

FOC	Fibre type					
	9..10/125 $\mu\text{m}$ single mode silica	50/125 $\mu\text{m}$ multimode silica	62,5/125 $\mu\text{m}$ multimode silica	980/1 000 $\mu\text{m}$ step index POF	200/230 $\mu\text{m}$ step index hard clad silica	Others
BFOC/2,5	No	Yes	Yes	No	No	No
SC	No	No	No	No	No	No
SC-RJ	No	No	No	No	No	No
LC	No	No	No	No	No	No
F-SMA	No	No	No	No	No	No
V-PIN	No	No	No	No	Yes	No

Insertion loss correction factors shall be used when using MMF fibres smaller than 62,5/125  $\mu\text{m}$ .

#### A.4.4.2.6 Specific requirements for CPs

Not applicable.

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

#### A.4.4.3 Connections within a channel/permanent link

##### A.4.4.3.1 Common description

Not applicable.

##### A.4.4.3.2 Balanced cabling connections and splices for CPs based on Ethernet

Not applicable.

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

###### A.4.4.3.3.1 Common description

###### A.4.4.3.3.2 Connections minimum distance

*Replacement:*

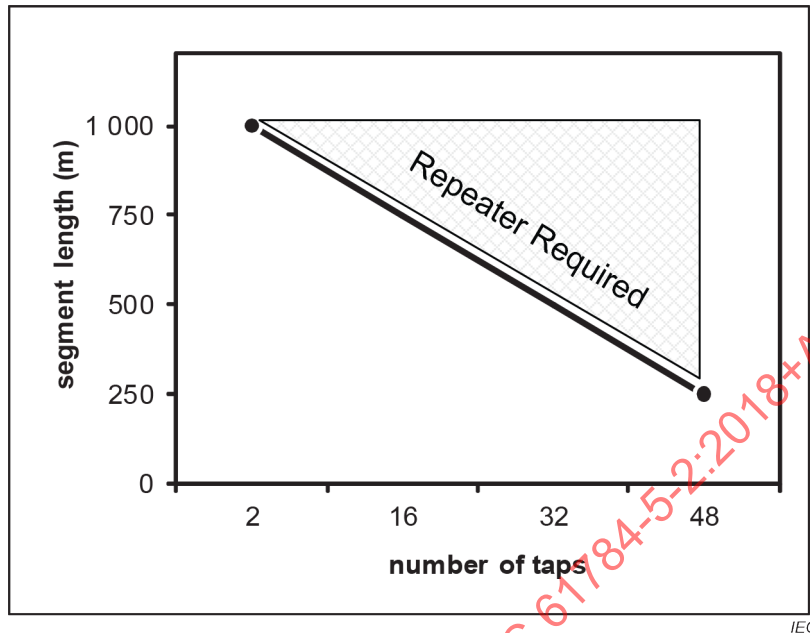
###### a) General

The shortest path for routing the cable shall be selected to minimize the amount of cable needed. The specific details of planning cabling route depend upon the needs of the network.

When determining the cable length of trunk-cable sections, it is important to measure the actual cable path as it is routed in the network. Vertical dimensions as well as horizontal dimensions shall be considered. The three-dimensional routing path distance shall always be calculated when determining cable lengths.

The total allowable length of a segment containing standard RG6 quad shield depends on the requirements of Table A.1 and Table A.3, and of the number of taps in the segment. There is no minimum trunk-cable section or segment length requirement. The maximum allowable total length of a segment is 1 000 m with two taps installed. Each additional tap decreases the

maximum length of the segment by 16,3 m. The maximum number of taps allowed on a segment is 48. With 48 taps the maximum segment length is limited to 250 m. Figure A.10 details the relationship between the number of taps allowed in a segment and the segment length. If the network design falls in the grey area, then a repeater is required.



**Figure A.10 – Maximum allowable taps per segment**

Maximum allowable segment length = 1 000 m – 16,3 m × [number of taps – 2]

**EXAMPLE 1**

The following is an example of how to calculate the number of taps allowed for different segment lengths.

If the segment requires 10 taps, then the maximum segment length is:

$$1\,000\text{ m} - 16,3\text{ m} \times [10 - 2]$$

$$1\,000\text{ m} - 130,4\text{ m} = 869,6\text{ m}$$

The amount of high flex RG6 cable that can be used in a system is less than the amount of standard RG6 cable. The designer is encouraged to keep the length of high flex cable use to a minimum. BNC bullet connectors or isolated bulkhead connectors shall be used to isolate areas that require high flex RG6 cable from areas that require standard RG6 cable; this allows the high flex RG6 section to be replaced before flex life is exhausted. An allowable total length of RG6 flex cable segment in the application can be determined using the equation below. Each additional tap decreases the maximum length of the segment. The maximum segment length depends on the attenuation of the high flex cable used. The maximum allowable segment length is then as follows:

$$\text{Segment}_{\text{Length}} = \frac{[20,29\text{ dB} - (\text{Number}_{\text{taps}} \times 0,32\text{ dB})]}{\text{Cable}_{\text{Attenuation@10MHz}}}$$

Important: The cable attenuation at 10 MHz per unit length is defined as the signal loss measured at 10 MHz per 100 m of cable.

Cable attenuation for ControlNet cables are listed in the manufacturers' data sheets.

**EXAMPLE 2**

The cable selected for this example is high flex cable. The attenuation for this high flex coaxial cable is 2,36 dB per 100 m at 10 MHz. For a segment that requires 3 taps using high flex cable, the maximum segment length is:

$$\text{Segment}_{\text{Length}} = \left[ \frac{[20,29 \text{ dB} - (3 \times 0,32 \text{ dB})]}{2,36 \text{ dB}} \right] \times 100\text{m}$$

or

$$\text{Segment}_{\text{Length}} = \left[ \frac{19,33 \text{ dB}}{2,36 \text{ dB}} \right] \times 100 \text{ m} = 820 \text{ m}$$

The total trunk-cable length or number of taps (connections) can be increased by breaking up the segment into smaller segments.

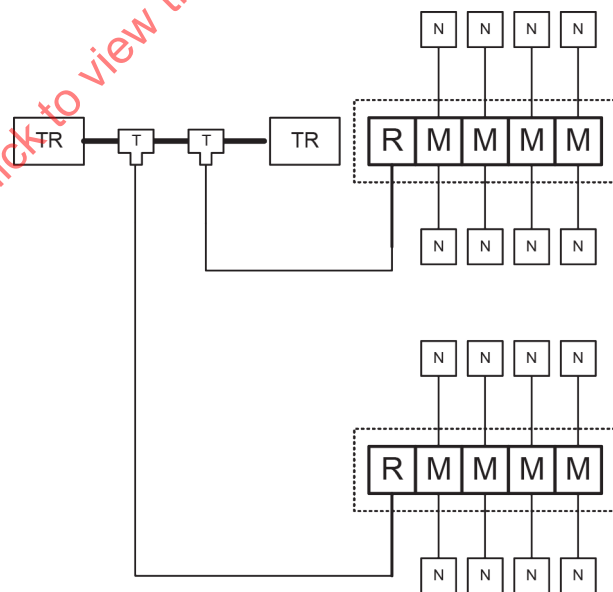
**b) Repeaters**

ControlNet supports copper and fibre repeaters. Regardless of the media, the repeaters can be configured in the following topologies.

A link may be configured in one of five ways:

- series up to 20 repeaters;
- star topology (see Figure A.11);
- parallel up to 48 repeaters (see Figure A.12);
- combination of series and parallel (see Figure A.13);
- ring up to 20 repeaters (see Figure A.14).

The total link length is limited to 20 km due to delay limitations of 121 μs each way (242 μs round trip).



**M** Media dependant interface (MDI)  
**R** Repeater

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**Figure A.11 – Example of repeaters in star configuration**

The appropriate repeater module is required for the specific repeater topology needed. For example ring capable repeaters are required for fibre ring topologies.

A repeater can be connected to a segment at any tap location along the trunk. Fibre repeaters may be connected in series through the fibre ports.

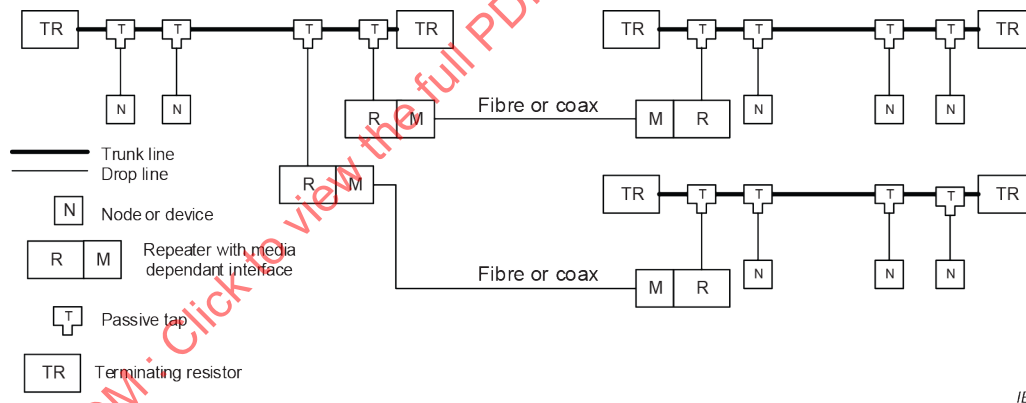
The maximum link length is based on the distance between any two nodes. The maximum distance between any two nodes in a link is limited by the delay between the nodes. The maximum delay is limited to 121  $\mu$ s end-to-end or 242  $\mu$ s round trip.

**c) Series connected repeaters**

When installing repeaters in series, ControlNet network management software should be used to verify that the system is an allowable configuration. The system size is based on the maximum number of repeaters (20) in series and length of the media used between any two nodes. The total network delay described above in b) shall not be exceeded. See the installation instructions that were shipped with the repeater for an example series topology drawing and configuration instructions.

**d) Parallel connected repeaters**

When installing repeaters in parallel, a maximum of 48 repeaters (the maximum number of taps per 250 m segment) on any one segment is allowed. If the link is configured using repeaters in parallel, one shall count one of the repeater taps for one segment and the other repeater tap for the parallel segment that the repeater is connecting to the backbone network. See Figure A.12 for an example of repeaters in parallel. For further instructions on repeaters in series and parallel, see the instructions that were shipped with the repeater.



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**Figure A.12 – Repeaters in parallel**

**e) Repeaters in a combination of series and parallel**

Repeaters can be installed in a combination of series and parallel connections to form a link. The guidelines listed for each type shall be followed. For mixed topologies (series and parallel), the maximum number of repeaters and media should be verified by using the appropriate network configuration software. See the installation instructions that were shipped with the repeater for an example combination series/parallel topology drawing. There shall not be more than one communication path to a node on a network. Ring repeaters have two paths by definition.

When the network is configured using repeaters in combination of series and parallel as shown in Figure A.13, it is important to count the taps and repeaters in all segments.

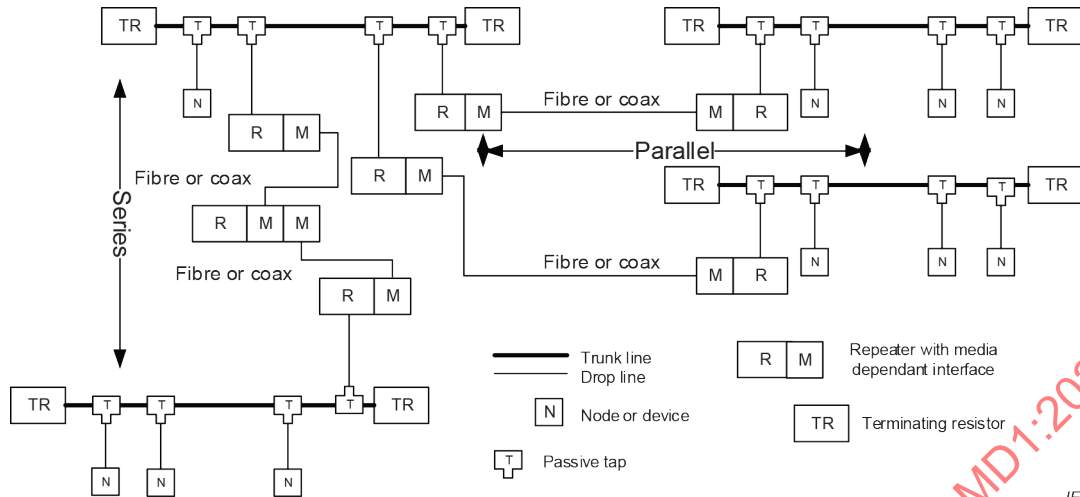


Figure A.13 – Repeaters in combination series and parallel

**f) Ring repeaters**

For a ring topology, the network designer shall use the appropriate ControlNet fibre ring repeaters. See Figure A.14 for an example of a fibre ring. See the installation instructions that were shipped with the repeater for instructions on setting up the ring. ControlNet supports both linear redundancy and ring topologies.

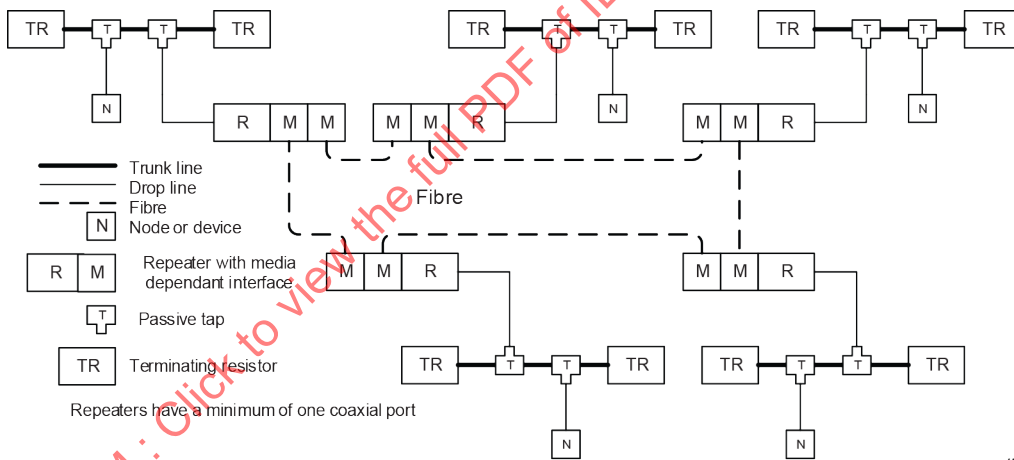


Figure A.14 – Ring repeater

**A.4.4.3.3.3 Copper cabling splices**

*Addition:*

The planner shall specify J-J BNC or TNC couplers when splices are necessary.

**A.4.4.3.3.4 Copper cabling bulkhead connections**

*Replacement:*

Copper bulkheads shall be isolated from earth. Copper bulkheads shall be constructed of back-to-back BNC jacks, TNC jacks or a combination of BNC and TNC jacks. They shall provide environmental isolation. Examples of how bulkheads are used in this profile are shown in Figure A.15.

When copper adaptors are used they shall have a nominal characteristic impedance of 75  $\Omega$ , 45  $\Omega$  minimum and 80  $\Omega$  maximum, from DC to 50 MHz.

In this example, ControlNet cable:

- enters and exits the panel enclosure from the side using isolated-bulkhead connectors;
- contains two adjacent taps connected by a barrel connector;
- reserves one future tap location with a bullet.

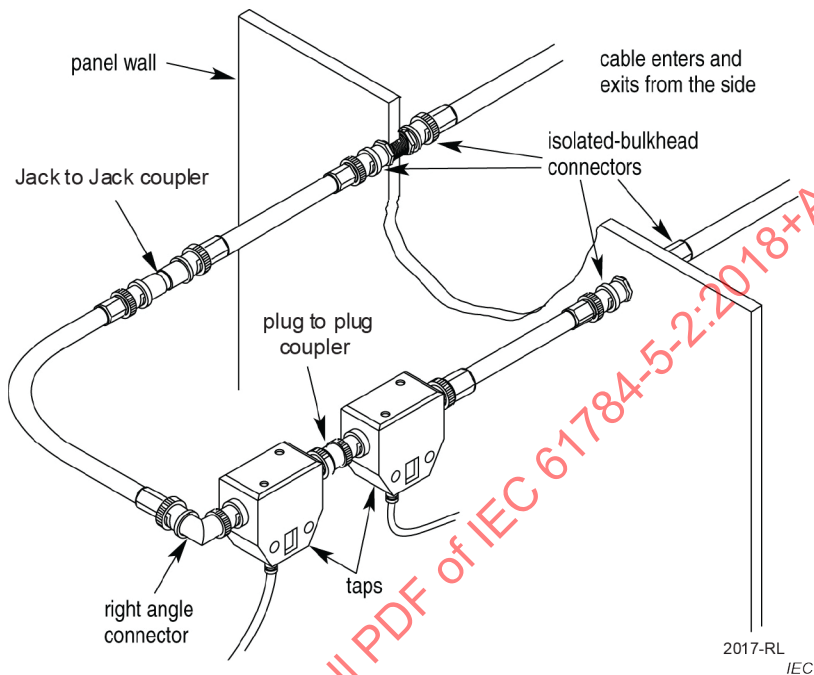


Figure A.15 – Installing bulkheads

#### A.4.4.3.3.5 Copper cabling J-J couplers (J-J adaptors)

*Replacement:*

When extending a trunk section, the appropriate BNC or TNC J-J coupler connector shall be used (see Figure A.15).

Copper adaptors shall have a nominal characteristic impedance of 75  $\Omega$ , 45  $\Omega$  minimum and 80  $\Omega$  maximum, from DC to 50 MHz

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

Not applicable.

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

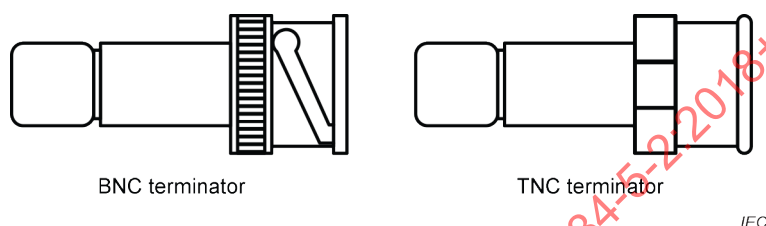
*Addition:*

The designer is encouraged to minimize the number of mechanical connections to minimize the risk of failure.

Each connection adds losses that shall be accounted for in the power budget found in Table A.2.

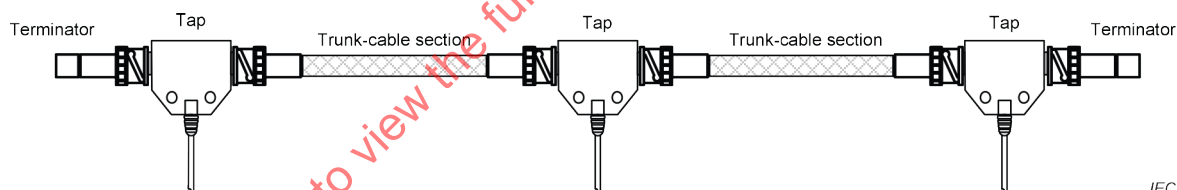
**A.4.4.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****A.4.4.4 Terminators****A.4.4.4.1 Common description****A.4.4.4.2 Specific requirements for CPs***Addition:*

Terminators are required for ControlNet in order to minimize reflections in the trunk system. Figure A.16 shows examples of BNC and TNC coaxial terminators. A 75  $\Omega$  terminator shall be placed at the end of each segment for the ControlNet cable system (see Figure A.17 for placement).

**Figure A.16 – Coaxial BNC and TNC terminators**

The number of required terminators is determined by multiplying the number of segments by two.

The terminators shall be coaxial 75  $\Omega$  1 %, 0,5 W low inductance BNC or TNC.

**Figure A.17 – Terminator placement in a segment****A.4.4.4.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

Not applicable.

**A.4.4.5 Device location and connection****A.4.4.5.1 Common description****A.4.4.5.2 Specific requirements for CPs***Addition:*

Devices shall be installed in accordance with the following:

- manufacturer's documentation;
- planner's documentation;
- cable routing;

- location of the taps. Taps have a 1 metre maximum drop length.

**A.4.4.5.3 Specific requirements for wireless installation**

Not applicable.

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

**A.4.4.6 Coding and labelling**

**A.4.4.7 Earthing and bonding of equipment and devices and shielded cabling**

**A.4.4.7.1 Common description**

**A.4.4.7.2 Bonding and earthing of enclosures and pathways**

**A.4.4.7.2.1 Equalization and earthing conductor sizing and length**

*Addition:*

ControlNet supports both earthing schemes, Star and Equipotential earthing systems. If the building does not have an adequate equipotential earthing system, then the star earthing system shall be used to mitigate earth potential offsets within the communications coverage area. Equipotential earthing system can be installed in accordance with IEC 61918:2018.

**A.4.4.7.2.2 Bonding straps and sizing**

**A.4.4.7.3 Earthing methods**

**A.4.4.7.3.1 Equipotential**

**A.4.4.7.3.2 Star**

**A.4.4.7.3.3 Earthing of equipment (devices)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions.

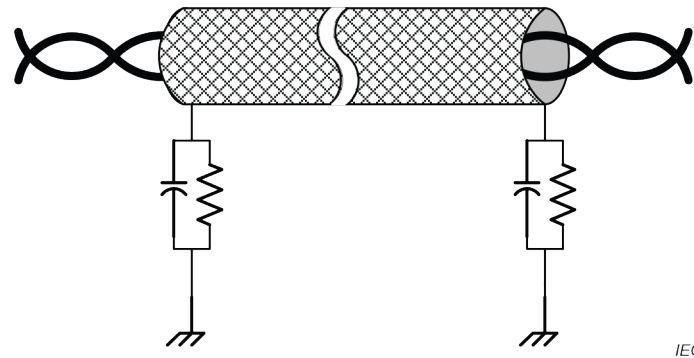
**A.4.4.7.3.4 Copper bus bars**

**A.4.4.7.4 Shield earthing**

**A.4.4.7.4.1 Non-earthing or parallel RC**

*Modification:*

ControlNet coaxial shields are connected to earth via a parallel RC circuit that is integral to the active devices as modelled in Figure A.18. The coaxial shields shall not be directly bonded to earth as this will introduce noise in the network.



**Figure A.18 – RC Shield Termination in Active Devices**

**A.4.4.7.4.2 Direct**

Not applicable.

**A.4.4.7.4.3 Derivatives of direct and parallel RC**

Not applicable.

**A.4.4.7.5 Specific requirements for CPs**

Not applicable.

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

**A.4.4.8 Storage and transportation of cables**

**A.4.4.9 Routing of cables**

**A.4.4.9.1 Common description**

**A.4.4.9.2 Cable routing of assemblies**

**A.4.4.9.3 Requirements for cable routing inside enclosures**

*Addition:*

Cable sections that run inside protective equipment enclosures are relatively short. For wiring external to enclosures, the maximum separation shall be maintained between ControlNet cable and Category-1 conductors. The minimum separation from other circuits is defined in Table 17 of IEC 61918:2018. When running cable inside an enclosure, the installer shall route the conductors external to all pathways in the same enclosure, or in a pathway separate from Category-1 conductors.

**A.4.4.9.4 Cable routing inside buildings**

**A.4.4.9.5 Cable routing outside and between buildings**

**A.4.4.9.6 Installing redundant communication cables**

*Addition:*

A second trunk cable is used between ControlNet nodes for redundant media. With redundant media, nodes send signals on two separate segments. The receiving node compares the quality of the two signals and accepts the better signal to permit use of the best signal. This

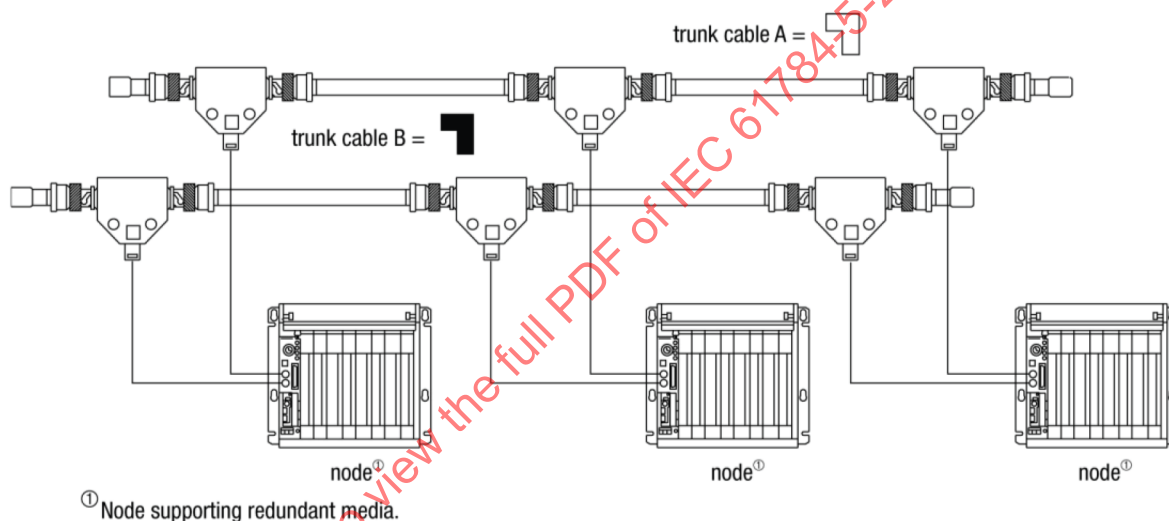
also provides a backup cable if one cable fails. Trunk cables on a redundant cable link are defined by the segment number and the redundant trunk-cable letter.

ControlNet products are labelled with the icons in Figure A.19. The light-coloured icon should be placed on drop cables connected to port A of the devices. The dark-coloured icon should then be placed on redundant node ports marked B. See Figure A.20 for redundant coax media example. Figure A.21 is an example of a redundant network using repeaters to extend the network. The difference in length of redundant network A and network B shall not exceed the limits in Figure A.22 for coax repeaters and Figure A.23 for fibre repeaters.



**Figure A.19 – Redundant network icons**

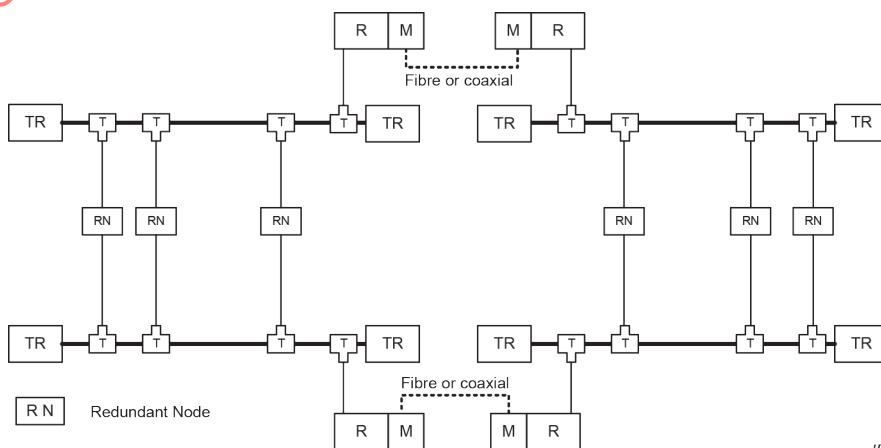
In Figure A.20, trunk cable A is denoted by the light icon and trunk cable B is denoted by the dark icon. The cabling system should be marked accordingly with the proper icon or letter. Redundant nodes are connected to trunk cable A and trunk cable B as shown in Figure A.20



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**Figure A.20 – Redundant coax media**

Fibre media can be used to extend a redundant network as shown in Figure A.21.



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**Figure A.21 – Redundant fibre media**

The following guidelines shall be observed when planning a redundant media system.

- The two trunk cables (trunk cable A and trunk cable B) shall be routed differently to reduce the chance of both cables being damaged at the same time.
- Each node on a redundant-cable link shall support redundant coax connections and be connected to both trunk cables at all times. Any nodes connected to only one side of a redundant-cable link will result in media errors on the unconnected trunk cable.
- The cabling system shall be installed so that the trunk cables at any physical device location can be easily identified and labelled with the appropriate icon or letter. Each redundant ControlNet device is labelled so that it can be connected to the corresponding trunk cable.
- Both trunk cables (trunk cable A and trunk cable B) of a redundant-cable link shall have the same configurations. Each segment shall contain the same number of taps, nodes and repeaters. Nodes and repeaters shall be connected in the same relative sequence on both trunk cables.
- Cable shall be installed on each side of a redundant cable system so that each cable is about the same length. As the number of repeaters in a network increases, the allowable difference in length of the two redundant cabling systems is decreased as shown in Figure A.22.
- The difference in length between the two paths (trunk cable A and trunk cable B) shall not exceed the worst-case limit line as detailed in Figure A.22 for coax media when using repeaters.
- The difference in length between the two paths (trunk cable A and trunk cable B) shall not exceed the worst-case limit line as detailed in Figure A.23 for fibre media when using repeaters.
- When there are no repeaters in a redundant network, the difference between the redundant paths (trunk cable A and trunk cable B) shall not exceed that detailed for zero repeaters in Figure A.22 or Figure A.23.
- Both redundant connections of a node shall not be connected to the same network; doing so will cause erratic operation. In addition, all nodes with redundant ports shall be connected to a redundant network at the same physical location within the network. See Figure A.24 and Figure A.25 for both proper and improper connection of redundant nodes.
- The two networks shall not be connected together.
- ControlNet supports linear redundancy and ring topology. Dual redundant rings are not supported and will result in multiple communications paths and lead to network instabilities.

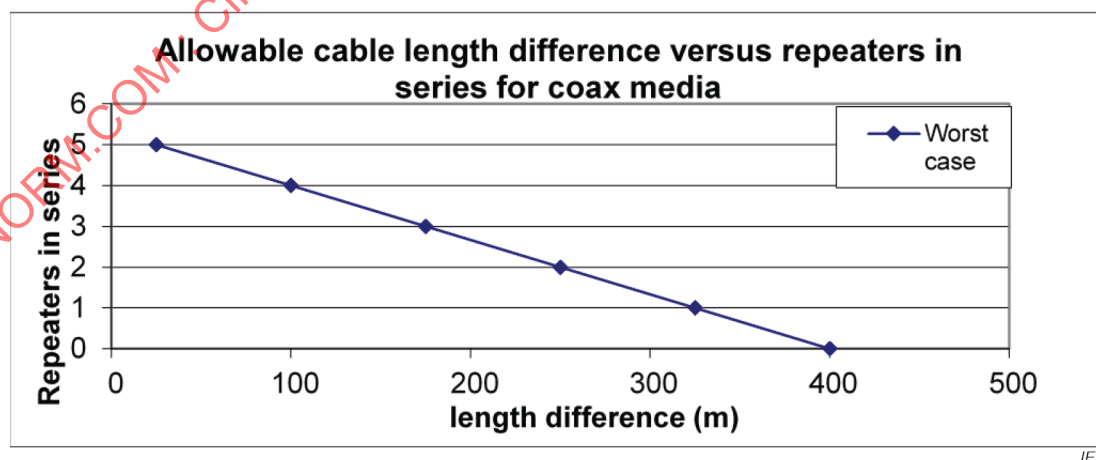


Figure A.22 – Repeaters in series versus length difference for coax media

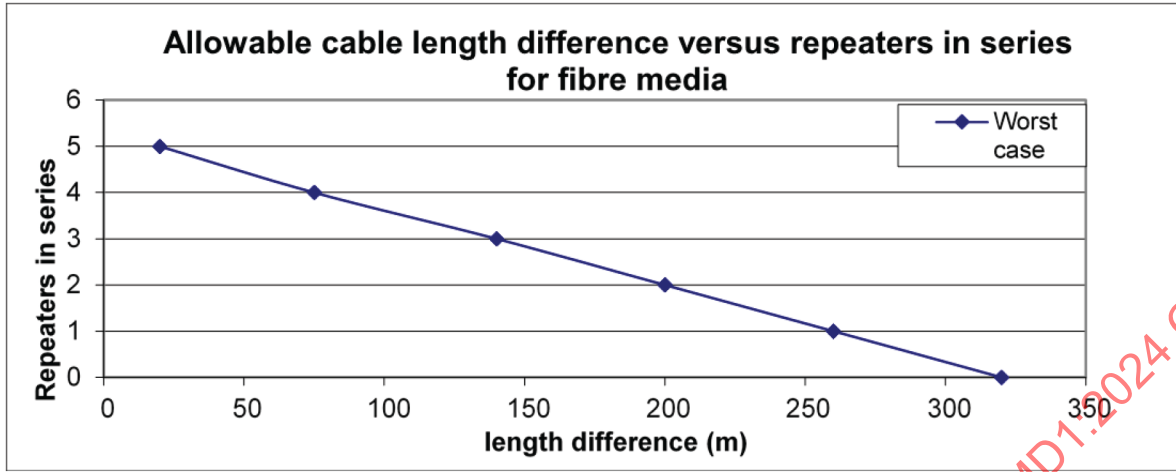


Figure A.23 – Repeaters in series versus length difference for fibre media

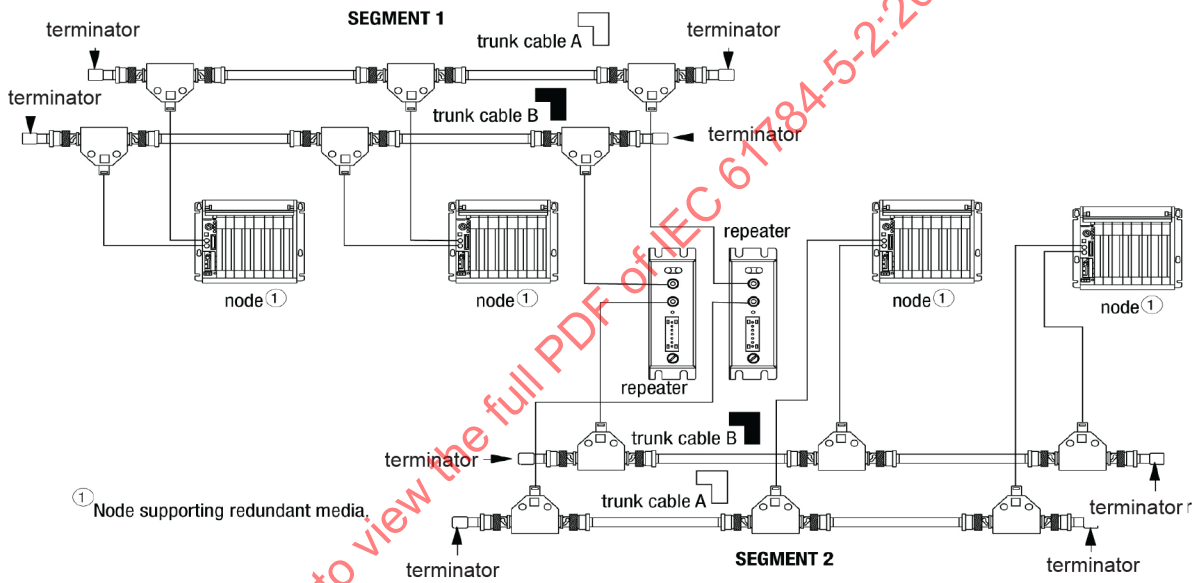
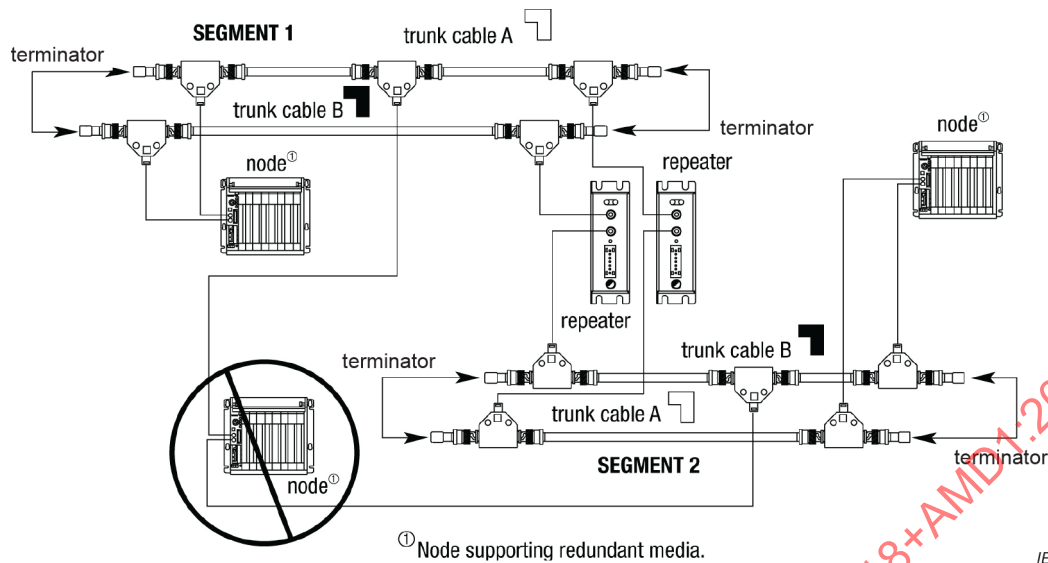


Figure A.24 – Example of redundant coax network with repeaters



**Figure A.25 – Example of improper redundant node connection**

The allowable difference in length of trunk cable A and B can be found by counting the number of repeaters needed for the network and looking in the graph for coax repeaters above. When one repeater is used, the allowable difference in length between network cable A and B is limited to 325 m (see Figure A.22 and Figure A.24).

A node supporting redundant trunk-cable connections will function even if trunk cable A is connected to the B connector on the node and vice-versa. However, doing so is not recommended because this makes cable fault indications (on the hardware or in the software) difficult to interpret and this makes locating a bad cable segment very difficult.

#### **A.4.4.10 Separation of circuits**

*Addition:*

These additional guidelines shall be followed for wiring all ControlNet cables:

- if cables are required to cross power lines, they should do so at right angles;
- cable shall be routed at least 1,5 m (5 ft.) from high-voltage enclosures, or sources of rf/microwave radiation.

If the conductor is in a metal wireway or conduit, each section of the wireway or conduit shall be bonded to each adjacent section so that it has electrical continuity along its entire length, and shall be bonded to the enclosure at the entry point.

#### **A.4.4.11 Mechanical protection of cabling components**

##### **A.4.4.11.1 Common description**

Specific requirements for CPs.

Not applicable.

**A.4.4.11.2 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

**A.4.4.12 Installation in special areas**

**A.4.4.12.1 Common description**

**A.4.4.12.2 Specific requirements for CPs**

*Addition:*

The cabling components shall be selected based on the environmental and application requirements. Highflex applications shall use cables designed to meet high flex. Cables expected to be subjected to weld splatter shall have the appropriate protection or jacket designs. Cables used in outdoor applications shall have the appropriate UV protection or jacketing design.

**A.4.5 Cabling planning documentation**

**A.4.6 Verification of cabling planning specification**

**A.5 Installation implementation**

**A.5.1 General requirements**

**A.5.1.1 Common description**

**A.5.1.2 Installation of CPs**

**A.5.1.3 Installation of generic cabling in industrial premises**

Not applicable.

**A.5.2 Cable installation**

**A.5.2.1 General requirements for all cabling types**

**A.5.2.1.1 Storage and installation**

**A.5.2.1.2 Protecting communications cables against potential mechanical damage**

*Addition:*

When pulling the RG6 type coax cable through multiple conduit bends, the specifications detailed in Table A.10 shall be followed.

**Table A.10 – Parameters for coaxial RG6 cables**

Characteristic		Value	
		PVC	FEP
Mechanical force	Minimum bending radius, single bending (mm)	77	70
	Bending radius, multiple bending (mm)	See manufacturer's data sheet	See manufacturer's data sheet
	Pull forces (N)	400	600
	Permanent tensile forces (N)	See manufacturer's data sheet	See manufacturer's data sheet
	Maximum lateral forces (N/cm)	See manufacturer's data sheet	See manufacturer's data sheet
	Temperature range during installation (°C)	See manufacturer's data sheet	See manufacturer's data sheet

When pulling the RG6 type coax cable outside of the conduit, the specifications detailed in Table A.11 shall be followed. Table A.12 and Table A.13 provide values based on the template given in IEC 61918:2018, Table 19 and Table 21.

**Table A.11 – Bend radius for coaxial cables outside conduit**

For this coax cable	The bend radius shall not exceed
PVC	38 mm
FEP	36 mm
Tap drop-cable	26 mm

**Table A.12 – Parameters for silica optical fibre cables**

Characteristic		Value	
		GI Single mode	GI Multi mode
Mechanical force	Minimum bending radius, single bending (mm)	See manufacturer's data sheet	See manufacturer's data sheet
	Bending radius, multiple bending (mm)	See manufacturer's data sheet	See manufacturer's data sheet
	Pull forces (N)	See manufacturer's data sheet	See manufacturer's data sheet
	Permanent tensile forces (N)	See manufacturer's data sheet	See manufacturer's data sheet
	Maximum lateral forces (N/cm)	See manufacturer's data sheet	See manufacturer's data sheet
	Temperature range during installation (°C)	See manufacturer's data sheet	See manufacturer's data sheet

**Table A.13 – Parameters for hard clad silica optical fibre**

Characteristic		Value
		200 µm SI MM Fibre
<b>Mechanical force</b>	Minimum bending radius, single bending (mm)	See manufacturer's data sheet
	Bending radius, multiple bending (mm)	See manufacturer's data sheet
	Pull forces (N)	See manufacturer's data sheet
	Permanent tensile forces (N)	See manufacturer's data sheet
	Maximum lateral forces (N/cm)	See manufacturer's data sheet
	Temperature range during installation (°C)	See manufacturer's data sheet

**A.5.2.2 Installation and routing**

**A.5.2.3 Specific requirements for CPs**

Not applicable.

**A.5.2.4 Specific requirements for wireless installation**

Not applicable.

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

**A.5.3 Connector installation**

**A.5.3.1 Common description**

**A.5.3.2 Shielded connectors**

**A.5.3.3 Unshielded connectors**

Not applicable.

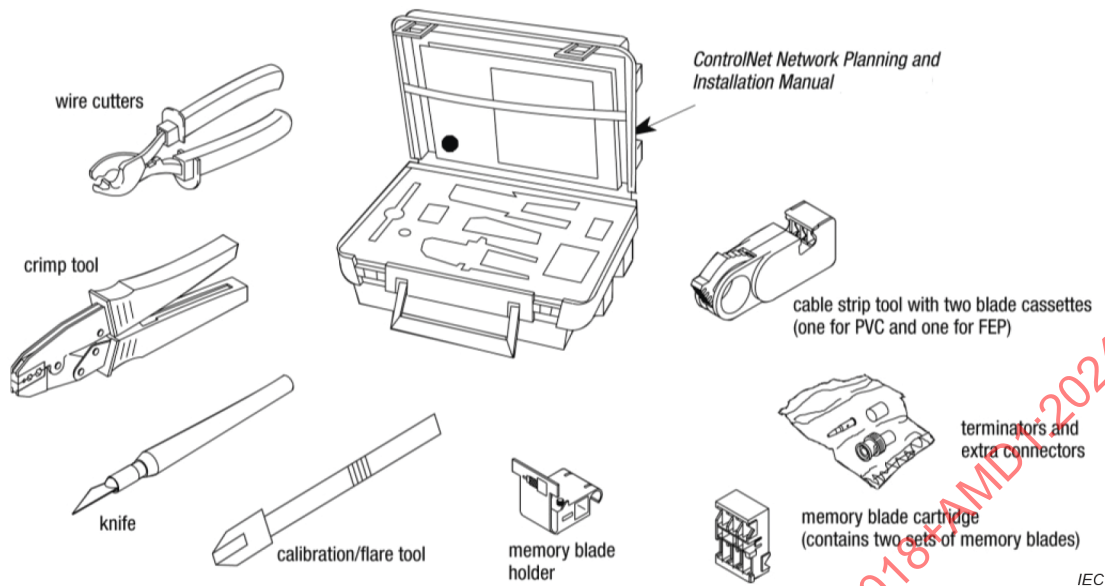
**A.5.3.4 Specific requirements for CPs**

*Addition:*

**a) Tools**

To install the cable connector, it is recommended that the proper tools be used that match the cable and the connectors. An example toolkit is provided in Figure A.26.

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**Figure A.26 – Example tool kit for installing BNC connectors**

Additional tools:

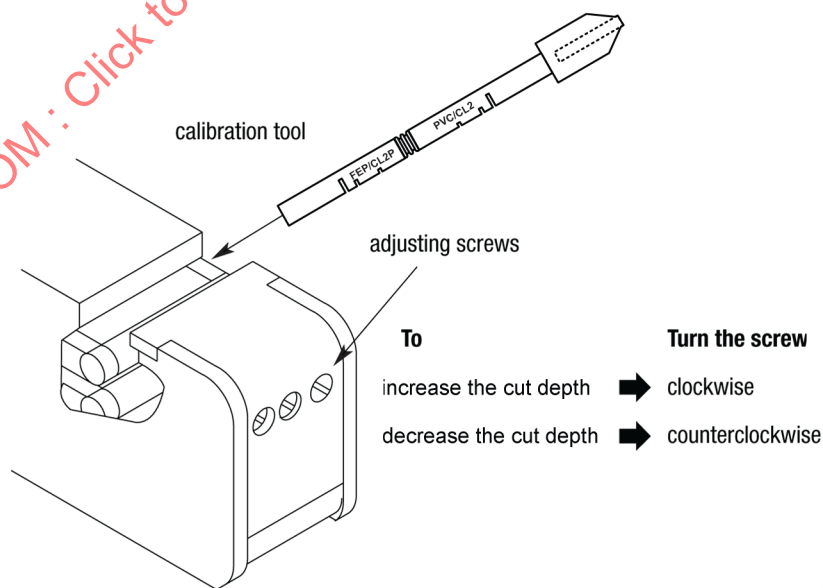
- Heat gun (for IP67 sealed connectors)

If using a coaxial stripping tool, calibration is required.

**b) Tool calibration**

The following procedure shall be used to calibrate the cable strip tool to cut FEP or PVC cable.

- 1) Turn the three screws outward to back the blades out. This prevents the calibration tool from bottoming out.
- 2) Place the calibration tool into the cable strip tool with the narrow end installed and facing forward for FEP cable (use the wider end for PVC) as shown in Figure A.27.



**Figure A.27 – Calibration of coaxial stripper**

- 3) Tighten the chamber gauge ring until the calibration tool is locked in place. Close all the way to the chamber gauge stop.

NOTE When aligned properly, the grooves of the calibration tool will be aligned with the blades.

- 4) Adjust the three screws clockwise until the blades just contact the bottom of the calibration grooves.
- 5) Retract the handle of the cable strip tool.
- 6) Remove the calibration tools from the cable strip tool.

When finished, the blade shall make a cut of the following dimensions in the cable as shown in Figure A.28.

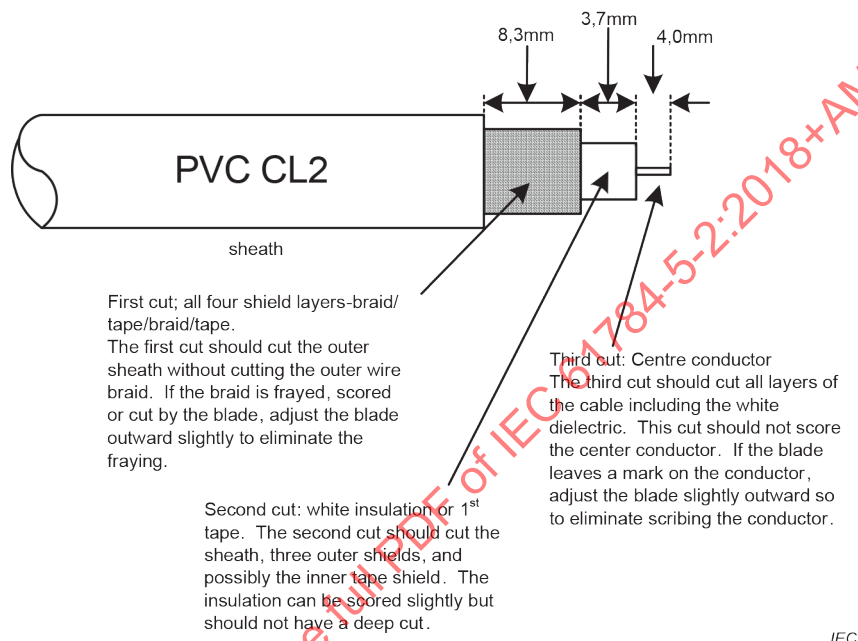


Figure A.28 – Coax PVC strip length detail (informative)

### c) Stripping the cable

Important: The first and second cut adjustments need to be precise. Adjustments of 1/12 to 1/8 of a turn can make the difference between a correct and incorrect cut.

The calibration procedure shall be performed the first time the tool is used and every time the blade is changed. In addition, the calibration procedure shall be performed for each different coaxial cable that will be used.

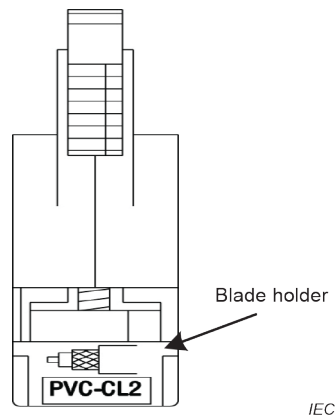
Check the outer braid of the cable for cut or scored braid wire after stripping the cable. If the braid is damaged, cut the damaged end off and strip the cable again. If needed, adjust the appropriate cutting blade by backing the set screw out 1/8 of a turn. Do not crimp the BNC to a damaged braid. This type of mistake accounts for the majority of the connectivity problems that occur. Precise, clean connections will reduce network errors.

When cutting cable sections, make them long enough to route from one tap to the next with sufficient length so that the bend radius is not less than:

- 77 mm for wiring external to enclosures;
- 38 mm for wiring inside enclosures.

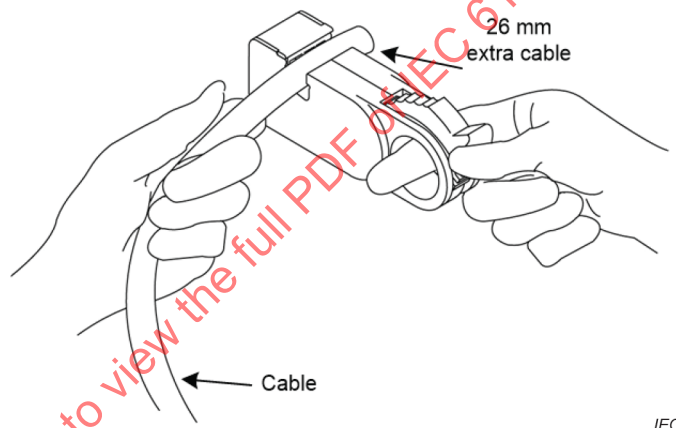
Proceed as follows.

- 1) Verify that the proper memory blade holder is installed for the type of cable to be stripped (PVC-CL2 or FEP-CL2P), see Figure A.29. The blades shall be recalibrated if the memory cartridge is replaced, see the calibration procedure above.



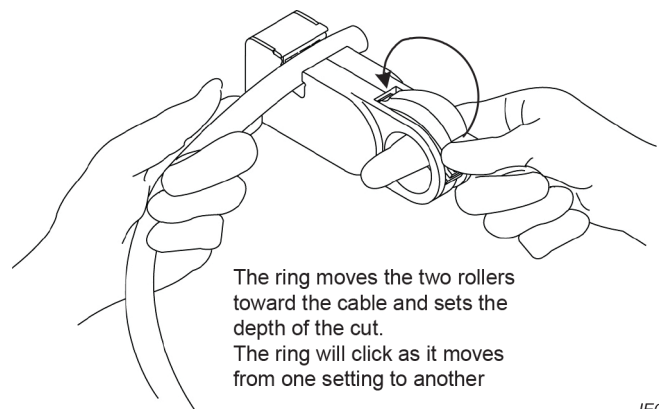
**Figure A.29 – Memory cartridge and blade**

- 2) Straighten out the end of the cable.
- 3) Insert the cable into the cable strip tool's cutting chamber so that approximately 26 mm (1 in) of extra cable extends beyond the edge of the tool as shown in Figure A.30.



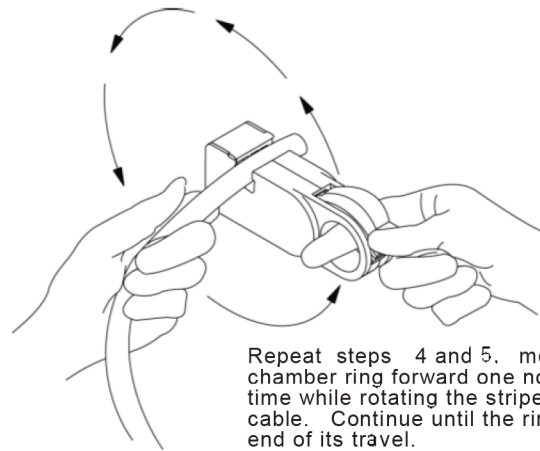
**Figure A.30 – Cable position**

- 4) Lock the cable into place by moving the chamber-gauge ring forward (see Figure A.31) until it meets the cable with slight resistance.



**Figure A.31 – Locking the cable**

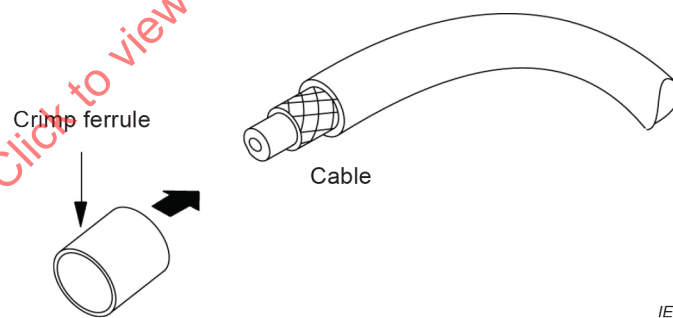
- 5) Holding the cable in one hand, place the index finger of the other hand inside the chamber-gauge ring and turn the strip tool 360° around the cable. Turn four or five full rotations until the strip tool glides easily around the cable as indicated in Figure A.32.



**Figure A.32 – Stripping the cable**

On the last repetition of steps 4) and 5), it is important to apply sufficient pressure on the chamber gauge ring to make sure the ring has reached the last stage. The chamber gauge should read "stop" for the last repetition.

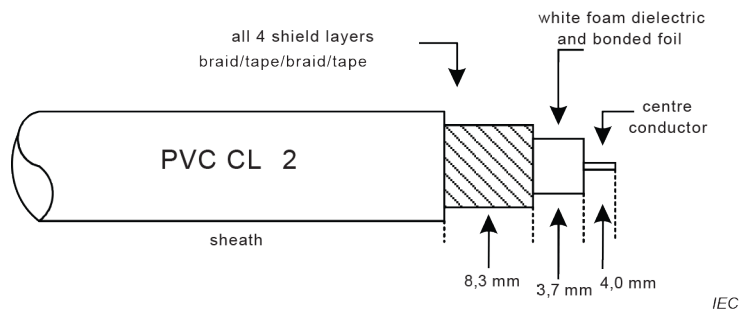
- 6) After the chamber ring has been moved to the last position and turned a final time around the cable:
  - i) Move the chamber ring backward to release the strip tool and remove it from the cable.
  - ii) If using IP65/67, corrosion-resistant connectors, slide the heat shrink tubing over the cable.
  - iii) Slip the crimp ferrule onto the cable as shown in Figure A.33. Push it back to the sheath area of the cable to keep it out of the way for the moment.



**Figure A.33 – Install the crimp ferrule**

- iv) Strip away the appropriate portion of the cable without using the strip tool.
- v) Clean the remaining cable parts from the strip chamber after each use.

This procedure should appropriately strip the cable, exposing these layers of the cable as detailed in Figure A.34.

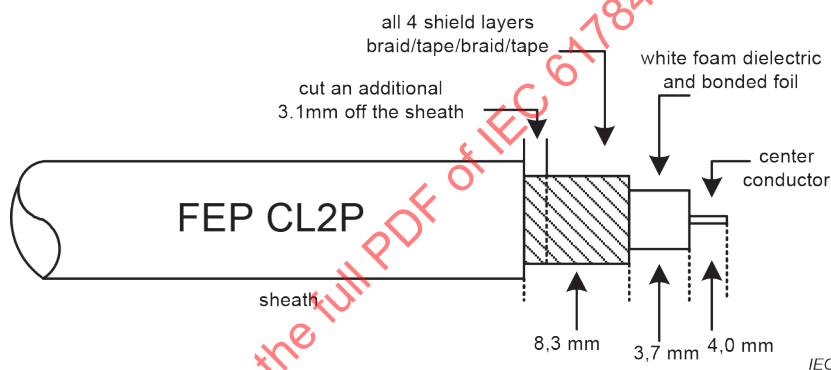


**Figure A.34 – Cable preparation for PVC type cables (informative)**

If there are not three distinct layers of cable or if the outer braid has been scored or cut, snip off the exposed end with the wire cutters and repeat the entire cable-stripping process. It is very important that the outer braid be intact before crimping the connector.

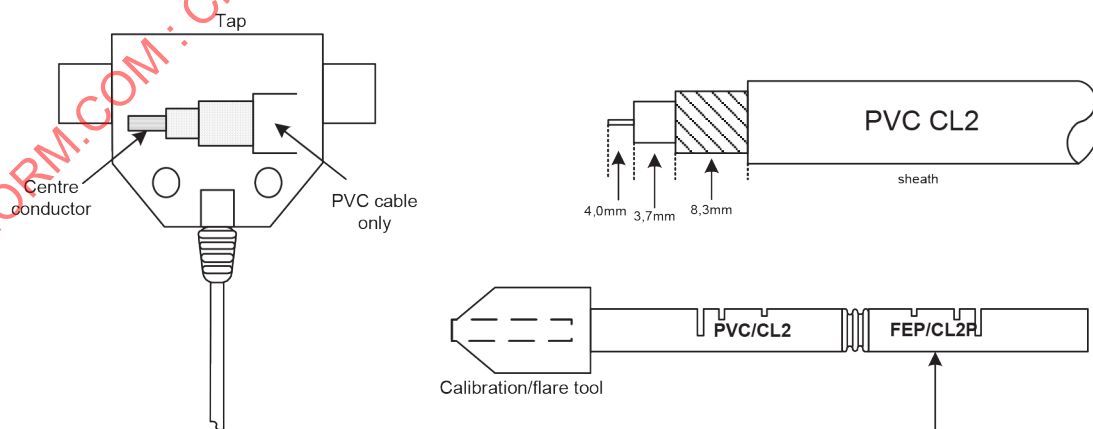
If stripping problems persist, the strip tool may need adjustment. See the calibration section for instructions on calibration.

- 7) For FEP cable, cut off an additional 3,1 mm of the outer sheath with a knife as shown in Figure A.35.



**Figure A.35 – Cable preparation for FEP type cables (informative)**

- 8) Confirm that the centre conductor is 4,0 mm long by using the strip guides on the tap body or an appropriate tool. Figure A.36 provides two examples of guides available.



The centre conductor should be 4,0 mm exactly. If the centre conductor is too long, cut off the excess with the wire cutter provided in the cable kit. If it is too short, repeat the entire cable stripping process.

Use this end of the calibration/strip tool to verify proper measurements for FEP cables.

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**Figure A.36 – Strip guides**

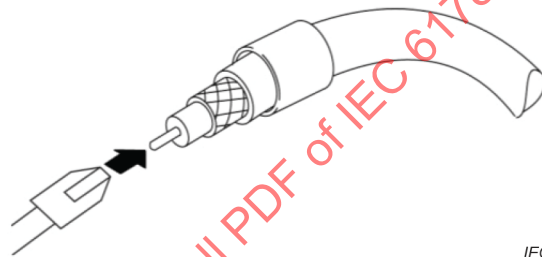
Check for any braid stranding that may not have been cut to the proper length. If any strand comes into contact with the centre conductor, it will short out the cable. Cut any shield strands to the proper length.

Important: Check the outer braid of the cable for cut or scored braid wire after stripping the cable. If the braid is damaged, cut off the end and strip the cable again. Adjustment of the appropriate stripper blade by backing the set screw out 1/8 of a turn may be necessary. Do not crimp the connector to a damaged braid. This type of mistake accounts for most of the connectivity problems that can occur. Precise, clean connections will reduce network errors.

#### d) Installing the connectors

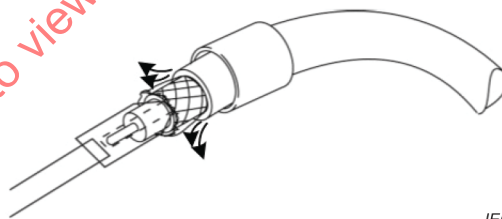
Proceed as follows.

- 1) Place the crimp ring over the cable if not already on the cable.
- 2) If installing an IP65/67, corrosion-resistant connector, slip the heat shrink tubing (provided by the connector manufacturer) onto the cable.
- 3) Push the flare tool onto the cable with a slight twisting motion (with sufficient inward pressure) to expand the braid as shown in Figure A.37 and Figure A.38.
- 4) Push the flare/calibration tool gently in, working the tool in a circular motion onto the cable while applying forward pressure. This will work the tool underneath the wire braid.



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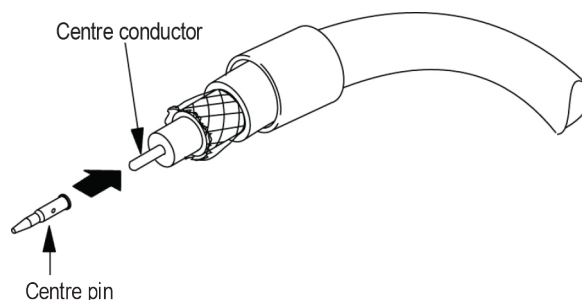
Figure A.37 – Using the flare tool



IEC

Figure A.38 – Expanding the shields

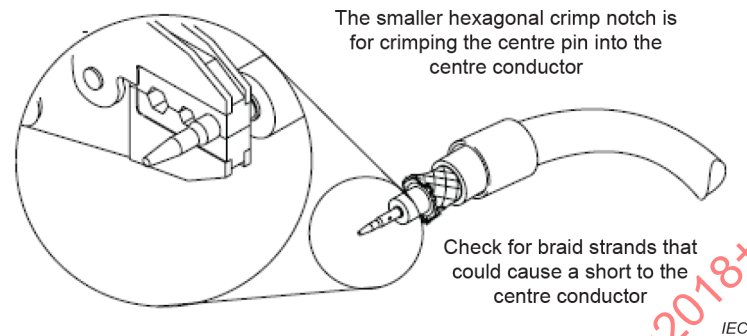
Figure A.39 shows the placement of the centre pin over the centre conductor.



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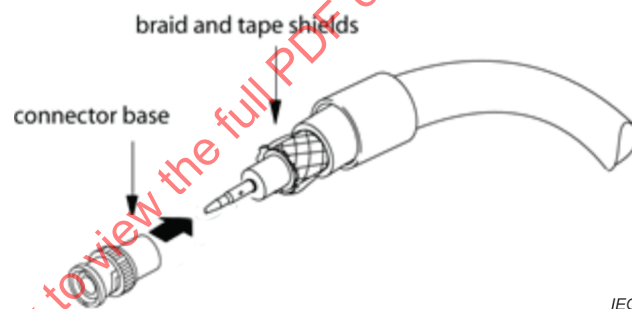
Figure A.39 – Install the centre pin

- 5) Check for strands of insulation or braid that are not cut properly. Remove any debris from the centre conductor before installing the centre pin.
- 6) Confirm that the centre pin slips onto the centre conductor completely. The back shoulder of the centre pin shall be up against the white dielectric. If it is not, recheck the centre wire length, trim if necessary.
- 7) With the centre pin in place, use the crimp tool to crimp the pin in place as shown in Figure A.40.



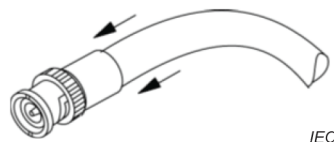
**Figure A.40 – Crimping the centre pin**

- 8) If the innermost shield is not bonded to the dielectric, then all four (foil, braid, foil, braid) shall remain on the outside of the connector body. If the innermost shield is bonded to the dielectric, it shall go inside the connector base. The outer three shields shall remain on the outside of the connector body. Slide the connector body onto the cable (see Figure A.41).



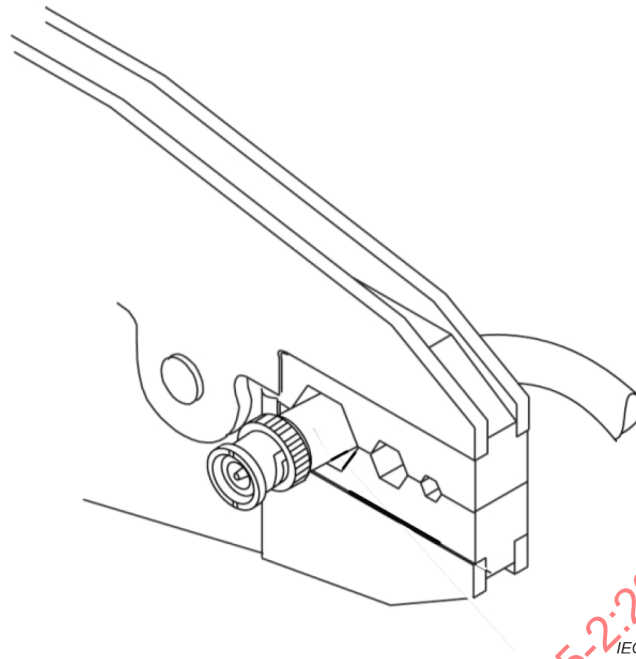
**Figure A.41 – Installing the connector body**

- 9) Slide the crimp ferrule over the three outer shields and connector base until it meets the shoulder of the connector as shown in Figure A.42.



**Figure A.42 – Installing the ferrule**

- 10) Using the crimp tool in Figure A.43, crimp the ferrule. Position the crimp tool on the ferrule as close as possible to the connector base and ferrule meeting line. The larger hexagonal crimping notch is for crimping the ferrule which holds the connector to the cable. Squeeze the crimp tool handles until the crimp tool crimps the ferrule to the connector body and releases.



**Figure A.43 – Crimp tool**

Important: Many network problems are caused by improperly installed connectors. The connectors shall be tight-fitting on the end of all the cables. Pull the connector to verify that it is properly attached. If it is loose or comes off, cut off the end of the cable and install a new connector. The connector retention should be a minimum of 270 N if properly installed.

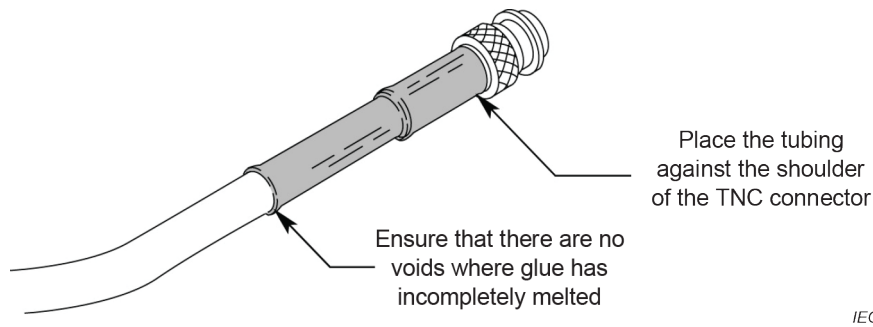
11) If installing IP65/67, corrosion-resistant connectors:

Use only the ACUM heat-shrink tubing provided in the IP65/67 Tap and Cable Kit. Do not substitute other types of heat-shrink tubing. Substitutions may cause a loss of the IP65/67 rating.

**Warning:** Be careful when using heat guns. High temperatures can lead to burns, risk of fire, or other property damage.

12) Follow these guidelines when heating the tubing (see Figure A.44):

- i) Place the tubing against the shoulder of the TNC connector.
- ii) Allow the heat gun to come to a temperature of between 110 °C and 160 °C.
- iii) Hold the cable assembly approximately 50 mm away from the heat exhaust area of the heat gun while shrinking the tubing.
- iv) Continuously rotate the cable assembly around the heat exhaust area of the heat gun. The entire process should take about 4 min.
- v) Inspect the heat-shrink tubing to ensure that there are no voids where the glue has incompletely melted. Voids could cause a loss of the IP65/67 rating.
- vi) Test the connection.
- vii) Test the final cable.



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**Figure A.44 – Sealed IP65/67 cable**

#### A.5.3.5 Specific requirements for wireless installation

Not applicable.

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

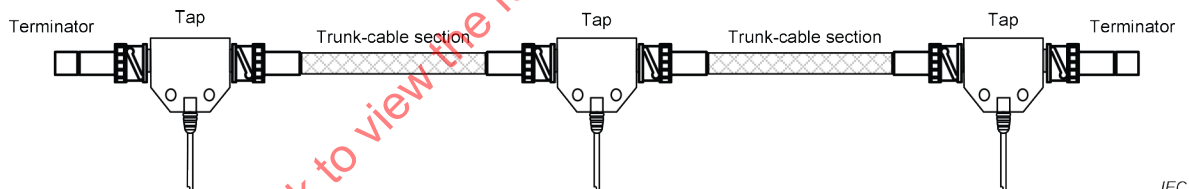
#### A.5.4 Terminator installation

##### A.5.4.1 Common description

##### A.5.4.2 Specific requirements for CPs

*Addition:*

Each end or each cable segment shall be terminated with a coaxial BNC or TNC terminator. The location of the terminator shall be at the outermost port of the passive tap as shown in Figure A.45. For more details, see the planner's documentation and Clause A.4.



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**Figure A.45 – Terminator placement**

#### A.5.5 Device installation

##### A.5.5.1 Common description

##### A.5.5.2 Specific requirements for CPs

*Addition:*

The drop cable on the tap shall not be extended or shortened under any circumstances.

Selecting where to mount the taps:

- there is no spacing requirement between taps; install two adjacent taps by using a barrel connector;
- be certain that the location where the tap is to be mounted is convenient for the cable route;
- be certain that the location where the tap is to be mounted does not cause any cable bend radii to exceed the limits listed in this Clause A.5;

- do not mount the tap in a position that routes the drop cable over any AC power terminals on nearby modules.

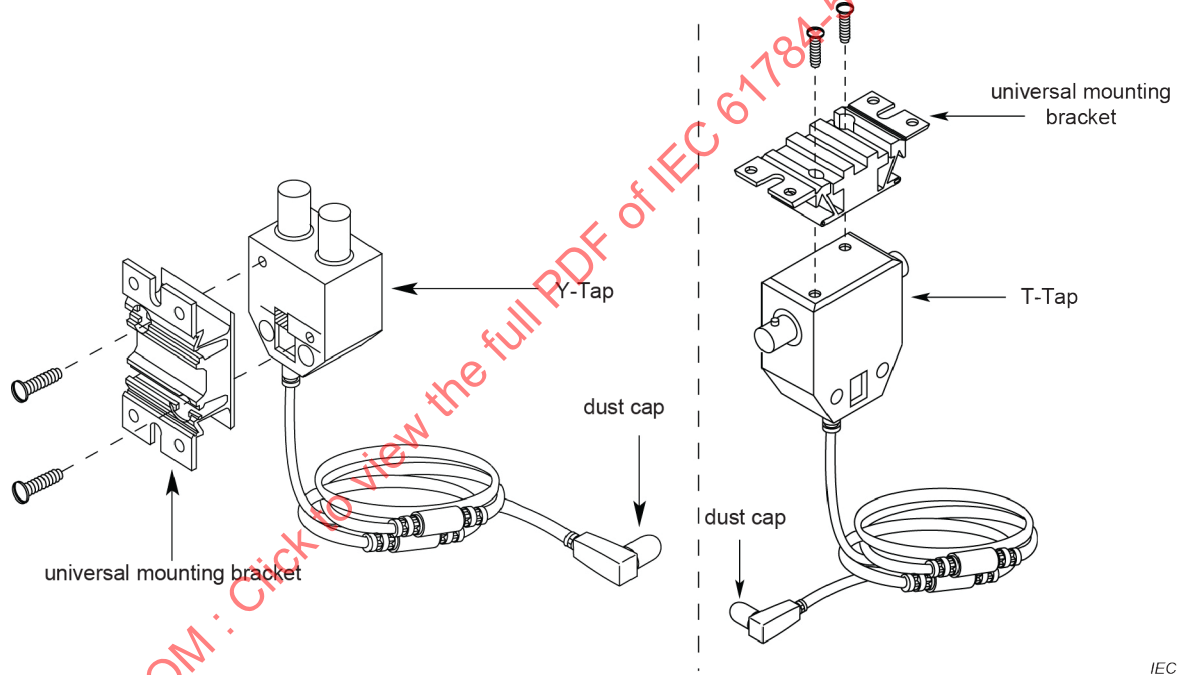
Do not allow any metal portions of the tap, such as the universal mounting bracket screws or connectors, to contact any conductive material. This contact could introduce noise on the network.

Mount the ControlNet taps (Y-tap and T-tap) options:

- to a universal mounting bracket, and then mount the tap and bracket as an assembly;
- through the body holes in the tap using:
  - screws and flat washers,
  - a tie wrap.

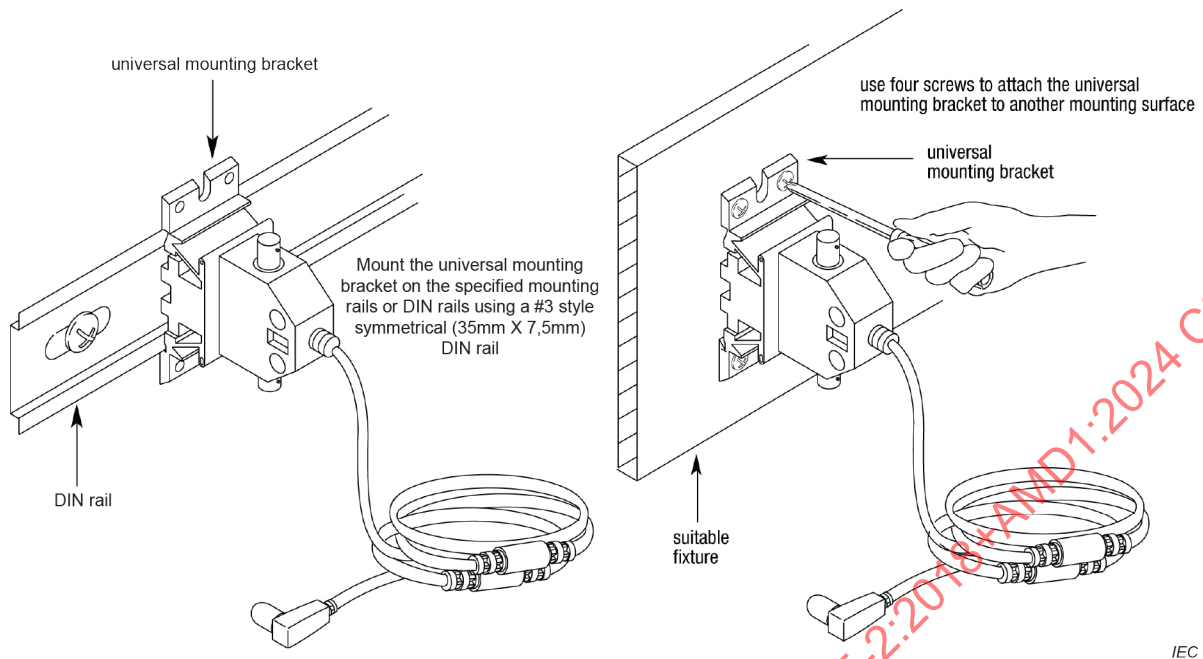
If mounting the ControlNet taps to the universal mounting bracket as shown in Figure A.46, follow the steps below:

- 1) Align the universal mounting bracket with the mounting holes on the tap.
- 2) Using the screws provided with the tap, attach the tap to the universal mounting bracket.



**Figure A.46 – Mounting the taps**

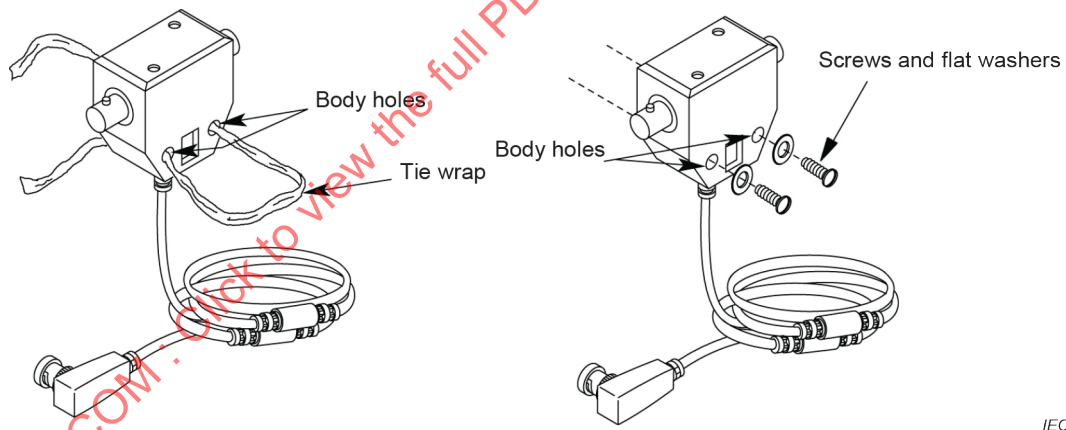
- 3) Figure A.47 shows how to mount the tap and bracket assembly to a DIN rail or flat surface.



**Figure A.47 – Mounting the tap assembly using the universal mounting bracket**

Figure A.48 shows two alternate mounting methods using the mounting holes provided in the ControlNet tap body.

Mount the taps to a suitable fixture using tie wraps or screws as shown in Figure A.48.



**Figure A.48 – Mounting the tap using tie wraps or screws**

Do not over-tighten the screws. Over-tightening the screws can damage the tap.

## A.5.6 Coding and labelling

### A.5.6.1 Common description

### A.5.6.2 Specific requirements for CPs

*Addition:*

ControlNet products are labelled in accordance with the icons in Figure A.49 with the dark icon representing redundant media.



**Figure A.49 – Redundant network icons**

## **A.5.7 Earthing and bonding of equipment and devices and shield cabling**

### **A.5.7.1 Common description**

### **A.5.7.2 Bonding and earthing of enclosures and pathways**

### **A.5.7.3 Earthing methods**

#### **A.5.7.3.1 Equipotential**

*Addition:*

The earthing method shall be in accordance with the planner's documentation. If there is an earth potential offset in the communication coverage area, equalization conductors shall be installed to mitigate the offset. The cross-sectional area of these conductors shall be in accordance with IEC 61918:2018, 4.4.7.2.1, Table 14.

#### **A.5.7.3.2 Star**

*Addition:*

In addition to the requirements of A.4.4.7.3.2, the following shall be observed.

Cable shields for the communications equipment shall be referenced only to the signal earth (functional earth). Other equipment such as motors or motor controllers shall not be referenced to the functional earth. The star earth of the two systems (functional earth and protective earth) shall converge at one point within the building as shown in IEC 61918:2018, Figure 17. Earthing connections for the cabinets shall not be daisy chained.

#### **A.5.7.3.3 Earthing of equipment (devices)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions and the planner's documentation.

### **A.5.7.4 Shield earthing methods**

#### **A.5.7.4.1 General**

#### **A.5.7.4.2 Parallel RC**

*Addition:*

The cable shield ends are terminated to earth via parallel RC circuits that are integral to the active interfaces. The coaxial cables are not connected directly to earth at any point in the system; doing so may cause noise loops in the network causing communications faults. The installer shall verify the completed installation in such a way that the shield resistance to earth is greater than 2 M $\Omega$  when the active devices are disconnected. A suitable DVM may be used for this verification. For each active device connected the shield resistance to earth shall follow the following formula.

$$\text{Shield to earth} = \frac{1 \text{ M}\Omega}{\text{number of nodes}}$$

Since the repeaters are also required to have a 1 M $\Omega$  resistor from the cable shield to earth, they are also included in the number of counted nodes.

#### **A.5.7.4.3 Direct**

Not applicable.

#### **A.5.7.4.4 Derivatives of direct and parallel RC**

Not applicable.

#### **A.5.7.5 Specific requirements for CPs**

Not applicable.

#### **A.5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **A.5.8 As-implemented cabling documentation**

### **A.6 Installation verification and installation acceptance test**

#### **A.6.1 General**

#### **A.6.2 Installation verification**

##### **A.6.2.1 General**

##### **A.6.2.2 Verification according to cabling planning documentation**

##### **A.6.2.3 Verification of earthing and bonding**

##### **A.6.2.4 Verification of shield earthing**

*Addition:*

The ControlNet cabling system uses a parallel RC between earth and the shield. The installer shall verify that the shield resistance to earth is greater than 2 M $\Omega$  when the active devices are disconnected using a suitable DVM. For each active device connected, the shield resistance to earth shall follow the following formula:

$$\text{Shield to earth} = \frac{1 \text{ M}\Omega}{\text{number of nodes}}$$

Since the repeaters are also required to have a 1 M $\Omega$  resistor from the cable shield to earth, they are also included in the number of counted nodes.

### A.6.2.5 Verification of cabling system

#### A.6.2.5.1 Verification of cable routing

#### A.6.2.5.2 Verification of cable protection and proper strain relief

### A.6.2.6 Cable selection verification

#### A.6.2.6.1 Common description

#### A.6.2.6.2 Specific requirements for CPs

*Addition:*

The installer shall use cables defined in the installation documentation.

#### A.6.2.6.3 Specific requirements for wireless installation

Not applicable.

### A.6.2.7 Connector verification

#### A.6.2.7.1 Common description

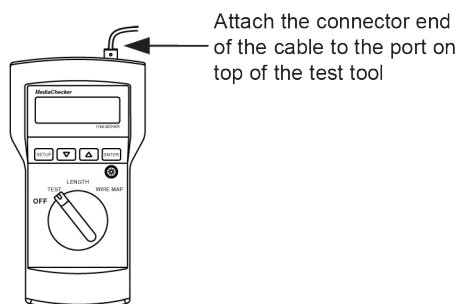
#### A.6.2.7.2 Specific requirements for CPs

*Addition:*

The coaxial cabling test tool shall be fitted with a BNC/TNC interface and capable of determining:

- cabling faults (open and shorts);
- distance to cable fault;
- presence of proper terminator;
- segment and or section length.

After installing the BNC or TNC connector use a suitable coaxial cable tester or a DVM or suitable network test tool as shown in Figure A.50 to confirm proper continuity.

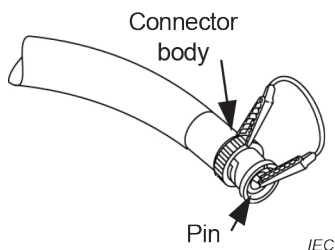


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**Figure A.50 – Network test tool**

An alternate method is to use an ohmmeter or continuity tester to test for a short between the connector body and centre pin.

Use a shorting clip as shown in Figure A.51 to connect a temporary short between the centre pin and connector body at one end of the cable.



**Figure A.51 – Shorting the cable to test for continuity**

At the other end of the cable, use a continuity tester or ohmmeter to test for electrical continuity. Use Table A.14 to determine the course of action to be taken depending on test results.

**Table A.14 – Test matrix for BNC/TNC connectors**

If resistance reading indicates:		Then:
Far end shorted with jumper	that a short exists	Remove jumper and test open
	there is no short	Use a set of wire cutters to cut off the connector, install a new connector and begin testing again
Far end open	that a short exists	Use a set of wire cutters to cut off the connector, install a new connector and begin testing again
	there is no short	Continue to next section

Replace the trunk cable section if the problem persists with the cable after completing the tests.

Each cable section shall be fitted with a BNC or TNC plug. Inline cable jacks are not supported. Sections may be extended using a back-to-back jack (bulkhead or inline bullet).

Properly installed BNC/TNC connectors (crimp style) shall have a retention force of no less than 270 N. If the connector pulls off at less than 270 N, it is either improperly installed or an incorrect match between the cable, connector and crimp tool.

The following may help in determining the problem:

- confirm that the cable and connector are mechanically compatible;
- confirm that the strip lengths meet the connector manufacturer's data sheet;
- check the connector manufacturer's data sheet for crimp tool recommendations;
- verify the crimp dies are within specification (not worn out); if the crimp force is too high, the braid will be damaged. A crimp force that is too high or too low will reduce the retention of the connector.

**A.6.2.7.3 Specific requirements for wireless installation**

Not applicable.

**A.6.2.8 Connection verification**

**A.6.2.8.1 Common description**

**A.6.2.8.2 Number of connections and connectors**

**A.6.2.8.3 Wire mapping**

Not applicable.

### **A.6.2.9 Terminator verification**

#### **A.6.2.9.1 Common description**

#### **A.6.2.9.2 Specific requirements for CPs**

*Addition:*

With a DVM or suitable coaxial cable tester, verify that the terminator is properly installed. If a DVM is used, the DCR of the cable will need to be taken into account. If both terminators are installed in a segment, the DCR measurement shall be no less than 37,5  $\Omega$  and increase as a function of screen DCR/unit length X cable length.

#### **A.6.2.10 Coding and labelling verification**

#### **A.6.2.11 Verification report**

### **A.6.3 Installation acceptance test**

#### **A.6.3.1 General**

*Addition:*

The following are other tools that may be useful in the verification and certification of the network:

- suitable coaxial cable test tool or time domain reflectometer (TDR);
- suitable fibre optic optical time domain reflectometer (OTDR).

#### **A.6.3.2 Acceptance test of Ethernet-based cabling**

Not applicable.

#### **A.6.3.3 Acceptance test of non-Ethernet-based cabling**

##### **A.6.3.3.1 Copper cabling for non-Ethernet-based CPs**

###### **A.6.3.3.1.1 Common description**

###### **A.6.3.3.1.2 Specific requirements for copper cabling for non-Ethernet-based CPs**

*Addition:*

The segment length shall be measured and confirmed to be within the length limit specified in Figure A.10 and the planner's documentation.

The cable attenuation shall be verified to meet the requirements in Clause A.4.

##### **A.6.3.3.2 Optical fibre cabling for non-Ethernet-based CPs**

###### **A.6.3.3.2.1 Common description**

###### **A.6.3.3.2.2 Specific requirements for non-Ethernet-based CPs**

*Addition:*

The segment length shall be measured and confirmed to be within the design guidelines in Clause A.4.

The fibre path loss shall be verified to be within the allowable power budget as defined in Clause A.4. If the path loss is greater than allowed and the fibre length is within the path length limit, then the connector attenuation may be too great and may necessitate re-termination or additional polishing.

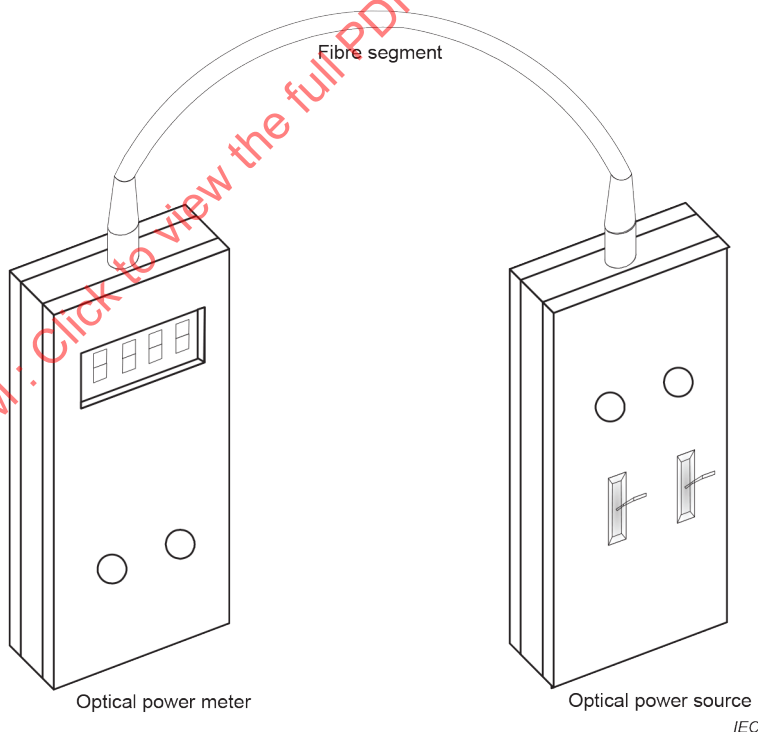
After the initial installation of fibre cable, the sections shall be checked using an optical power meter or OTDR to verify that the attenuation is less than the limits specified in Table A.2. The power source used to test the fibre shall match the power source rating of the cable being tested.

The power loss measurement shall be within the limits described in Table A.2 and Table A.6 for the types of fibres used as shown in Table A.15. The cable shall not be tested with the wrong light source; inaccurate readings will result. The power budgets are specified at the wavelengths of the light source.

Using a reference light source at the specific wavelength and an optical power meter, as shown in Figure A.52, the insertion loss of the fibre optic segment can be determined.

A ControlNet software configuration tool should be used to determine whether or not the system meets the network parameter requirements. Based on the system parameters entered, such as NUT, SMAX, UMAX, and worst case network delay, the ControlNet software configuration tool will calculate scheduled messaging for the network.

Once the values have been entered into the ControlNet software configuration tool and scheduled messaging is calculated, the software will indicate whether the configured network is acceptable as planned. If the network is not valid, adjustments shall be made to meet the planned requirements.



**Figure A.52 – Testing fibre segments**

**Table A.15 – Wavelength and fibre types**

Wavelength nm	Fibre type
640	200/230 µm Graded Index MM
1 300	62,5/125 µm MM
1 300	62,5/125 µm MM
1 300	62,5/125 µm and 9/125 µm SM

**A.6.3.3.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

**A.6.3.4 Specific requirements for wireless installation**

Not applicable.

**A.6.3.5 Acceptance test report**

**A.7 Installation administration**

Subclause 7.8 is not applicable.

**A.8 Installation maintenance and installation troubleshooting**

**A.8.1 General**

**A.8.2 Maintenance**

**A.8.3 Troubleshooting**

*Subclause 8.3.2 has addition:*

If testing a single-mode or multimode cable with a 640 nm light source, an incorrect loss measurement will result. The correct wavelength light source shall be used to test the fibre. For medium, long and extra-long fibre modules, a 1 300 nm light source that matches the cable rating shall be used. Records should always be maintained for attenuation levels for each cable section, strand. The attenuation records are valuable tools for troubleshooting and maintaining the network. Considerable power loss in the cable could be a result of:

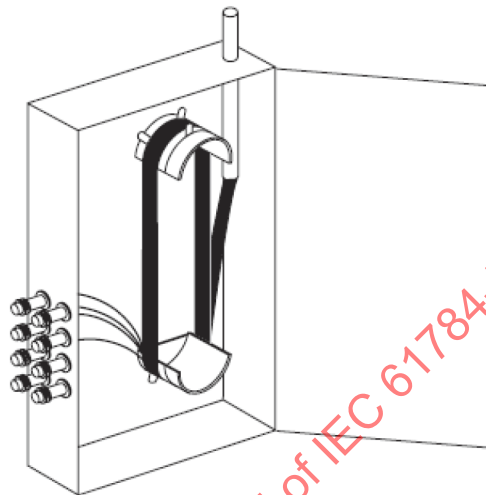
- poor splices;
- improper bend radius;
- bending losses;
- broken fibres;
- poor connections;
- contaminated or damaged connectors;
- poorly polished connector.

**a) OTDR measurement**

In addition to power loss measurement, the total fibre network should be examined using an OTDR. The OTDR emits light into a strand of fibre optic cable and displays the reflected light. OTDR tests provide the following measurements that will help to troubleshoot and maintain the network:

- total distance along the cable to a fibre break;
- distance to an event (splice, bend, connector) that attenuates the light;
- distance between two attenuating events;
- light attenuation between two points of the cable;
- total reflected light or light reflected from a single event.

Records should be kept of the traces for each cable strand on either hard copy or computer backup. Figure A.53 shows an example of a connector panel with incoming multi-fibre backbone cable and connectors for interconnect cables.



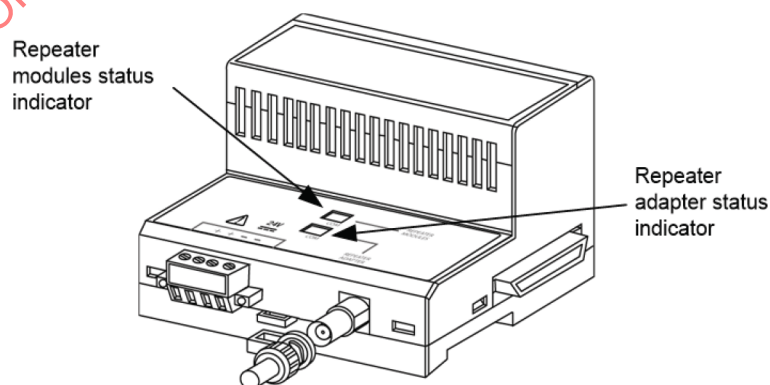
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**Figure A.53 – Multi-fibre backbone cable housing**

There are many choices of fibre optic cables designed for use in different environments. The applications' designer or an installation professional should be consulted to determine the best type of cable to use for the environmental conditions.

#### **b) Troubleshooting fibre repeaters**

See Figure A.54 for the following discussion. The fibre repeater has one LED for the coax connection and one for the accumulate indications of the fibre channels.



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**Figure A.54 – Repeater adapter module**

The status indicator LEDs in the repeater adapter module can be interpreted singly or together. Table A.16 to Table A.19 list different combinations of LEDs and their interpretations.

**Table A.16 – LED status table**

These status indicator LEDs and their interpretation	Are shown in
Repeater adapter and repeater modules	Table A.17
Repeater adapter only	Table A.18
Repeater modules only	Table A.19

The following are the only valid indicator combinations. Other combinations are not valid. For example, the combination of the repeater adapter indicator being solid green and the repeater modules indicator being solid red is not valid and probably indicates a defective module.

**Table A.17 – Repeater adapter and module diagnostic**

If both indicators are	This means	Resolution
Alternating red/green	The repeater adapter is being powered up or reset	Do nothing. The repeater adapter is operating properly
Solid red	A jabber condition has occurred. Another node or repeater on the network is transmitting constantly	Check the network and component for proper operation
Off	The repeater adapter is not powered or has failed	Check the power input to the repeater adapter for correct voltage and polarity

**Table A.18 – Repeater adapter indicator diagnostic**

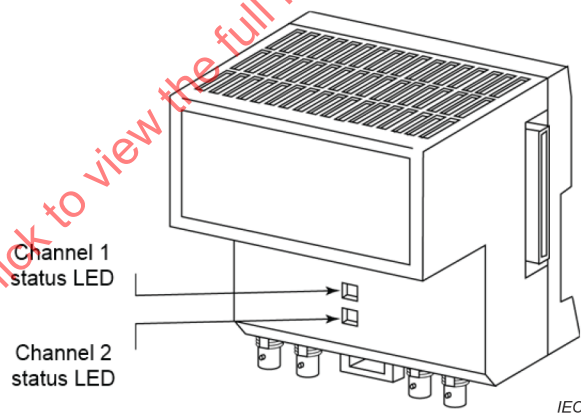
If the repeater adapter indicator is	This means	Resolution
Solid green	Error-free data is being recovered at the coax port of the repeater adapter	Do nothing. This is the normal operating mode
Flashing green/off	Data with errors is occasionally being recovered at the coax port of the repeater adapter	This situation will normally correct itself. If the situation persists check that: <ul style="list-style-type: none"> <li>– all BNC connector pins are seated properly</li> <li>– all taps are ControlNet taps</li> <li>– all terminators are 75 Ω and are installed at both ends of all segments</li> <li>– the coax cable has not been earthed</li> </ul>
Flashing red/off	Either no data is being received at the coax port of the repeater adapter, or data with a large number of errors is being received at the coax port of the repeater adapter	Check for: <ul style="list-style-type: none"> <li>– broken cables</li> <li>– broken taps</li> <li>– missing segment terminators</li> </ul>

**Table A.19 – Repeater module indicator**

If the repeater adapter indicator is	This means	Resolution
Solid green	Error-free data is being recovered at all of the attached repeater modules	Do nothing. This is the normal operating mode
Flashing green/off	Data with errors is occasionally being recovered at some or all of the repeater modules	This situation will normally correct itself. If the situation persists check that: <ul style="list-style-type: none"> <li>– all BNC connector pins are seated properly</li> <li>– all taps are ControlNet Taps</li> <li>– all terminators are 75 Ω and are installed at both ends of all segments</li> <li>– the coax cable has not been earthed</li> <li>– fibre optic connectors are of the correct type and are correctly attached to the fibre optic cable</li> <li>– fibre optic cable is of the correct type</li> </ul>
Flashing red/off	Either no data is being received at any repeater modules, or the received data at some or all of the repeater modules has a high number of errors	Check for: <ul style="list-style-type: none"> <li>– broken cables</li> <li>– broken taps</li> <li>– missing segment terminators</li> </ul>

**c) Short distance and medium distance diagnostic LEDs**

See Figure A.55 and Table A.20 for the diagnostic LED description.



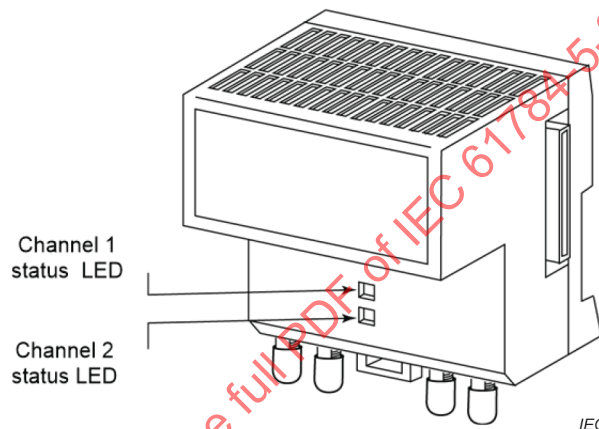
**Figure A.55 – Short and medium distance fibre module LEDs**

**Table A.20 – Short and medium distance troubleshooting chart**

If the repeater module indicator is	This means	Resolution
Off	Repeater not connected to the power supply or adapter module is faulted	Check power supply connections and status. Reset adapter by cycling power
Solid green	Repeater is running without network errors	Do nothing
Flashing green/off	No data activity on network	If the cable is attached: <ul style="list-style-type: none"> <li data-bbox="943 510 1353 584">– confirm that the receive channel is connected to the transmit channel on both modules</li> <li data-bbox="943 595 1225 618">– check for broken fibres</li> </ul>

**d) Long and extra long distance diagnostic LEDs**

See Figure A.56 and Table A.21 for the diagnostic LED description.



**Figure A.56 – Long and extra long repeater module LEDs**

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**Table A.21 – Long and extra long troubleshooting chart**

If the repeater module indicator is	This means	Resolution
Off	Repeater not connected to the power supply or adapter module is faulted	Reset module
Solid green	Repeater is running without network errors	No action required
Flashing green/off	No data activity on network. If the cable is attached	<ul style="list-style-type: none"> <li>– confirm that the receive channel is connected to the transmit channel on both modules</li> <li>– check for broken fibres</li> </ul>
Flashing red/off	Module is powered, but not ready for operation	This state should also occur during module reset and last for approximately 5 s
Intermittent red	As more data errors are detected the frequency of the flashing red increases until a solid red displays	Verify network parameters. Verify the network cabling
Red	Excessive receive signal distortion	<ul style="list-style-type: none"> <li>– confirm that the correct fibre type matches the module</li> <li>– check fibre length and attenuation to ensure that it is within specification</li> <li>– replace the downstream fibre repeater module on the channel having the intermittently flashing red LED</li> <li>– confirm that the total network length is not out of specification (see Clause A.4)</li> <li>– confirm that SMAX is correctly defined in the ControlNet software configuration tool</li> </ul>

**A.8.4 Specific requirements for maintenance and troubleshooting**

Not applicable.

## Annex B (normative)

### CP 2/2 (EtherNet/IP™) specific installation profile

#### B.1 Installation profile scope

*Addition:*

This Annex specifies the installation profile for Communication Profile CP 2/2 (EtherNet/IP). The CP 2/2 is specified in IEC 61784-1 and IEC 61784-2. This profile is based on standard implementations of ISO/IEC 8802-3 TP-PMDs and FO-PMD such as 100BASE-FX and 1000BASE-T.

#### B.2 Normative references

*Addition:*

IEC 60603-7-2, *Connectors for electronic equipment – Part 7-2: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 100 MHz*

IEC 60603-7-3, *Connectors for electronic equipment – Part 7-3: Detail specification for 8-way, shielded, free and fixed connectors, for data transmission with frequencies up to 250 MHz*

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

IEC 60603-7-5, *Connectors for electronic equipment – Part 7-5: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz*

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

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

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 61156-5, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Horizontal floor wiring – Sectional specification*

ANSI/TIA-568-C.4.2-D, *Commercial building telecommunications cabling standards – Part 1: General requirements*

ANSI/TIA-1005-A, *Telecommunications Infrastructure Standard for Industrial Premises*

IEEE Std 802.1Q-2018, *IEEE Standard for Local and Metropolitan Area Networks – Bridges and Bridged Networks*

### B.3 Installation profile terms, definitions, and abbreviated terms

#### B.3.1 Terms and definitions

#### B.3.2 Abbreviated terms

*Addition:*

FO-PMD	Fibre optic – Physical layer medium dependent
LLCR	Low level contact resistance
RF	Radio frequency
ST	Optical fibre connector in accordance with IEC 61754-2
T568A / T568B	Wiring conventions (see ANSI/TIA/EIA 568-C.1)
TN-S	Terminal node – Separate earth
TP-PMD	Twisted pair – Physical layer medium dependent

#### B.3.3 Conventions for installation profiles

Not applicable.

### B.4 Installation planning

#### B.4.1 General

##### B.4.1.1 Objective

##### B.4.1.2 Cabling in industrial premises

*Addition:*

CP 2/2 is designed to be deployed within the automation island and between automation islands as detailed in IEC 61918:2018, 4.1.2, Figure 5. CP 2/2 may be directly connected to a generic cabling system with the appropriate firewall protection and the AO as shown in Figure B.1. In this case, the AO is the demarcation point between the generic cabling and EtherNet/IP. The AO shall be the AO defined in this profile. For further requirements, see B.4.4.2.2.

The interconnection of CP 2/2 with CP 2/1 and CP 2/3 can be accomplished through a converter/adaptor (linking device) as shown in Figure B.1. Direct physical connection from the TO to the AO is possible, this CP 2/2 supports Variant 1 of IEC 61076-3-106 and the M12-8 X-coding connector. The two connector types provide a sealed connection that meets most industrial environments.

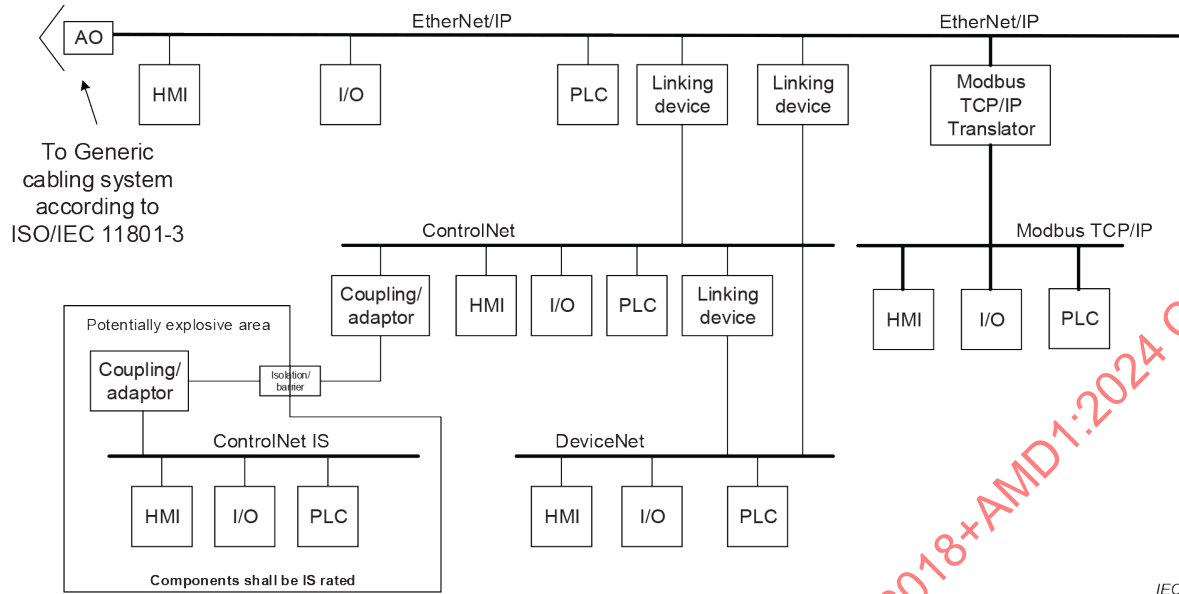


Figure B.1 – Interconnection of CPF 2 networks

## B.4.2 Planning requirements

### B.4.2.1 Safety

#### B.4.2.1.1 General

#### B.4.2.1.2 Electrical safety

#### B.4.2.1.3 Functional safety

#### B.4.2.1.4 Intrinsic safety

Not applicable.

#### B.4.2.1.5 Safety of optical fibre communication systems

### B.4.2.2 Security

*Addition:*

Control applications may require access to the control network 100 % of the time. Intrusions by other users into the control network could cause processing delays and loss of control. For this reason, the control network shall be isolated from the office environment and the Internet. The planner is strongly encouraged to provide appropriate security through the use of filtering devices, gateways, firewalls, routers, and/or appropriate security software. The planner and maintenance personnel are cautioned about installing devices on the control network that could bypass network security, such as telephone modems.

Network maintenance personnel in particular shall be made aware that inadvertent intrusions resulting from system maintenance and housekeeping, network upgrades, or broadcast storms may disrupt the control system. Details of network security are beyond the scope of this manual and the planner is advised to consult appropriate standards.

~~Careful consideration shall be given to the placement of access ports to prevent unauthorized connection of devices into control networks. Cabinets housing control networks shall not be accessible to unauthorized personnel. Cabling components shall be protected from damage by machinery or tampering.~~

CP 2/2 has provisions for supporting secure system designs aligned with IEC 62443. For each security level as defined by IEC 62443 there are different measures such as identification and authentication, data access control, tamper detection, data access restriction, data confidentiality, response time, and resource availability. Aspects of the system could need mitigations depending on the level of security risk identified.

NOTE See ODVA: PUB00148 [45] for more information on securing the installation of CP 2/2 systems. See ANSI/TIA 5017 [46] for more information for deterrence or restricted access measures that can be taken for securing the physical infrastructure of zones where it is deemed necessary or appropriate.

### B.4.2.3 Environmental considerations and EMC

#### B.4.2.3.1 Description methodology

#### B.4.2.3.2 Use of the described environment to produce a bill of material

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

### B.4.3 Network capabilities

#### B.4.3.1 Network topology

##### B.4.3.1.1 Common description

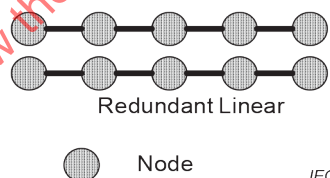
##### B.4.3.1.2 Basic physical topologies for passive networks

Not applicable.

##### B.4.3.1.3 Basic physical topologies for active networks

*Addition:*

EtherNet/IP supports redundant active linear bus topologies as shown in Figure B.2.



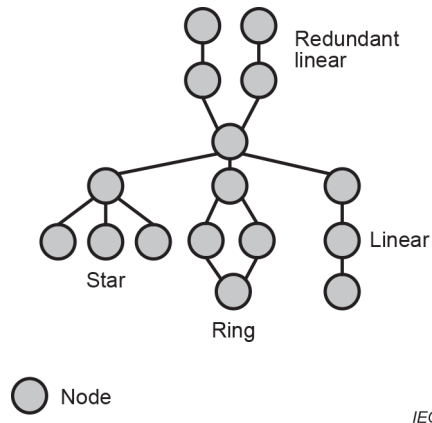
**Figure B.2 – Redundant linear bus**

##### B.4.3.1.4 Combination of basic topologies

~~Not applicable.~~

*Replacement:*

Combination of topologies is achieved through bridging defined in IEEE Std 802.1Q-2018 and subsequent documents. CP 2/2 provides for routing of data through active topologies and allows interfacing of all equipment through a hierarchical star topology. This is typically facilitated through a network zone approach where an individual node on a network can be replaced with an entire subnetwork configured in an independent topology such as a ring, active linear bus, redundant active linear bus, or an additional active star. This concept is shown in Figure B.18.



**Figure B.18 – Example of combination of basic active topologies**

#### **B.4.3.1.5 Specific requirements for CPs**

*Addition:*

EtherNet/IP supports point-to-point connections as shown in Figure B.3 through a crossover cable. The crossover cable shall meet the wiring scheme detailed in IEC 61918:2018, Annex H.



**Figure B.3 – Peer-to-peer connections**

#### **B.4.3.2 Network characteristics**

##### **B.4.3.2.1 General**

##### **B.4.3.2.2 Network characteristics for balanced cabling not based on Ethernet**

Not applicable.

##### **B.4.3.2.3 Network characteristics for balanced cabling based on Ethernet**

*Modification:*

Table B.1 provides values based on the template given in IEC 61918:2018, Table 2.

Table B.1 describes the minimum basic network characteristics for EtherNet/IP networks.

**Table B.1 – Network characteristics for balanced cabling based on Ethernet**

Characteristic	CP 2/2
Supported data rates (Mbit/s)	10/100 and 1 000
Supported channel length (m) <sup>b</sup>	100 maximum (see channel and link length and limits below)
Number of connections in the channel (max.) <sup>a,b</sup>	6 <sup>a</sup>
Patch cord length (m) <sup>a</sup>	See IEC 61918:2018, Clause 4 and ISO/IEC 11801-3
Channel class per ISO/IEC 11801-3 (min.) <sup>b, d</sup>	Class D
Cable category ISO/IEC 11801-3 (min.)	5
Connecting HW category per ISO/IEC 11801-3 (min.) <sup>c</sup>	5
Cable types	As needed for application
<sup>a</sup> See B.4.4.3.2. <sup>b</sup> For the purpose of this table the channel definitions of ISO/IEC 11801-3 are applicable. <sup>c</sup> For additional information see IEC 61156 series. <sup>d</sup> The TCL, ELTCTL and CA of ISO/IEC 11801-3 apply and are dependent on location of installation.	

Cabling shall be selected to meet the environmental conditions and channel class of the installation area and application bandwidth. The TCL defined for E3, ELTCTL and Coupling Attenuation (CA) defined for E3 shall be used for E3 environments and is recommended for E2 environments, see Table B.10, Table B.12 and Table B.14.

#### **B.4.3.2.4 Network characteristics for optical fibre cabling**

*Replacement:*

Table B.2 provides values based on the template given in IEC 61918:2018, Table 3.

Additional information on fibre cables supported by EtherNet/IP is specified in Table B.3, Table B.4, Table B.5 and Table B.6. Table B.2 should be used in conjunction with Table B.5 and Table B.6.

**Table B.2 – Network characteristics for optical fibre cabling**

CP 2/2		
Optical fibre type	Description	
Single mode silica	Bandwidth (MHz Mbit/s) or equivalent at $\lambda$ (nm)	1 000 MHz Mbit/s, 1 310 nm and 1 550 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	10 000
	Maximum channel Insertion loss/optical power budget (dB)	In according with ISO/IEC 11801
	Connecting hardware	See B.4.4.2.5
Multimode silica	Modal bandwidth (MHz × km) Bandwidth (Mbit/s) at $\lambda$ (nm)	1 000 MHz Mbit/s; 850 nm and 1 300 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	2 000
	Maximum channel Insertion loss/optical power budget (dB)	In according with ISO/IEC 11801
	Connecting hardware	See B.4.4.2.5
POF	Modal bandwidth (MHz × 100 m) Bandwidth (Mbit/s) at $\lambda$ (nm)	100 MHz Mbit/s, 650 nm
	Minimum length (m)	0,055
	Maximum length <sup>a</sup> (m)	See Table B.3 Table B.4
	Maximum channel Insertion loss/optical power budget (dB)	4,2 dB
	Connecting hardware	See B.4.4.2.5
Hard clad silica	Modal bandwidth (MHz × km) Bandwidth (Mbit/s) at $\lambda$ (nm)	125 MHz Mbit/s, 650 nm
	Minimum length (m)	0,055
	Maximum length <sup>a</sup> (m)	See Table B.3 Table B.4
	Maximum channel Insertion loss/optical power budget (dB)	4,2 dB
	Connecting hardware	See B.4.4.2.5

<sup>a</sup> This value is reduced by connections, splices and bends in accordance with Formula (1) in 4.4.3.4.1 of IEC 61918:2018.

**Table B.3 – Fibre lengths for 1 mm POF A4a.2 POF 0.5 NA**

Maximum link length with additional losses due to bend radius and number of connections			Number of connections <sup>b</sup>		
Number of bends / Loss	Worst case losses		0	1	2
	dB		0 dB	3 dB	6 dB
	Number of bends	Maximum losses due to bend radius <sup>c</sup>	Maximum length <sup>a</sup>		
		dB	m		
0		0,00	55	43	32
1		0,87	52	40	29
2		0,96	51	40	28
3		1,03	51	40	28
4		1,06	51	39	28
5		1,09	51	39	28

NOTE See footnotes a, b and c in Table B.4.

**Table B.4 – Fibre lengths for 1 mm POF A4d POF 0.3 NA**

Maximum link length with additional losses due to bend radius and number of connections			Number of connections <sup>b</sup>		
Number of bends / Loss	Worst case losses		0	1	2
	dB		0 dB	3 dB	6 dB
	Number of bends	Maximum losses due to bend radius <sup>c</sup>	Maximum length <sup>a</sup>		
		dB	m		
0		0,00	65	53	41
1		0,87	63	51	39
2		0,96	62	50	38
3		1,03	62	50	38
4		1,06	62	50	38
5		1,09	62	50	38

<sup>a</sup> Fibre loss

Fibre base loss includes environmental influences mainly from absorption of water (which is reversible), and the launch NA of the source.

<sup>b</sup> Connections

Bulkhead coupling loss is included in minimum launch power of the transmitter and worse case receiver sensitivity. Worst-case fibre-to-fibre loss by a connector is assumed to be 3,0 dB. Two mated connectors coupled with an adapter make a connection, see Figure B.4.



**Figure B.4 – Mated connections**

<sup>c</sup> Bending loss

Bending loss is measured for the fibre with maximum link length. The bending losses at 25 mm radius given in Table B.3 and Table B.4 are used as typical value, 1 bend = 360°. If a bend radius is greater than 180 mm, it is considered straight with no loss. Other bend radiuses are allowable. Manufacturer's data sheet should be consulted for bending losses.

The fibres detailed in Table B.5 are recommended for use in EtherNet/IP networks. The recommended lengths are provided in this table.

**Table B.5 – Recognized fibre types**

Fibre type	Supported fibres	Designations	Bandwidth @ at 850 nm/1 310 nm	Standard
Multimode	62,5 µm/125 µm	OM1	200 MHz × km/500 MHz × km	IEC 60793-2-10, type <del>A1b</del> A1-OM1
	62,5 µm/200 µm/230 µm	OM1	200 MHz × km/500 MHz × km	IEC 60793-2- <del>10</del> 30, type <del>A3f</del> A3g
	50 µm/125 µm	OM2	500 MHz × km/500 MHz × km	IEC 60793-2-10, type <del>A1a.1</del> A1-OM2
		OM3	2 000 MHz × km/500 MHz × km	IEC 60793-2-10, type <del>A1a.2</del> A1-OM3
		OM4	4 700 MHz × km/500 MHz × km	IEC 60793-2-10, type <del>A1a.3</del> A1-OM4
		OM5	4 700 MHz × km/500 MHz × km	IEC 60793-2-10, type A1-OM5
	50 µm/200 µm/230 µm	OM2	<del>500</del> 400 MHz × km/ <del>500</del> 400 MHz × km	IEC 60793-2- <del>10</del> 30, type <del>A3g</del> A3f
Single-mode	9 µm/125 µm	OS1	N/A	IEC 60793-2-50, type <del>B1.1B</del> -652.B
		OS2	N/A	IEC 60793-2-50, type <del>B1.3B</del> -652.D
Setp Index Multimode	980 µm/1 000 µm	N/A	<del>404</del> MHz × km	IEC 60793-2-40, type A4a.2 and A4d

The PMDs of Table B.6 are acceptable to be used in Ethernet/IP networks. They provide coverage for the most popular data rates, 100 Mb/s and 1 000 Mb/s. Other PMDs may be used but are not supported.

**Table B.6 – Recognized fibre PMDs**

IEEE 803.3 fiber PMD	Supported fibres	MSA	Application standard	Cabling standard
100BASE-FX	OM1, OM2, OM3 and OM4, OM5	GBIC, SFP	IEEE 802.3u	ISO/IEC 11801
100BASE-FX	980 µm/1000 µm POF, OM5	N/A	IEEE 802.3u	IEC 60794-2-42
1000BASE-LX	OM1, OM2, OM3, OM4, OS1, OS2, OM5	GBIC, SFP	IEEE 802.3z	ISO/IEC 11801
1000BASE-SX	OM1, OM2, OM3, OM4, OM5	GBIC, SFP	IEEE 802.3z	ISO/IEC 11801
1000BASE-LX10 and 100BASE-LX10	OM1, OM2, OM3, OM4, OS1, OS2, OM5	GBIC, SFP	IEEE 802.3z	ISO/IEC 11801

**B.4.3.2.5 Specific network characteristics**

Not applicable.

**B.4.3.2.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****B.4.4 Selection and use of cabling components****B.4.4.1 Cable selection****B.4.4.1.1 Common description****B.4.4.1.2 Copper cables****B.4.4.1.2.1 Balanced cables for Ethernet-based CPs**

Replacement for Table 4 and Table 5:

Addition for Table 6:

Table B.7 to Table B.14 provide values based on the template given in IEC 61918:2018, Table 4 and Table 5.

**Table B.7 – Information relevant to copper cable: fixed cables 10/100 MHz**

Characteristic	CP 2/2
Nominal impedance of cable (tolerance)	95 $\Omega$ to 110 $\Omega$ from 1 MHz to 4 MHz 95 $\Omega$ to 107 $\Omega$ from 4 MHz to 100 MHz
Return loss (dB)	1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \log_{10}(f/20)$
NEXT	$NEXT(f) \geq 64 - 15 \times \log_{10}(f)$
Balanced or unbalanced	Balanced
DCR of conductors	Compliant with ISO/IEC 11801
DCR of shield	Compliant with ISO/IEC 11801
Number of conductors	4 <sup>a</sup> and 8 <sup>a</sup>
Shielding	User defined
Colour code for conductor	Compliant with Table D.2 of IEC 61918:2018
Jacket colour requirements	User defined
Jacket material	User and application defined
Resistance to harsh environment (e.g.: UV, oil resist, LS0H)	User and application defined
Agency ratings	According to local regulations
<sup>a</sup> In pairs, star quad cable designs are not allowed.	

**Table B.8 – Information relevant to copper cable: fixed cables 1 000 MHz**

Characteristic	Type	
	Shielded	Unshielded
<b>Electrical</b>		
Nominal Impedance of cable (tolerance)	95 Ω to 110 Ω, 1 MHz to 4 MHz 95 Ω to 107 Ω, 4 MHz to 100 MHz	95 Ω to 110 Ω, 1 MHz to 4 MHz 95 Ω to 107 Ω, 4 MHz to 100 MHz
RL (dB)	1 MHz to 10 MHz: $20 + 6\text{Log}_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \text{Log}_{10}(f/20)$	1 MHz to 10 MHz: $20 + 6\text{Log}_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \text{Log}_{10}(f/20)$
NEXT (dB)	ANSI/TIA-568-C.2.2-D Cat 5e	ANSI/TIA-568-C.2.2-D Cat 5e
Conductors Gauge	0,40 mm (26AWG), 0,51 mm (24AWG), 0,65 mm (22AWG) 0,40 mm to 0,65 mm (26AWG to 22AWG)	
Configuration	2 or 4 pairs + Shield	2 or 4 pairs
Attenuation Solid Conductors	ANSI/TIA-568-C.2.2-D Cat 5e Horizontal	ANSI/TIA568-C.2.2-D Cat 5e Horizontal
Attenuation Stranded Conductors	ANSI/TIA568-C.2.2-D Cat 5e Patch <sup>1</sup>	ANSI/TIA568-C.2.2-D Cat 5e Patch <sup>a</sup>
Coupling Attenuation (dB)	See Table B.14	n/a
Shielding Effectiveness	tbd	n/a
Capacitance unbalance	<= 150 pf/100 m	<= 150 pf/100 m
DCR 26 AWG	14 Ω/100 m	14 Ω/100 m
DCR 24 AWG	9,38 Ω/100 m	9,38 Ω/100 m
DCR 22 AWG	9 Ω/100 m	9 Ω/100 m
DCR Unbalance	3 %	3 %
TCL	n/a	$89 - 15 \times \log(f)$ for $0,7 < f \leq 30$ (MHz) $96,4 - 20 \log(f)$ for $30 < f < 250$ (MHz)
ELTCTL	n/a	$54 - 20 \times \log(f)$ $0,7 < f < 250$ (MHz)
<b>Mechanical</b>	<b>Shielded</b>	<b>Unshielded</b>
Pulling Tension	111 N	111 N
Breaking Strength	400 N	400 N
Bend Radius	5× cable OD at -20 °C	5× cable OD at -20 °C
<b>Dimensional</b> (Recommended for RJ 45 compatibility)	<b>Shielded</b>	<b>Unshielded</b>
Jacket OD	8 mm (0,315") Max	8 mm (0,315") Max
Insulated Conductor	1,22 mm (0,048") Max	1,22 mm (0,048") Max
<sup>a</sup> The insertion loss is based on Commercial cables. Other constructions, such as high flex, may have different performance. Consult the manufacturer for more information.		

**Table B.9 – Information relevant to copper cable: cords 10/100 MHz**

Characteristic	CP 2/2
Nominal impedance of cable (tolerance)	95 Ω to 110 Ω from 1 MHz to 4 MHz 95 Ω to 107 Ω from 4 MHz to 100 MHz
Return loss (dB)	1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \log_{10}(f/20)$
NEXT	$\text{NEXT}(f) \geq 64 - 15 \times \log_{10}(f)$

Characteristic	CP 2/2
Balanced or unbalanced	Balanced
DCR of conductors	Compliant with ISO/IEC 11801
DCR of shield	Compliant with ISO/IEC 11801
Number of conductors	4 <sup>a</sup> and 8 <sup>a</sup>
Length	82 m maximum (see IEC 61918:2018, Clause 4)
Shielding	User defined
Colour code for conductor	Compliant to Annexe D of IEC 61918:2018
Jacket colour requirements	User defined
Jacket material	User and application defined
Resistance to harsh environment (e.g.: UV, oil resist, LS0H)	User and application defined
Agency ratings	According to local regulations
<sup>a</sup> In pairs, star quad cable designs are not allowed.	

Where category 6 or 6a cables are used, the extended requirements of ANSI/TIA 568.2-D apply in addition to the requirements listed in this Subclause B.4.4.1.2.1.

**Modification:**

~~The following additional cable performance is required.~~

~~Cables shall be selected based on ability to support the channel and permanent link balance as defined below.~~

~~The UTP cable shall be selected and installed based on the ability to meet the Transverse Conversion Loss (TCL) and Equal Level Transverse Conversion Transfer Loss (ELTCTL) requirements at both ends of the cabling in accordance with Table B.10 and Table B.12 and the environment local to the cabling.~~

**Table B.10 – TCL limits for unshielded twisted pair cabling serving 10/100 Mb/s**

Category	ISO/IEC 11801 Class	Frequency MHz	Minimum TCL dB		
			E1	E2	E3
5e	D	$1 \leq f < 30$	$60 - 20 \times \log_{10}(f)$	$63 - 15 \times \log_{10}(f)$	$73 - 15 \times \log_{10}(f)$
		$30 \leq f \leq 100$		$70,4 - 20 \times \log_{10}(f)$	$80,4 - 20 \times \log_{10}(f)$
6	E	$1 \leq f < 30$	$60 - 20 \times \log_{10}(f)$	$63 - 15 \times \log_{10}(f)$	$73 - 15 \times \log_{10}(f)$
		$1 \leq f \leq 250$		$70,4 - 20 \times \log_{10}(f)$	$80,4 - 20 \times \log_{10}(f)$

**Table B.11 – TCL limits for unshielded twisted-pair cabling serving 1 000 Mb/s**

Category	ISO/IEC 11801 Class	Frequency MHz	Minimum TCL dB		
			E1	E2	E3
5e	D	$1 \leq f < 30$	See E1 of Table B.10	See E2 of Table B.10	$77 - 15 \times \log_{10}(f)$
		$1 \leq f \leq 250$			$86,6 - 20 \times \log_{10}(f)$
6	E	$1 \leq f < 30$	See E1 of Table B.10	See E2 of Table B.10	$80 - 20 \times \log_{10}(f)$
		$1 \leq f \leq 250$			$86,6 - 20 \times \log_{10}(f)$

The values of Table B.12 and Table B.13 are valid for Class D and Class E channels.

**Table B.12 – ELTCTL limits for unshielded twisted-pair cabling serving 10/100 Mb/s**

Frequency MHz	Minimum ELTCTL dB		
	E1	E2	E3
$1 \leq f \leq 30$	$30 - 20 \times \log_{10}(f)$ (max. 45 dB)	$40 - 20 \times \log_{10}(f)$ (max. 45 dB)	$50 - 20 \times \log_{10}(f)$ (max. 45 dB)

**Table B.13 – ELTCTL limits for unshielded twisted-pair cabling serving 1 000 Mb/s**

Frequency MHz	Minimum ELTCTL dB		
	E1	E2	E3
$1 \leq f \leq 30$	See E2 of Table B.12	See E2 of Table B.12	$52 - 20 \times \log_{10}(f)$

The shielded cable shall be selected and installed based on the ability to meet the coupling attenuation requirements at both ends of the cabling in accordance with Table B.14 and the environment local to the cabling. Coupling attenuation (see Table B.14) shall be measured in accordance with IEC 61156-5.

**Table B.14 – Coupling attenuation limits for screened twisted-pair cabling**

ANSI/TIA 1005A Category	ISO/IEC 11801 Class	Frequency MHz	Minimum dB		
			E1	E2	E3
5e	D	$30 \leq f \leq 100$	$30 - 20 \times \log_{10}(f/100)$ (max. 45 dB)	$40 - 20 \times \log_{10}(f/100)$ (max. 45 dB)	$50 - 20 \times \log_{10}(f/100)$ (max. 45 dB)
6	E	$30 \leq f \leq 250$	$30 - 20 \times \log_{10}(f/100)$ (max. 45 dB)	$90 - 20 \times \log_{10}(f/100)$	$100 - 20 \times \log_{10}(f/100)$

Colour codes for 2-pair and 4-pair cabling shall conform to the colour code in IEC 61918:2018, Annex D. The connector pin mapping shall conform to IEC 61918:2018, Annex H.

*Addition:*

Cables shall be selected based on ability to support one of the four options of channel and link electromagnetic performance as defined below.

- a) The UTP cable supporting 10BASE-T or 100BASE-T applications shall be selected and installed based on the ability to meet the Transverse Conversion Loss (TCL) and Equal Level Transverse Conversion Transfer Loss (ELTCTL) requirements at both ends of the cabling in accordance with Table B.27 and the environment local to the cabling.

**Table B.27 – Unbalance attenuation limits for unshielded twisted-pair cabling serving 10BASE-T and 100BASE-T applications**

Parameter	Frequency MHz	Limit dB <sup>a</sup>
TCL	$1 \leq f < 100$	Compliant with ISO/IEC 11801 series
ELTCTL	$1 \leq f < 30$	Compliant with ISO/IEC 11801 series
<sup>a</sup> Limits are applicable to all environmental classifications aligned with delineation in ISO/IEC 11801-1.		

- b) The UTP cable supporting 1000BASE-T applications shall be selected and installed based on the ability to meet the Transverse Conversion Loss (TCL) and Equal Level Transverse Conversion Transfer Loss (ELTCTL) requirements at both ends of the cabling in accordance with Table B.28 and the environment local to the cabling.

**Table B.28 – Unbalance attenuation limits for unshielded twisted-pair cabling serving 1000BASE-T applications with enhanced components**

Parameter	Frequency MHz	Limit dB		
		E1	E2	E3
TCL	$1 \leq f < 30$	Compliant with ISO/IEC 11801 series	$69,2 - 15 \times \log_{10}(f)$	$79,2 - 15 \times \log_{10}(f)$
	$1 \leq f \leq 100$		$76,6 - 20 \times \log_{10}(f)$ (max. 40 dB)	$86,6 - 20 \times \log_{10}(f)$ (max. 46 dB)
ELTCTL	$1 \leq f < 30$	Compliant with ISO/IEC 11801 series	$42 - 20 \times \log_{10}(f)$ (max. 40 dB)	$52 - 20 \times \log_{10}(f)$ (max. 40 dB)

- c) The UTP cable supporting 1000BASE-T applications shall be selected and installed based on the ability to meet the Transverse Conversion Loss (TCL) and Equal Level Transverse Conversion Transfer Loss (ELTCTL) requirements at both ends of the cabling while also restricting the insertion loss and indirectly the associated cable length in accordance with Table B.29 and the environment local to the cabling. Under this condition the nominal maximum cable length is limited to 72 m instead of the expected 100 m.

**Table B.29 – Unbalance attenuation limits for unshielded twisted-pair cabling serving 100BASE-T applications with length derating**

Parameter	Frequency MHz	Limit dB <sup>a</sup>
Insertion Loss	$1 \leq f \leq 100$	$0,72 \times (1,967\sqrt{f} + 0,023 \times f + 0,1/\sqrt{f})$
TCL	$1 \leq f \leq 100$	Compliant with ISO/IEC 11801 series
ELTCTL	$1 \leq f \leq 30$	Compliant with ISO/IEC 11801 series

<sup>a</sup> Limits are applicable to all environmental classifications aligned with delineation in ISO/IEC 11801-1.

d) The shielded cable shall be selected and installed based on the ability to meet the coupling attenuation requirements at both ends of the cabling in accordance with Table B.30 and the environment local to the cabling. Coupling attenuation (see Table B.30) shall be measured in accordance with IEC 61156-5.

**Table B.30 – Coupling attenuation limits for screened twisted-pair cabling**

Parameter	Frequency MHz	Limit dB <sup>a</sup>
Coupling Attenuation	$30 \leq f \leq 100$	Compliant with ISO/IEC 11801 series

<sup>a</sup> Limits are applicable to all environmental classifications aligned with delineation in ISO/IEC 11801-1.

**B.4.4.1.2.2 Copper cables for non-Ethernet-based CPs**

Not applicable.

**B.4.4.1.3 Cables for wireless installation**

**B.4.4.1.4 Optical fibre cables**

Replacement:

Table B.15 provides values based on the template given in IEC 61918:2018, Table 6.

**Table B.15 – 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	OS1 or OS2	<del>OM1, OM2</del> or, OM3, OM4, OM5	OM1, <del>OM2 or</del> <del>OM3</del>	--	--
Maximum attenuation per km (650 nm)	–	–	–	18 dB	For further study 12 dB
Maximum attenuation per km (820 nm)	–	– 2,5 dB	– 3,0 dB	–	–
Maximum attenuation per km (1 310 nm)	<del>1,0</del> 0,4 dB	<del>2,0</del> 0,8 dB	<del>3,0</del> 1,0 dB	–	–
Number of optical fibres	2 minimum	2 minimum	2 minimum	–	–
Connector type (e.g. duplex or simplex)	Duplex, duplex-able, simplex	Duplex, duplex-able, simplex	Duplex, duplex-able, simplex	–	–

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 POE	200/230 µm step index hard clad silica
Jacket colour requirements	User defined	User defined	User defined	–	–
Jacket material	User defined	User defined	User defined	–	–
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	As needed to support application and environment	As needed to support application and environment	As needed to support application and environment	–	–

**B.4.4.1.5 Special purpose balanced copper and optical fibre cables****B.4.4.1.6 Specific requirements for CPs**

Not applicable.

**B.4.4.1.7 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****B.4.4.2 Connecting hardware selection****B.4.4.2.1 Common description****B.4.4.2.2 Connecting hardware for balanced cabling CPs based on Ethernet***Replacement:*

Table B.16 and Table B.17 provide values based on the template given in IEC 61918:2018, Table 7.

**Table B.16 – Connectors for balanced cabling CPs based on Ethernet**

	IEC 60603-7 series <sup>a</sup>		IEC 61076-3-106 <sup>b</sup>		IEC 61076-3-117 <sup>b</sup>	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
<b>CP 2/2</b>	IEC 60603-7 or IEC 60603-7	IEC 60603-7 or IEC 60603-7	Yes	No	No	Yes	Yes

<sup>a</sup> For IEC 60603-7 series, the connector selection is based on the desired channel performance.

<sup>b</sup> Housings to protect connectors.

**Table B.17 – TCL limits for connectors based on Ethernet serving 1 000 Mb/s**

Category	ISO/IEC 11801 Class	Frequency MHz	Minimum TCL dB		
			E4	E2	E3
6	E	$1 \leq f < 250$	Not defined	Not defined	$94 - 20 \times \log_{10}(f)$

**Table B.17 – Unbalance Attenuation limits for connectors based on Ethernet serving 1000BASE-T applications**

Parameter	Frequency MHz	Limit dB		
		E1	E2	E3
TCL	$1 \leq f < 250$	Not defined	Not defined	$94 - 20 \times \log_{10}(f)$
TCTL	$1 \leq f < 30$	Not defined	Not defined	$71.5 - 20 \times \log_{10}(f)$

*Addition:*

**a) EtherNet/IP sealed 8-way modular connector housings**

Sealed 8-way modular connectors play an important role in providing a reliable connection in harsh environments. EtherNet/IP supports Variant 1 in IEC 61076-3-106. This connector is suitable for use in information and control applications. The planner shall consult the manufacturer's data sheet for environmental compatibility as defined by the MICE concept.

Table B.18 contains the connector parameters for the 8-way modular connectors for use in sealed and unsealed industrial EtherNet/IP systems.

**Table B.18 – Industrial EtherNet/IP 8-way modular connector parameters**

Parameter	Type	
	Shielded	Unshielded
Conductors	8 + 1 shielded	8
Contact LLCR over life	< 20 mΩ	< 20 mΩ
Initial	< 2,5 mΩ	< 2,5 mΩ
Contact life	750 insertions and extractions min.	750 insertions and extractions min.

Sealed 8-way modular connectors shall meet the EtherNet/IP specification and utilize the encapsulation method defined in IEC 61076-3-106, Variant 1. Figure B.5 and Figure B.6 provide examples of the Variant 1 connector housing.



**Figure B.5 – The 8-way modular sealed jack & plug (plastic housing)**



**Figure B.6 – The 8-way modular sealed jack & plug (metal housing)**

**b) 4-Pole M12 D-coding connectors**

4-Pole M12 D-coding connectors are sealed to meet the IP65/67 specification for EtherNet/IP and designed to operate in harsh environments in accordance with IEC 61076-2-101.

4-Pole M12 D-coding connectors shall be used only with 2-pair cables. If support for all generic applications such as voice, video and data (1 Gbit/s and 10 Gbit/s Ethernet) is required, 4-pair cables and 8-way modular connector and compatible components shall be used.

See IEC 61918:2018, 4.4.3 for rules on 2- and 4-pair cabling within a channel.

Table B.19 provides the contact requirements for the M12-4 D-coding connector to ensure network reliability and connector compatibility.

**Table B.19 – Industrial EtherNet/IP M12-4 D-coding connector parameters**

Parameter	Type	
	M12 shielded	M12 unshielded
Conductors	4+1 shield	4
Contact LLCR over Life	Maximum: 5 mΩ	Maximum: 5 mΩ
Initial Contact LLCR	Nominal: < 1 mΩ	Nominal: < 1 mΩ
Contact rating	3 A minimum	3 A minimum
Contact Plating	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum
Contact Life	750 insertions-extractions	750 insertion-extractions

Figure B.7 is an example of a metallic shell M12-4 D-coding connector.



**Figure B.7 – M12-4 connectors**

The manufacturer's assembly instructions shall be followed to minimize the chance of failure or degraded performance.

### c) 8-Pole M12 X-coding connectors

8-Pole M12 X-coding connectors are sealed to meet the IP65/67 specification for EtherNet/IP and designed to operate in harsh environments in accordance with IEC 61076-2-109.

8-Pole M12 X-coding connectors shall be used only with 4-pair cables. If support for all generic applications such as voice, video and data (1 Gbit/s and 10 Gbit/s Ethernet) is required, 4-pair cables and 8-way modular connector and compatible components shall be used.

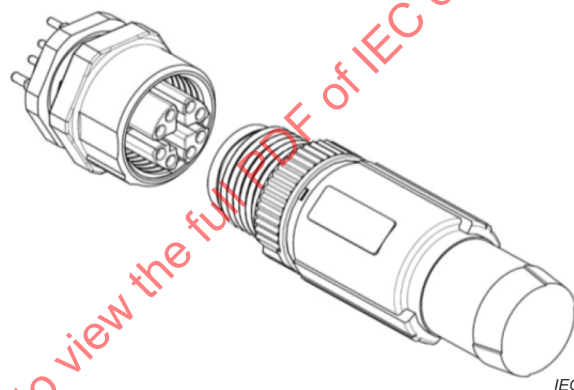
See IEC 61918:2018, 4.4.3 for rules on 2- and 4-pair cabling within a channel.

Table B.20 provides the contact requirements for the M12-8 X-coding connector to ensure network reliability and connector compatibility.

**Table B.20 – Industrial EtherNet/IP M12-8 X-coding connector parameters**

Parameter	Type	
	M12 shielded	M12 unshielded
Conductors	4+1 shield	4
Contact LLCR over Life	Maximum: 5 mΩ	Maximum: 5 mΩ
Initial Contact LLCR	Nominal: < 1 mΩ	Nominal: < 1 mΩ
Contact rating	3-A minimum	3-A minimum
Contact Plating	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum
Contact Life	750 insertions-extractions	750 insertion-extractions

Figure B.8 is an example of a metallic shell M12-8 X-coding connector.



**Figure B.8 – Example of a metallic shell M12-8 X-coding connectors**

Construction of conversion cables is permissible. Conversion cables constructed with M12 X-coding connector to 8-Way modular connectors shall be constructed from 4 pair cables containing the wire colour codes defined in Colour codes for 2-pair and 4-pair cabling shall conform to the colour code in IEC 61918:2018, Annex D. The connector pin mapping shall conform to IEC 61918:2018, Annex H. Construction of crossover cables between T568A and T568B is permissible.

**B.4.4.2.3 Connecting hardware for copper cabling CPs not based on Ethernet**

Not applicable.

**B.4.4.2.4 Connecting hardware for wireless installation**

**B.4.4.2.5 Connecting hardware for optical fibre cabling**

*Replacement:*

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 B.21 provides values based on the template given in IEC 61918:2018, Table 9.

**Table B.21 – 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	Circular M12
<b>CP 2/2</b>	Yes	Yes	Yes	Yes	No	Yes

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 IEC 61753 series.

*Addition:*

Most ferrules are ceramic, but some are metal or plastic. To minimize potential noise coupling, ceramic or plastic ferrules are recommended.

**LC style connector**

LC is a small form factor connector that uses a plastic or ceramic 1,25 mm diameter ferrule. It is available in a simplex or duplex configuration (see Figure B.9 and Figure B.10). The LC connector is available in sealed housing compliant with Variant 1 of IEC 61076-3-106 and the EtherNet/IP specification as shown in Figure B.11. The LC shall meet the requirements of IEC 61754-20.



IEC

**Figure B.9 – Simplex LC connector**



IEC

**Figure B.10 – Duplex LC connector**

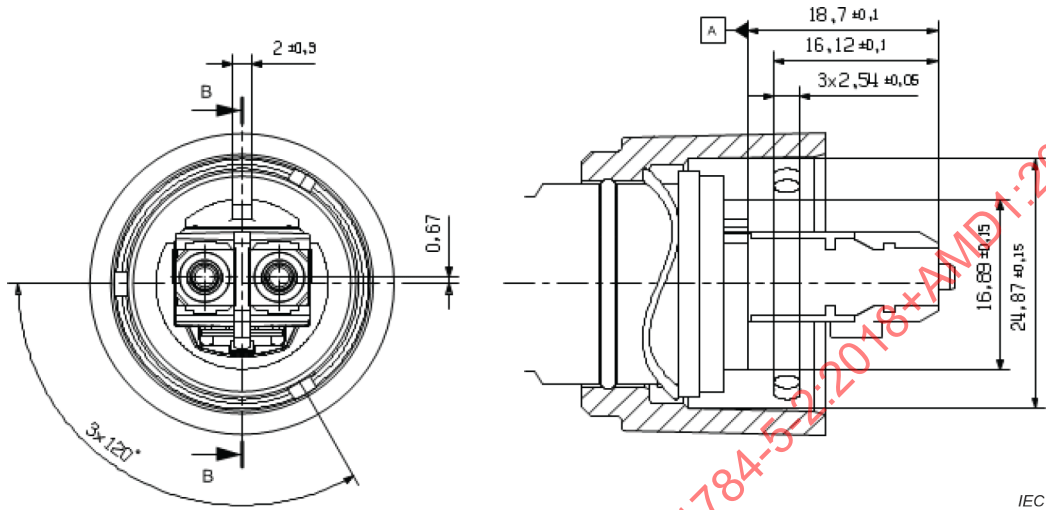


IEC

**Figure B.11 – IP65/67 sealed duplex LC connector**

**SC-RJ style connector**

SC-RJ is a small form factor connector that uses a plastic or ceramic 2,5 mm diameter ferrule. It is available in a simplex or duplex configuration (see Figure B.12). The SC-RJ connector is available in sealed housing compliant with Variant 1 of IEC 61076-3-106 and the EtherNet/IP specification as shown in Figure B.12.



**Figure B.12 – IP65/67 sealed duplex SC-RJ connector**

*Replacement:*

Table B.22 provides values based on the template given in IEC 61918:2018, Table 10, modified as needed.

**Table B.22 – Relationship between FOC and fibre types (CP2/2)**

FOC	Fibre type					
	9/125 μm	50/125 μm	62,5/125 μm	POF 1 mm	200/230 μm Step index Hard clad silica	Others
SC	Yes	Yes	Yes	Yes	No Yes	–
ST	Yes	Yes	Yes	Yes	No Yes	–
LC	Yes	Yes	Yes	No	No	–
SC-RJ	Yes	Yes	Yes	Yes	No Yes	–
Circular M12	No	Yes	Yes	No	No	–

The connector insertion loss shall be met by the connectors as shown in Table B.23.

**Table B.23 – Connector insertion loss**

Connector type	Insertion loss	Return loss
SC, ST, SC-RJ and LC, Circular M12	0,75 dB maximum	Single-mode 26 dB minimum Multimode 20 dB minimum
SC-RJ	2,0 dB maximum (POF)	SI Multimode 20 dB minimum

The installation of fibre connectors is manufacturer specific and requires the manufacturer's specific tools for installation. Please consult the specific manufacturer for installation tools and methods for installing the connector.

#### **B.4.4.2.6 Specific requirements for CPs**

Not applicable.

#### **B.4.4.2.7 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.4.4.3 Connections within a channel/permanent link**

##### **B.4.4.3.1 Common description**

##### **B.4.4.3.2 Balanced cabling connections and splices for CPs based on Ethernet**

###### **B.4.4.3.2.1 Common description**

*Addition:*

The number of mated connections allowed in a channel is determined by the desired channel performance (category) and the performance level of the components selected as detailed in IEC 61918:2018, Annex J.

Alternate configurations shall be field tested to ensure adequate performance.

###### **B.4.4.3.2.2 Connections minimum distance**

*Addition:*

There is no minimum distance between back-to-back jacks or connections.

###### **B.4.4.3.2.3 Balanced cabling splices**

###### **B.4.4.3.2.4 Balanced cabling bulkhead connections**

*Replacement:*

See IEC 61918:2018, Annex J, for the performance requirements of the bulkhead connector.

The designer shall be aware of metallic bulkhead feedthroughs that connect the cabling shield at the enclosure wall. This may form an earth loop that could disrupt communications. Where an earth loop is formed, a separate equalization conductor shall be installed to create an equal potential between the two points. An alternative method would be to isolate the bulkhead feedthrough using an insulator between the bulkhead feedthrough and the enclosure wall.

Bulkhead feedthroughs connectors allow systems to be designed and built in modular configurations. This method should be considered based on user design and service preferences. Modularity provides quick deployment and ease of serviceability.

When bulkhead connectors or adaptors are used, they need to be counted in the number of connections within a channel. See IEC 61918:2018, Annex J, to determine how many connections are allowed in a channel.

Figure B.13 is an example of M12-4 D-coding EtherNet/IP bulkhead feedthrough connectors.



**Figure B.13 – M12-4 to 8-way modular bulkhead**

See the manufacturer's data sheet for mounting hole cut-out dimensions. Consider the panel minimum and maximum wall thickness of the enclosure when selecting a bulkhead connector. In addition, consider the earthing aspects when using shielded cabling with bulkhead connectors that provide earthing connections local to the bulkhead. Noise loops may be formed in the cabling system as a result of shield being earthed in the system.

**B.4.4.3.2.5 Balanced cabling J-J coupler (J-J adaptor)**

*Addition:*

See IEC 61918:2018, Annex J, for the performance requirements of the J-J couplers.

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

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

**B.4.4.3.4.1 Common description**

**B.4.4.3.4.2 Optical fibre splices**

**B.4.4.3.4.3 Optical fibre bulkhead connections**

**B.4.4.3.4.4 Optical fibre J-J couplers (or adaptors)**

*Addition:*

The fibre cable should be long enough for the intended installation. Splices should be avoided.

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

Not applicable.

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

**B.4.4.4 Terminators**

Not applicable.

**B.4.4.5 Device location and connection**

**B.4.4.5.1 Common description**

**B.4.4.5.2 Specific requirements for CPs**

*Addition:*

Devices shall be installed in accordance with the following:

- manufacturer's documentation;
- planner's documentation;
- cable routing.

#### **B.4.4.5.3 Specific requirements for wireless installation**

Not applicable.

#### **B.4.4.5.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.4.4.6 Coding and labelling**

#### **B.4.4.7 Earthing and bonding of equipment and devices and shielded cabling**

##### **B.4.4.7.1 Common description**

##### **B.4.4.7.2 Bonding and earthing of enclosures and pathways**

##### **B.4.4.7.2.1 Equalisation and earthing conductor sizing and length**

*Addition:*

If the building does not have an adequate equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets in the communications coverage area.

##### **B.4.4.7.2.2 Bonding straps and sizing**

*Modification:*

Equipotential bonding conductors should preferably be constructed of copper. Aluminium and steel constructions are not recommended for communications bonding straps.

Bonding plates and busbars should preferably be of copper construction. Tin or zinc coating may be used to reduce corrosion. The plating minimum thickness shall be as detailed in IEC 61918:2018, Table 15 and Table 16.

##### **B.4.4.7.2.3 Surface preparation and methods**

##### **B.4.4.7.2.4 Bonding and earthing**

#### **B.4.4.7.3 Earthing methods**

##### **B.4.4.7.3.1 Equipotential**

##### **B.4.4.7.3.2 Star**

##### **B.4.4.7.3.3 Earthing of equipment (devices)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions.

**B.4.4.7.3.4 Copper bus bars**

**B.4.4.7.4 Shield earthing**

**B.4.4.7.4.1 Non-earthing or parallel RC**

~~Not applicable.~~

**B.4.4.7.4.2 Direct**

~~Not applicable.~~

**B.4.4.7.4.3 Derivatives of direct and parallel RC**

*Addition:*

EtherNet/IP ~~requires~~ recommends that the communications shield be parallel RC earthed at one end of the channel and directly to earth at the other end (see IEC 61918:2018, Figure 37). The communications shield is normally directly earthed at the switch. If the device does not provide a parallel RC between the connector shell and earth, then the communications shield shall be left unterminated at the connector plug. If this is not possible, then appropriate steps shall be taken to equalize any earth potential offset.

**B.4.4.7.5 Specific requirements for CPs**

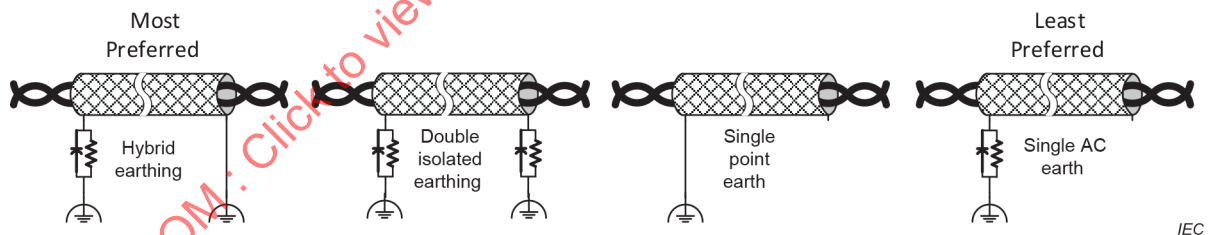
~~Not applicable.~~

*Addition:*

CP 2/2 ranks the shield application according to the applied earthing and bonding system.

a) Star earthing

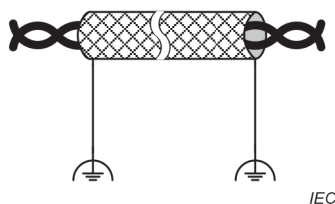
Ranking of preferred shield termination application in a star earthing arrangement is shown in Figure B.19 in order from left to right.



**Figure B.19 – Shield termination in star earthing arrangements**

b) Equipotential/mesh earthing

In equipotential/mesh earthing arrangements, application of direct grounding at multiple points of the cable is preferred (see Figure B.20).



**Figure B.20 – Shield termination in mesh earthing arrangements**

**B.4.4.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****B.4.4.8 Storage and transportation of cables****B.4.4.9 Routing of cables****B.4.4.9.1 Common description****B.4.4.9.2 Cable routing of assemblies****B.4.4.9.3 Requirements for cable routing inside enclosures**

*Addition:*

To guard against coupling noise from one conductor to another, the general guidelines in IEC 61918:2018, Table 17, shall be followed when routing wires and cables (both inside and outside of an enclosure). The spacing given in these general guidelines shall be used, with the following exceptions:

- where connection points (for conductors of different EMC categories) on a device are closer together than the specified spacing;
- application-specific configurations for which the spacing is described in a publication for that specific application.

These guidelines are for noise immunity only. All local regulations for safety requirements shall be followed.

**B.4.4.9.4 Cable routing inside buildings**

*Addition:*

**B.4.4.9.4.1 Outside enclosures**

Cables that run outside protective enclosures can run along other conductors and circuits. To minimize cross-talk from nearby cables, it is good practice to maintain maximum separation between the Ethernet/IP cables and other potential noise carrying conductors. The magnitude of the coupled noise voltage increases as a function of the length that the two cables run in close proximity. Most of the noise coupling will occur within the first 3 m.

With respect to low voltages, the EtherNet/IP cables shall be routed following the guidelines in IEC 61918:2018, Table 17.

**B.4.4.9.4.2 Pathways**

Consult the local and national regulations regarding the grouping of cables. Ethernet cables shall be installed in accordance with the minimum limits defined in IEC 61918:2018, 4.4.9.3 and 4.4.9.4.

**B.4.4.9.5 Cable routing outside and between buildings****B.4.4.9.6 Installing redundant communication cables****B.4.4.10 Separation of circuits****B.4.4.11 Mechanical protection of cabling components****B.4.4.11.1 Common description**

*Addition:*

Communication enclosures may sometimes be placed close to the work area and in harsh conditions. Entry into and exit out of these enclosures either through openings in the side, back, bottom, top, or door, may require an adapter to transition from the dry, clean interior of the enclosure to the possible wet or dirty exterior, i.e. one MICE environment to another MICE environment. The connector shall be located in such a way to minimize exposure to liquids, dusts, mechanical damage and vibration. Bulkhead connectors or bulkhead cable glands shall be used where cables enter or exit the enclosures to maintain enclosure seal integrity. The sealed IP65/67 connectors specified in this installation profile shall be used in the bulkhead assemblies.

#### **B.4.4.11.2 Specific requirements for CPs**

Not applicable.

#### **B.4.4.11.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.4.4.12 Installation in special areas**

##### **B.4.4.12.1 Common description**

##### **B.4.4.12.2 Specific requirements for CPs**

*Addition:*

The cabling components shall be selected based on the environmental and application requirements. Highflex applications shall use cables designed to meet high flex. Cables expected to be subjected to weld splatter shall have the appropriate protection or jacket designs. Cables used in outdoor applications shall have the appropriate UV protection or jacketing design.

##### **B.4.4.12.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.4.5 Cabling planning documentation**

#### **B.4.6 Verification of cabling planning specification**

### **B.5 Installation implementation**

#### **B.5.1 General requirements**

*Addition:*

The installer should be trained and certified in installation practices for generic cabling.

##### **B.5.1.1 Common description**

##### **B.5.1.2 Installation of CPs**

##### **B.5.1.3 Installation of generic cabling in industrial premises**

#### **B.5.2 Cable installation**

##### **B.5.2.1 General requirements for all cabling types**

###### **B.5.2.1.1 Storage and installation**

###### **B.5.2.1.2 Protecting communication cables against potential mechanical damage**

*Replacement:*

Table B.24, Table B.25 and Table B.26 provide values based on the template given in IEC 61918:2018, Table 18, Table 19 and Table 20.

**Table B.24 – Parameters for balanced cables**

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	25 at –20 °C
	Bending radius, multiple bending (mm)	Vendor specified
	Pull forces (N)	110
	Permanent tensile forces (N)	–
	Maximum lateral forces (N)	400
	Temperature range during installation (°C)	Vendor specified

**Table B.25 – Parameters for silica optical fibre cables**

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

**Table B.26 – Parameters for POF optical fibre cables**

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

#### **B.5.2.2 Installation and routing**

##### **B.5.2.3 Specific requirements for CPs**

Not applicable.

##### **B.5.2.4 Specific requirements for wireless installation**

Not applicable.

##### **B.5.2.5 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.5.3 Connector installation**

##### **B.5.3.1 Common description**

*Addition:*

Not all 8-way modular connectors are suitable for harsh environments as classified by the MICE concept. The 8-way modular connector shall be carefully selected for the intended environment. The planner shall specify connectors that meet the requirements of Clause B.4 and IEC 61918:2018, Clause 4, and the environment as classified by MICE.

The connector housings in Figure B.14 and Figure B.15 are examples of the EtherNet/IP compliant housings in accordance with B.4.4.2.2. The planner shall specify in the design documentation the correct shell material (plastic or metal) for the application.



**Figure B.14 – The 8-way modular sealed jack & plug (plastic housing)**



**Figure B.15 – The 8-way modular sealed jack & plug (metal housing)**

The EtherNet/IP specification provides for the use of small sealed connectors such as the M12-4 D-coding connector found in Figure B.16.



**Figure B.16 – M12-4 connectors**

The connector wiring standard to use shall be determined.

There are two 8-way modular wiring methods in use today. Pairs 2 and 3 are swapped depending on which wiring standard, T568A or T568B is used (see Figure H.2 of IEC 61918:2018).

T568A shall be used in generic applications where support of 2-pair phone systems is needed. If 2-pair phone system support is not needed, then either wiring system (T568A or T568B) is acceptable. ~~See Figure H.2 of IEC 61918:2018 for wiring.~~ See IEC 61918:2018, Annex H and IEC 61918:2018/AMD1:2022, Annex H. The wiring scheme selected shall be used throughout the entire link and/or channel.

#### **B.5.3.2 Shielded connectors**

#### **B.5.3.3 Unshielded connectors**

#### **B.5.3.4 Specific requirements for CPs**

*Addition:*

See the manufacturer's data sheet for the assembly instructions of the sealed RJ-45 connector housing.

#### **B.5.3.5 Specific requirements for wireless installation**

Not applicable.

#### **B.5.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.5.4 Terminator installation**

Not applicable.

#### **B.5.5 Device installation**

#### **B.5.6 Coding and labelling**

#### **B.5.7 Earthing and bonding of equipment and devices and shield cabling**

##### **B.5.7.1 Common description**

##### **B.5.7.2 Bonding and earthing of enclosures, and pathways**

##### **B.5.7.3 Earthing methods**

###### **B.5.7.3.1 Equipotential**

*Addition:*

The earthing method shall be in accordance with the planner's documentation. If there is an earth potential offset in the communication coverage area, equalization conductors shall be installed to mitigate the offset. The cross sectional area of these conductors shall be in accordance with IEC 61918:2018, 4.4.7.2.1, Table 14. EtherNet/IP supports both an Equipotential earthing system, and the Star earthing system. Due to its simplicity and effectiveness, it is recommended that the Star earthing system be employed.

###### **B.5.7.3.2 Star**

*Addition:*

In addition to the requirements of B.4.4.7.3.2, the following shall be observed.

Cable shields for the communications equipment shall be referenced only to the signal earth (functional earth). Other equipment such as motors or motor controllers shall not be referenced to the functional earth. The star earth of the two systems (functional earth and protective earth) shall converge at one point within the building as shown in IEC 61918:2018, Figure 17. Earthing connections for the cabinets shall not be daisy chained.

###### **B.5.7.3.3 Earthing of equipment (devices)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions and the planner's documentation.

#### B.5.7.4 Shield earthing methods

##### B.5.7.4.1 General

##### B.5.7.4.2 Parallel RC

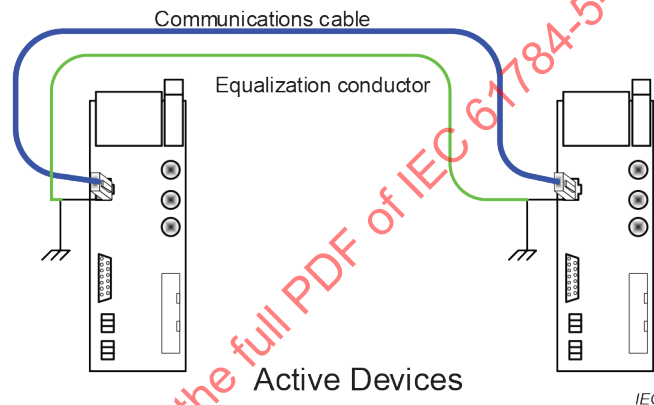
##### B.5.7.4.3 Direct

##### B.5.7.4.4 Derivatives of direct and parallel RC

*Modification:*

Figure B.17 only applies if both the switch and the device are directly earthed. In this case, an equalization conductor shall be installed to assure that noise currents are not carried by the communications cable shields. The sizing of the conductor shall be in accordance with Table 14 of IEC 61918:2018. EtherNet/IP ~~requires~~ recommends that the active devices provide a parallel RC termination for the communications shield integral to the device. Therefore IEC 61918:2018, Figure 37 applies.

The switch provides direct connection to functional or protective earth.



**Figure B.17 – Earthing of cable shield**

*Addition:*

If the active device ~~is other than a switch (or hub) and~~ provides a low DC resistance (less than 500 kΩ) to earth at the jack and connects to a link partner device that also provides a low DC resistance to earth at its jack, an equalizing shunt conductor shall be used to mitigate earth voltage offsets between the two end points, see ~~Figure 35 in~~ IEC 61918:2018, Figure 35. The sizing of the conductor shall be in accordance with ~~Table 14 of~~ IEC 61918:2018, Table 14.

##### B.5.7.5 Specific requirements for CPs

Not applicable.

**B.5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****B.5.8 As-implemented cabling documentation****B.6 Installation verification and installation acceptance test****B.6.1 General****B.6.2 Installation verification****B.6.2.1 General**

*Addition:*

The following additional parameters shall be verified:

- jacketed length;
- kinks in cable;
- breaks in the jacket, abraded or burned;
- bend radius;
- presence of dust caps for unused connectorized cabling and equipment;
- labelling per design documentation (outlets and cables);
- routing of cables with respect to other ~~EMC 1, 2 and 3~~ circuits according to IEC 61918:2018, Table 17.

**B.6.2.2 Verification according to cabling planning documentation****B.6.2.3 Verification of earthing and bonding****B.6.2.4 Verification of shield earthing****B.6.2.5 Verification of cabling system****B.6.2.5.1 Verification of cable routing**

*Addition:*

- a) The length of the ~~permanent~~ end-to-end link/ or a channel is the sum of the lengths of the fixed horizontal cables and cords between the two end points. The length of a permanent link is the sum of the fixed horizontal cable and any intermediary cords not including those cords connecting directly to the end equipment. Length of the ~~permanent~~ link/channel ~~may~~ can be determined by physically measuring the length(s) of the cable(s), determined from the length markings on the cable(s), when present.
- b) The length of the permanent link shall not be greater than 90 m (295 ft). ~~Test equipment cords are excluded from the permanent link model.~~ The length of the end-to-end link or channel shall not be greater than 100 m (328 ft), including equipment cords and patch cords. If the channel or permanent link has been de-rated because of temperature or cable attenuation, then the total channel length is less than 100 m (328 ft) and the permanent link will be less than 90 m (295 ft). See the derating tables in IEC 61918:2018 (Table 11 and Table 12).

**B.6.2.5.2 Verification of cable protection and proper strain relief**

**B.6.2.6 Cable selection verification**

**B.6.2.6.1 Common description**

**B.6.2.6.2 Specific requirements for CPs**

Not applicable.

**B.6.2.6.3 Specific requirements for wireless installation**

Not applicable.

**B.6.2.7 Connector verification**

**B.6.2.7.1 Common description**

**B.6.2.7.2 Specific requirements for CPs**

Not applicable.

**B.6.2.7.3 Specific requirements for wireless installation**

Not applicable.

**B.6.2.8 Connection verification**

**B.6.2.9 Terminator verification**

Not applicable.

**B.6.2.10 Coding and labelling verification**

**B.6.2.10.1 Common description**

**B.6.2.10.2 Specific coding and labelling verification requirements**

Not applicable.

**B.6.2.11 Verification report**

**B.6.3 Installation acceptance test**

**B.6.3.1 General**

**B.6.3.2 Acceptance test of Ethernet-based cabling**

**B.6.3.2.1 Validation of balanced cabling for CPs based on Ethernet**

**B.6.3.2.1.1 Common description**

*Addition:*

Acceptance testing shall include the following aspects of the network:

- Physical installation attributes that may affect the life of the installation, such as;
  - location of cabling with respect to electrical noise and environmental conditions,
  - earthing of devices and equipment where specified,
  - wire ways,

- bend radii,
- cable supports (hangers),
- cable loading and crushing,
- proper media commensurate with the environment.
- Electrical performance commensurate with the needs of the application, such as:
  - electrical and physical lengths of channels and permanent links,
  - swept frequency measurements as detailed later in this Clause B.6.

Electrical performance testing shall be performed either on ~~the channel or permanent link or both~~ the end-to-end link, channel, or permanent link or any combination thereof.

#### **B.6.3.2.1.2 Transmission performance test parameters**

*Addition:*

The network test tools required for certification are usually more complex than the go/no go tools used in verification. These tools are required to perform both DC and swept frequency at both the local and remote ends of a channel or permanent link. There are several off-the-shelf test tools that provide different levels of accuracy. Field test tool shall be Level IIe or higher and it is highly recommended to use either a Level III or IV tester for network certification. Additionally, the test time and frequency range are also a variable. For example, testers may take anywhere from 5 s to 20 s per channel or permanent link. Additionally, they may only test to Category 5E channels/permanent links. The test tool usually requires separate test heads for testing channels, permanent links and cords. It is important to have a tester that is capable of testing all components and parts of a channel, including cords. Additional tools that are beneficial for the certification process are digital camera, digital multimeter with milliohm scale, hand tools and software for generating reports. It is assumed that the certifier has access to a computer and the design documentation. The field test tool should also be selected based on its ability to support TCL and ELTCTL measurements.

The test tool shall be capable of validating 2- and 4-pair cabling.

#### **B.6.3.2.1.3 Specific requirement for CPs based on Ethernet**

Not applicable.

#### **B.6.3.2.2 Validation of optical fibre cabling for CPs based on Ethernet**

#### **B.6.3.2.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.6.3.3 Acceptance test of non-Ethernet-based cabling**

Not applicable.

#### **B.6.3.4 Specific requirements for wireless installation**

Not applicable.

#### **B.6.3.5 Acceptance test report**

### **B.7 Installation administration**

Subclause 7.8 is not applicable.

## **B.8 Installation maintenance and installation troubleshooting**

Subclause 8.4 is not applicable.

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## Annex C (normative)

### CP 2/3 (DeviceNet™) specific installation profile

#### C.1 Installation profile scope

*Addition:*

This annex specifies the installation profile for Communication Profile CP 2/3 (DeviceNet). The CP 2/3 is defined in IEC 61784-1.

#### C.2 Normative references

*Addition:*

IEC 60947-5-2:2007, *Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches*

ISO 11898-1, *Road vehicles – Controller area network (CAN) – Part 1: Data link layer and physical signalling*

ISO 11898-2, *Road vehicles – Controller area network (CAN) – Part 2: High-speed medium access unit*

#### C.3 Installation profile terms, definitions, and abbreviated terms

##### C.3.1 Terms and definitions

##### C.3.2 Abbreviated terms

*Addition:*

CAN	Controller area network	(ISO 11898)
CL2/CL3	Class 2/3 power limited circuits	
DVM	Digital voltmeter	
PELV	Protective extra low voltage	
RF	Radio frequency	
SELV	Safety extra low voltage	
UL	Underwriters Laboratories	

##### C.3.3 Conventions for installation profiles

Not applicable.

## C.4 Installation planning

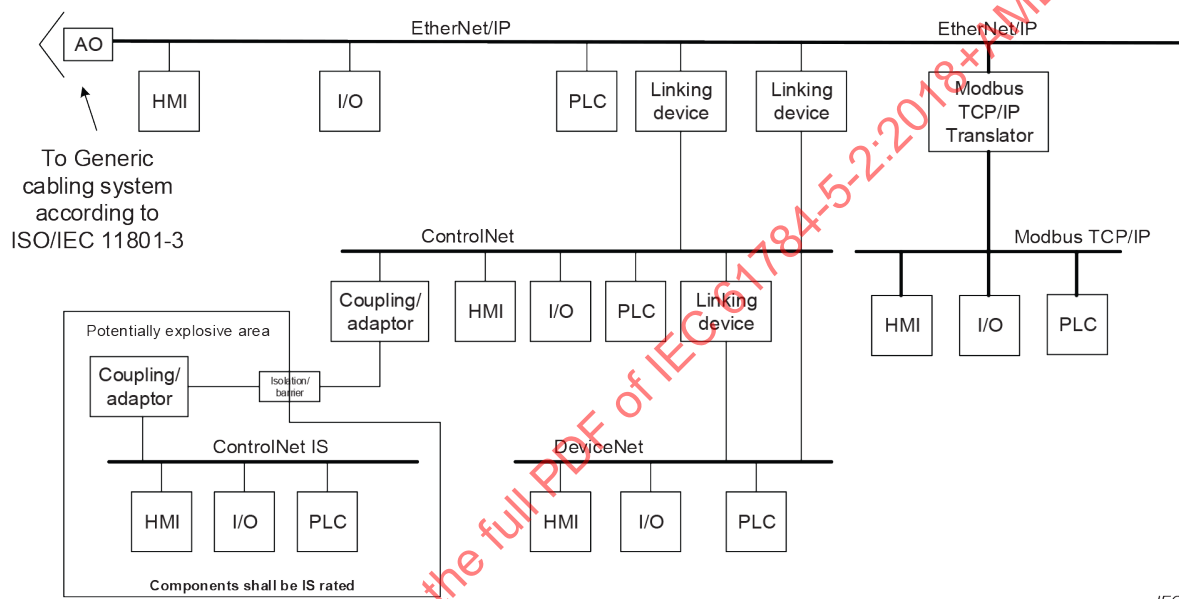
### C.4.1 General

#### C.4.1.1 Objective

#### C.4.1.2 Cabling in industrial premises

*Addition:*

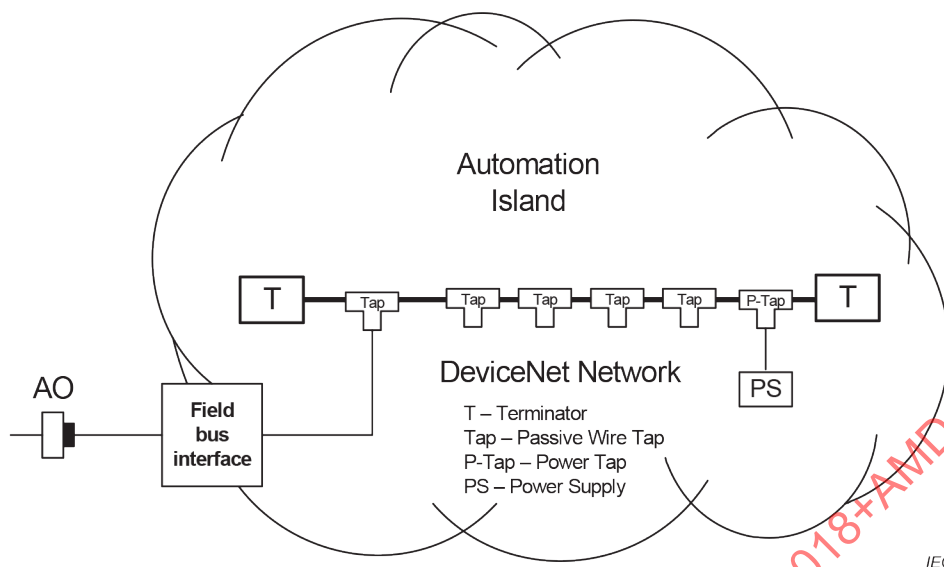
DeviceNet is a fieldbus network whose connectivity to the generic cabling system is accomplished through fieldbus interfaces directly, or through EtherNet/IP which connects directly to the generic cabling system through appropriate network security interfaces. Figure C.1 shows the relationship of CPF 2 networks and interconnectivity between them.



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**Figure C.1 – Interconnection of CPF 2 networks**

DeviceNet is a four- or five-wire linear passive powered bus topology. Devices are normally powered by the network or optionally self powered with a power supply either connected to the device or internal to the device. This topology also supports active devices (bridges) to extend the trunk and connect to other networks alike and not alike (see Figure C.2).



**Figure C.2 – Connection to generic cabling**

## C.4.2 Planning requirements

### C.4.2.1 Safety

#### C.4.2.1.1 General

#### C.4.2.1.2 Electrical safety

*Addition:*

The following additional requirements apply.

#### e) Requirement 1 (LV)

The configuration of the low-voltage power distribution system shall comply with applicable local, national or international regulations. In some cases, and geographical areas additional earthing and bonding is necessary to control noise currents and provide a low noise functional earth for the low signal communications devices. This may be achieved through methods described in IEC 61918:2018, 4.4.7 and C.4.4.7.3 of this document.

This network uses a parallel RC between the communications shield and earth. The shields are referenced to earth at one point in the system only. Multiple earth points may cause earth loop currents in the cabling shields thus causing high error rates in the network.

If multiple earthing is required by local regulations, then an equipotential earthing method is recommended.

#### f) Requirement 2 (protection by extra-low-voltage: SELV and PELV)

The 24 V power supplies in use shall be SELV/PELV rated. In the USA the power supply shall be limited to 8 A. For the UL CL2 type wiring the power supply current shall have a nameplate rating of  $\leq 100$  VA. For additional information on power supplies see C.4.3.2.5.

#### C.4.2.1.3 Functional safety

#### C.4.2.1.4 Intrinsic safety

Not applicable.

#### **C.4.2.1.5 Safety of optical fibre communication systems**

Not applicable.

#### **C.4.2.2 Security**

#### **C.4.2.3 Environmental considerations and EMC**

#### **C.4.2.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

Not applicable.

### **C.4.3 Network capabilities**

#### **C.4.3.1 Network topology**

##### **C.4.3.1.1 Common description**

##### **C.4.3.1.2 Basic physical topologies for passive networks**

*Modification:*

DeviceNet supports bus and complex bus drop branch configurations (see Figure C.3). A pure star is not recommended since there is no defined trunk line ends for terminator placement.

##### **C.4.3.1.3 Basic physical topologies for active networks**

*Modification:*

Active star and ring topologies are not supported by DeviceNet.

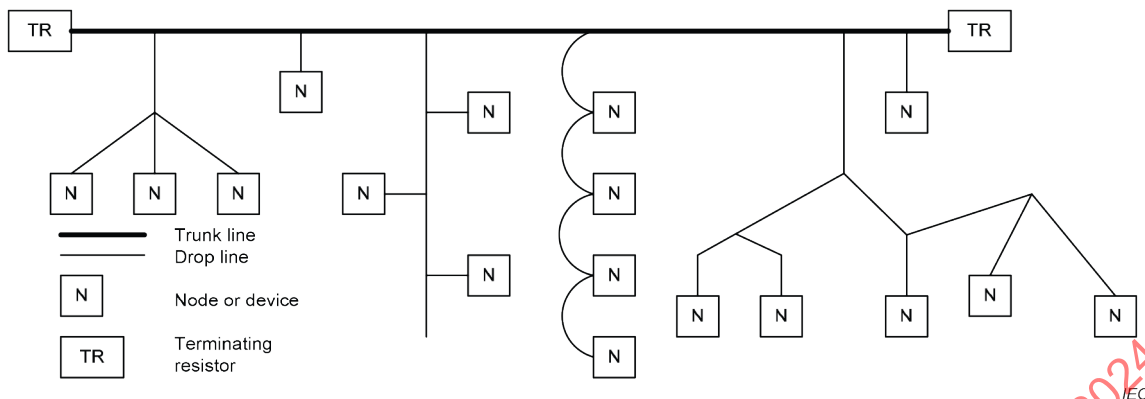
When repeaters are added to the network, the planner shall reduce the trunk length according to the delay of the repeater. Networks may be connected together through bridges or routers. When routers are used, each network will have its own independent addressing and timing constraints.

##### **C.4.3.1.4 Combination of basic topologies**

##### **C.4.3.1.5 Specific requirements for CPs**

*Addition:*

DeviceNet supports passive and active elements in the trunk system. Daisy chain, branch and "chicken foot" physical topologies are also supported. These derivative topologies are connected into the trunk line through passive taps and drop lines as shown in Figure C.3. Repeaters are not generally supported but can be used if proper length derating is used. Repeaters that use store and forward can be used to extend the network at the cost of latency.



**Figure C.3 – DeviceNet cable system uses a trunk/drop line topology**

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

Not applicable.

**C.4.3.2 Network characteristics**

**C.4.3.2.1 General**

**C.4.3.2.2 Network characteristics for balanced cabling not based on Ethernet**

*Replacement:*

Table C.1 provides values based on the template given in IEC 61918:2018, Table 1.

**Table C.1 – Basic network characteristics for copper cabling not based on Ethernet**

Characteristic	CP 2/3
<b>Basic transmission technology</b>	ISO 11898-1 and ISO 11898-2 (CAN)
<b>Length / transmission speed</b>	<b>Segment length</b> m
125 kbit/s	500 maximum (see Table C.2)
250 kbit/s	250 maximum (see Table C.2)
500 kbit/s	100 maximum (see Table C.2)
<b>Maximum capacity</b>	<b>Max. no.</b>
Devices / segment	64
Devices / network	64 <sup>a</sup>
<sup>a</sup> Unlimited addresses and nodes with routing.	

*Addition:*

Table C.2 provides guidance on selecting cables to support segment length and the required data rate.

**Table C.2 – Cable trunk and drop lengths for CP 2/3**

Cable profile	Trunk length			Cumulative drop length <sup>a</sup>		
	Data rate			Data rate		
	125 kbit/s	250 kbit/s	500 kbit/s	125 kbit/s	250 kbit/s	500 kbit/s
	Trunk length at data rate m			Cumulative drop length at data rate <sup>a</sup> m		
Thick	500	250	100	156	78	39
Thin	100	100	100	156	78	39
Flat	420	200	75	156	78	39
Flat II	265	150	75	135	48	35
Cable I	100	100	100	156	78	39
Cable II	500	250	100	156	78	39
Cable III	300	250	100	156	78	39
Cable IV	n/a	n/a	n/a	156	78	39
Cable V	420	200	75	156	78	39

<sup>a</sup> The length of any individual drop cable is limited to a maximum of 6 m.

DeviceNet is a delay, reflection delay and attenuation limited network. In addition, the connection of the taps and drop cables to the trunk cause reflections. The physical topology limits take into consideration 4 limiting parameters below:

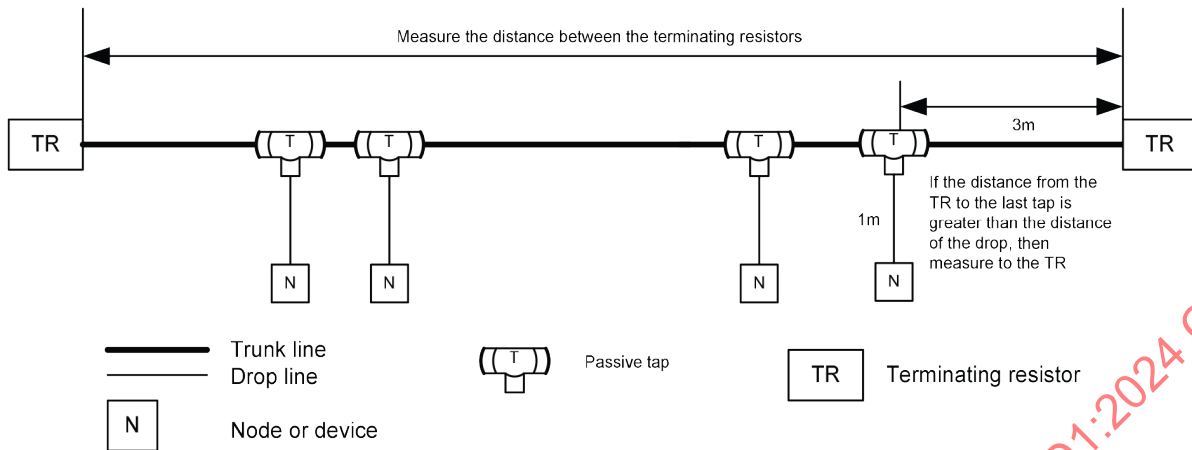
- delay;
- attenuation;
- reflection amplitude and delay;
- V- common mode offset (IR drop)

Table C.2 sets the lengths for drop and trunk based on the first three limits listed above. Under no circumstances shall the lengths in Table C.2 be exceeded. The last limit (common mode offset) is dependent on the power bus DCR of the cable being used, the node current requirements and placement of node with respect to the power supply. The common mode offset voltage and network calculations are described in C.4.3.2.5.

The maximum distance in a network is the distance between the farthest two devices as shown in Figure C.4 and Figure C.5. This distance shall be less than or equal to the distance in Table C.2 for the specific cable to be used. The drop cable length shall be considered in the total network length when the farthest distance between any two nodes is longer than the maximum distance between the two terminators as shown in Figure C.5. The length limits shall be considered independent of the voltage drop in V- caused by the devices.

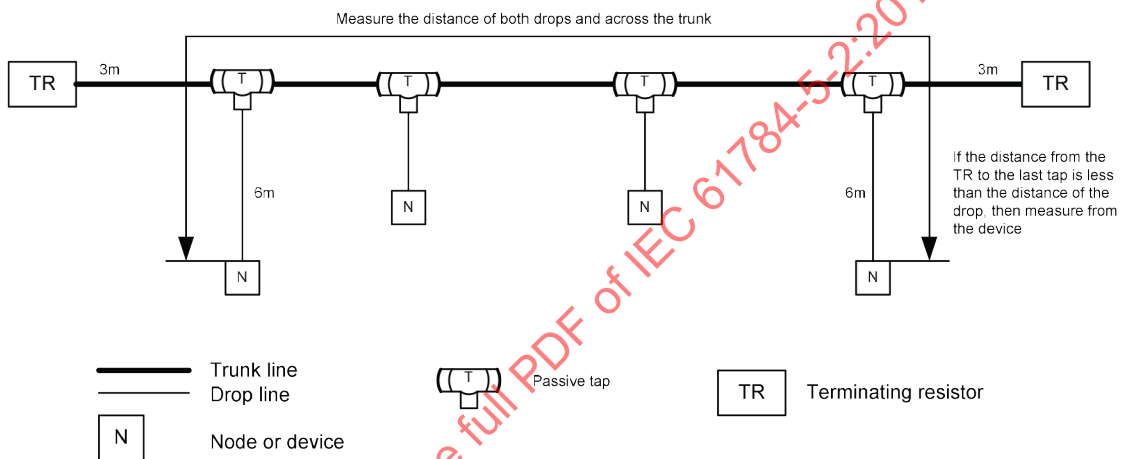
The maximum distance between any two nodes on the network includes drop line length. Therefore, the drop line lengths shall be counted when calculating the maximum delay. This is especially important when drop lines are at the end of the trunk.

Any individual drop line from the trunk is limited to 6 m in length. All drop lines shall be accounted for in the total cumulative drop line length.



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Figure C.4 – Measuring the trunk length

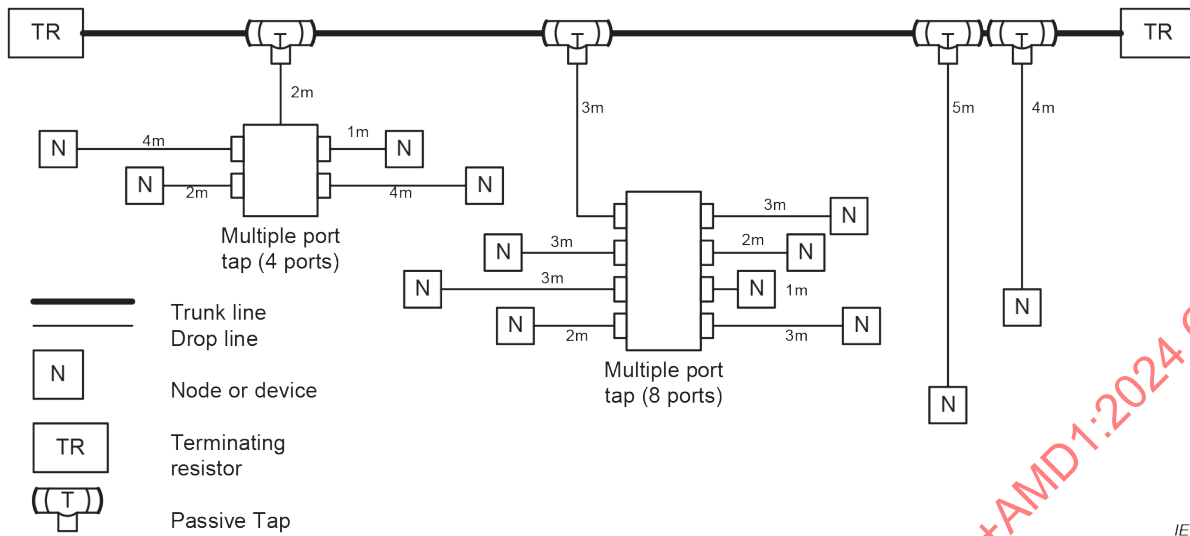


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Figure C.5 – Measuring the trunk and drop length

The drop cable length between the trunk and the farthest node shall not exceed 6 m. For example in Figure C.6 the 8-port tap is located 3 m from the trunk with devices located up to 3 m from the 8-port tap. The total length for this specific drop cable is then 6 m. The total cumulative drop cable of the 8-port tap and its connections is 20 m. The total cumulative drop cable length for this example is 42 m. The cumulative drop length of 42 m exceeds the permissible drop length for 500 kbit/s.

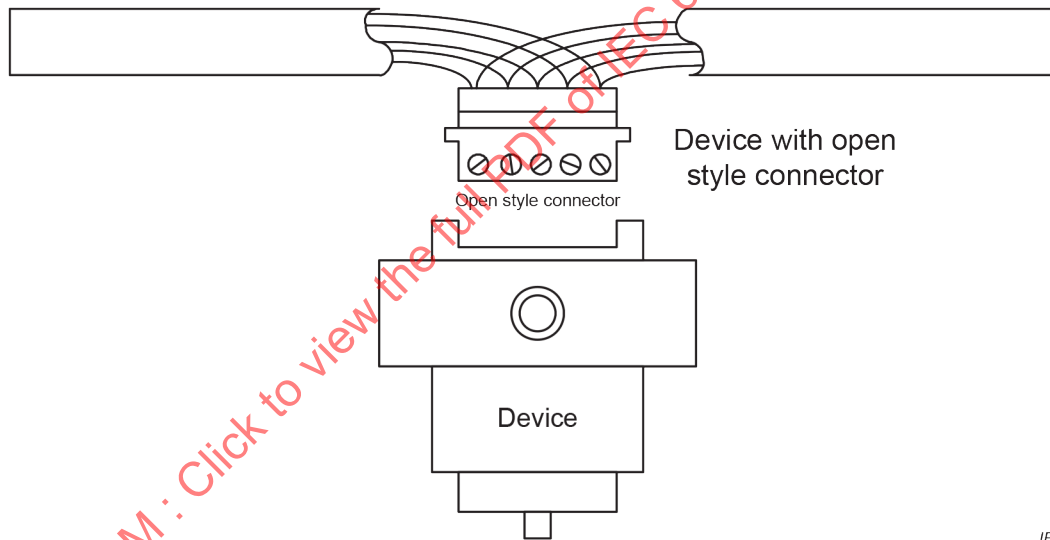
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**Figure C.6 – Measuring drop cable in a network with multiports**

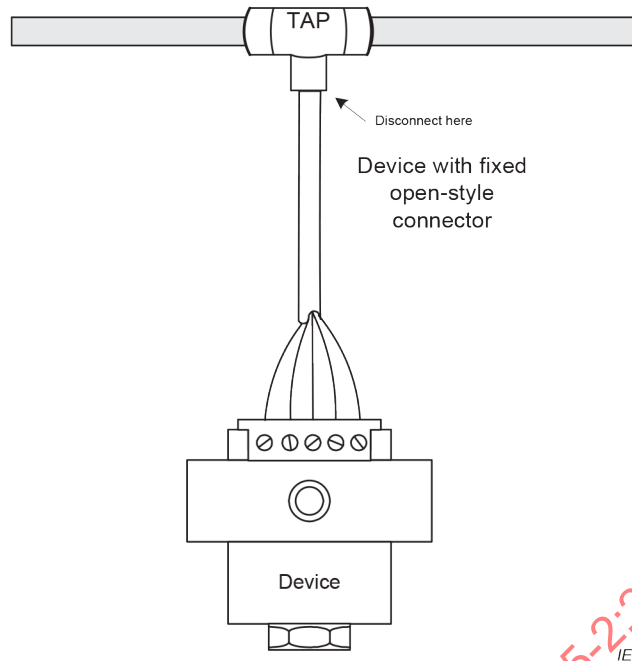
All devices connected to the network trunk cable shall be connected in such a way that removal is possible without severing the network. Examples in Figure C.7 and Figure C.8 show how connections shall be made that will allow removal without disrupting the network.



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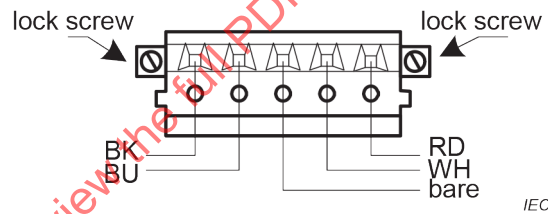
**Figure C.7 – Removable device using open-style connectors**

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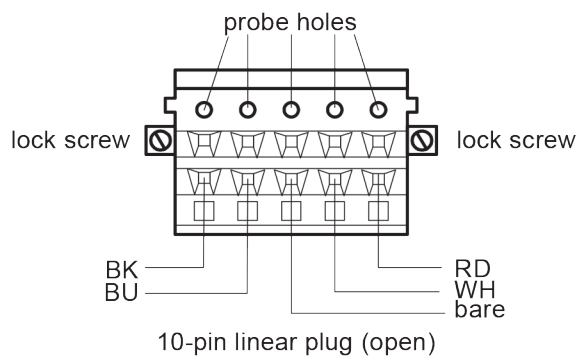


**Figure C.8 – Fixed connection using open-style connector**

The wiring colour code for fixed open-style connectors is detailed in Figure C.9 and Figure C.10. The 2X5 (10) position open-style connector should be used for daisy chaining. Both Figure C.9 and Figure C.10 support a diagnostic probe cable.



**Figure C.9 – Open-style connector pin out**



**Figure C.10 – Open-style connector pin out 10 position**

**C.4.3.2.3 Network characteristics for balanced cabling based on Ethernet**

Not applicable.

**C.4.3.2.4 Network characteristics for optical fibre cabling**

Not applicable.

**C.4.3.2.5 Specific network characteristics**

*Replacement:*

**C.4.3.2.5.1 General**

DeviceNet is a 24 V powered bus. The power supply placement shall be determined by the planner based on the network loading requirements to provide less than or equal to 4,65 V voltage drop on V- in the trunk at any point in the network. The minimum operating voltage for the devices is 11 V. The voltage drop is dependent on two parameters, the DCR of the cabling and the device current requirements. Table C.3 is provided to help the planner determine power supply placement and/or length of the cabling system. The current in any drop line is limited to 3 A maximum and limited to a voltage drop of 0,35 V in the V- line between the trunk connection point and the end of the drop cable. In some cases the voltage drop will limit the length of the drop cable. In some cases, the current in the trunk is limited to the ampacity of the cable. The ampacity of a specific cable is shown in Table C.3 in the zero-length column. Table C.4 provides current versus drop line length that shall be used by the planner in designing the cabling system. In some geographical areas such as North America there is another ampacity limit set by wiring standards for electric power and light. In North America these are Class 2 power limited circuits. Examples of these limits are shown in the figures Figure C.13 and Figure C.15 at the 4-ampere limit (100 VA).

**Table C.3 – Summary of available current for trunk cables (CP 2/3)**

Cable profile	Distance from power supply											
	m											
	0	25	50	100	150	200	250	300	350	400	450	500
Allowable current												
A												
Thick	8,00	8,00	5,42	2,93	2,01	1,53	1,23	1,03	0,89	0,78	0,69	0,63
Thin	3,00	2,50	1,26	0,64	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Flat	8,00	8,00	5,65	2,86	1,91	1,44	1,15	0,96	0,82	0,72	n/a	n/a
Flat II	5,00	5,00	4,40	2,20	1,50	1,10	0,90	0,80	n/a	n/a	n/a	n/a
Cable I	3,00	2,50	1,26	0,64	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cable II	8,00	8,00	5,42	2,93	2,01	1,53	1,23	1,03	0,89	0,78	0,69	0,63
Cable III	1,50	1,50	1,50	1,50	1,28	0,81	0,65	0,55	n/a	n/a	n/a	n/a
Cable IV	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cable V	8,00	8,00	5,65	2,86	1,91	1,44	1,15	0,96	0,82	0,72	n/a	n/a

NOTE Allowable current can be determined for other cable lengths by interpolation.

**Table C.4 – Permissible current for thin cable drop lines of various lengths**

Drop line length m	Allowable current A
1,5	3
2,0	2
3	1,5
4,5	1
6	0,75

The maximum current is calculated using the following formula:

$$I_{\max} = \frac{4,57}{L}$$

where

$I_{\max}$  is the maximum current in amperes (A);

$L$  is the drop line length in metres (m).

#### C.4.3.2.5.2 Choosing a power supply

The power supply used for powering the DeviceNet power bus shall meet the specifications in Table C.5. The planner shall also consider the voltage tolerance stack up in Table C.6 when selecting the network power supply.

**Table C.5 – Power supply specification for DeviceNet**

Parameter	Specification
Initial tolerance	(24 ± 1 %) V or adjustable to 0,2 %
Line regulation	0,3 % maximum
Load regulation	0,3 % maximum
Temperature coefficient	See Table C.6
Output ripple	250 mV p-p
Load capacitance capability	7 000 µF maximum
Temperature range	Operating 0 °C to 60 °C <sup>a</sup> Non-operating –40 °C to 85 °C
Inrush current limit	Less than 65 A peak
Over voltage protection	Yes (to maximum allowable voltage as defined in this table)
Over current protection	Yes (current limit 125 % maximum)
Turn-on time (with full load)	250 ms maximum at 5 % of final value
Turn-on overshoot	0,2 % maximum
Stability	0 % to 100 % load (all conditions)
Isolation	Output isolated from AC and chassis earth
System voltage	(24 ± 4 %) V
Output current	Up to 16 A
Surge current capability	10 % reserve capability
Agency ratings	Shall conform to local and national regulations
<sup>a</sup> Derating acceptable for 60 °C operation.	

**Table C.6 – Power supply tolerance stack up for DeviceNet**

Parameter	Specification
Initial power supply setting	1,00 %
Line regulation	0,30 %
Temperature coefficient <sup>a</sup>	0,60 % (total)
Time drift	1,05 %
Load regulation	0,30 %
Schottky diode drop (0,65 V nominal)	0,75 % (of 24 V)
<b>Total stack up</b>	<b>4 %</b>
<sup>a</sup> The temperature coefficient tolerance of 0,6 % is based on an actual rating of 0,03 % per °C and a 20 °C differential between supplies that are used on the same bus segment. If a supply in one location is in an ambient of 40 °C, it is assumed that other supplies are within 10 °C or in the range of 30 °C to 50 °C (or another 20 °C range). If this stipulation is not met, and all the other tolerances are just being met, then power capability will need to be derated.	

A power supply that is current limited as per the national and/or local regulations shall be used.

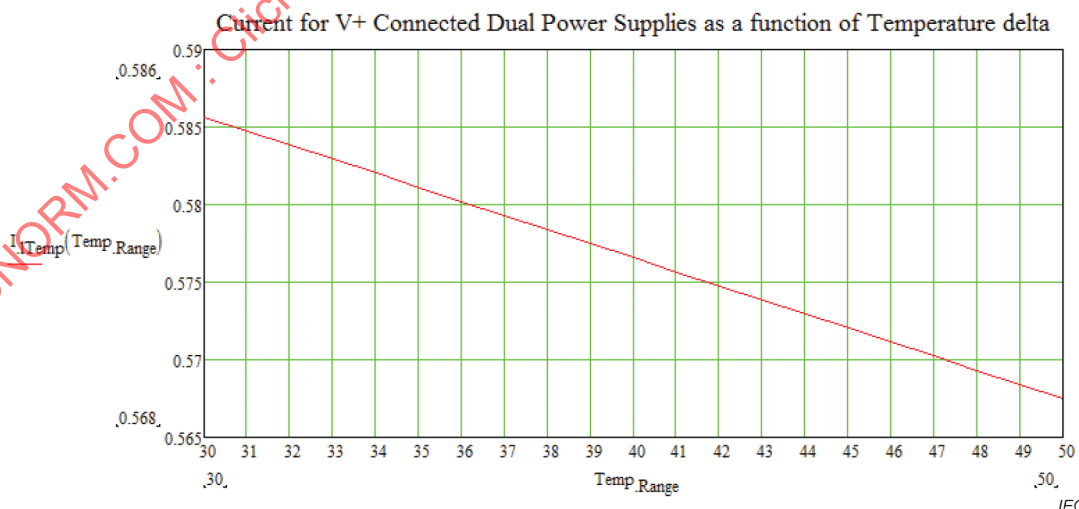
**C.4.3.2.5.3 Multiple Power Supplies in a continuous V+ network**

The voltage tolerances of the power supplies are important when they are common bus connected (continuous V+). The available current is reduced in a shared power bus network when there is a difference in the output voltages of the two power supplies.

The total current in a multiple shared power bus is a function of the following equation:

$$I_{total}(Trunk_{Len}) = \frac{(V_{low} + V_{cmm} - V_{high})}{\left[ (DCR_{contacts} \times NUM_{contacts} \times DCR_{cable@tempm}) \right]}$$

As the difference in  $V_{low}$  and  $V_{high}$  increases, the available current decreases. Figure C.11 shows the effects of the temperature differential between two V+ connected power supplies.



**Figure C.11 – Power Bus Current derate as a function of temperature differential**

When the power supply is supplied from an AC source, the DC output of all power supplies shall be isolated from the AC line and the power supply case (earthing connection).

The cable system requires the power supply to have a rise time of less than 250 ms to within 5 % of its rated output voltage under a load of 7 000  $\mu\text{F}$ .

The designer shall verify the following:

- the power supply has its own current limit protection;
- fuse protection is provided for each segment of the cable system – any section leading away from a power supply shall have protection;
- the power supply is sized correctly to provide each device with its required power;
- derate the supply for temperature using the manufacturer's guidelines.

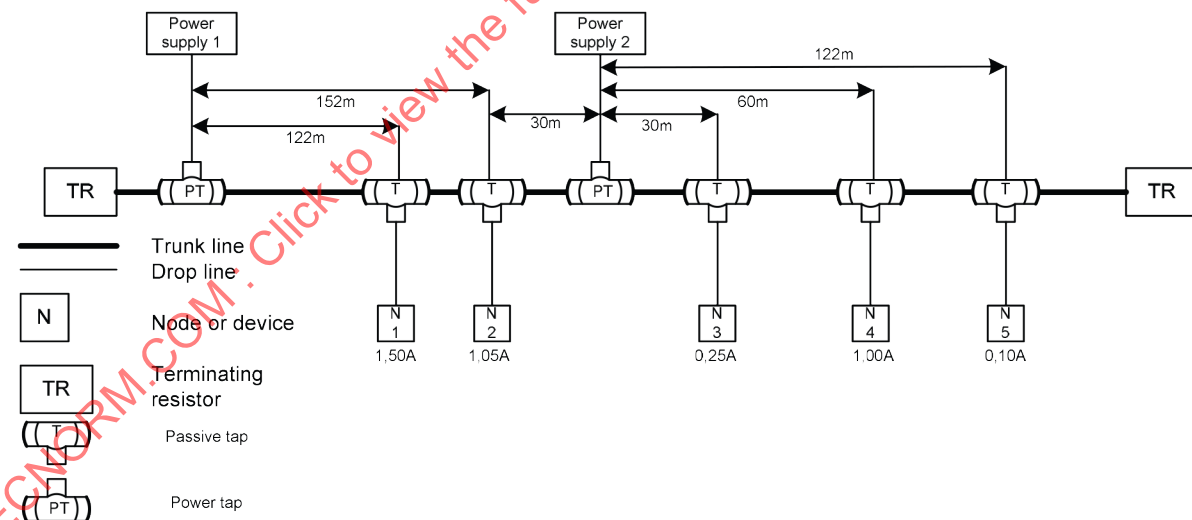
Some local regulations may not permit the full use of the power system capacity when installed as building wiring. The designer is strongly encouraged to consult national and local regulations for power restrictions. If local regulations restrict the power to levels less than needed to support the application, segmenting may be necessary (see Figure C.20).

#### C.4.3.2.5.4 Sizing the power supply

The maximum allowable current on the drop line applies to the sum of currents for all devices on the drop line regardless of physical placement on the drop line. The maximum allowable current is also limited by the voltage drop in the V+ and V- lines and the common mode offset voltage in the V-. The voltage across V+ and V- shall not drop below 11,0 V. Further, for common mode performance, the voltage drop in V- of the trunk line shall not exceed 4,65 V. The power supply placement can be optimized to reduce the common mode offset in a network.

#### EXAMPLE

The example in Figure C.12 will help to determine the minimum continuous current rating of a power supply servicing a common section. In this example the V+ line is cut between the tap for N2 and the power tap for power supply 2.



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**Figure C.12 – Power supply sizing example**

The following example calculations (a and b), derive the currents for power supply 1 and power supply 2, in reference to Figure C.12

- a) Power supply #1 current is equal to; Add each device's (N1, N2) DeviceNet current draw together for power supply #1 (1,5 A + 1,05 A = 2,55 A).

2,55 A is the minimum rating of power supply #1.

b) Power supply #2 current is equal to; Add each device's (N3, N4, N5) currents together for power supply #2 (0,25 A + 1,00 A + 0,10 A = 1,35 A).

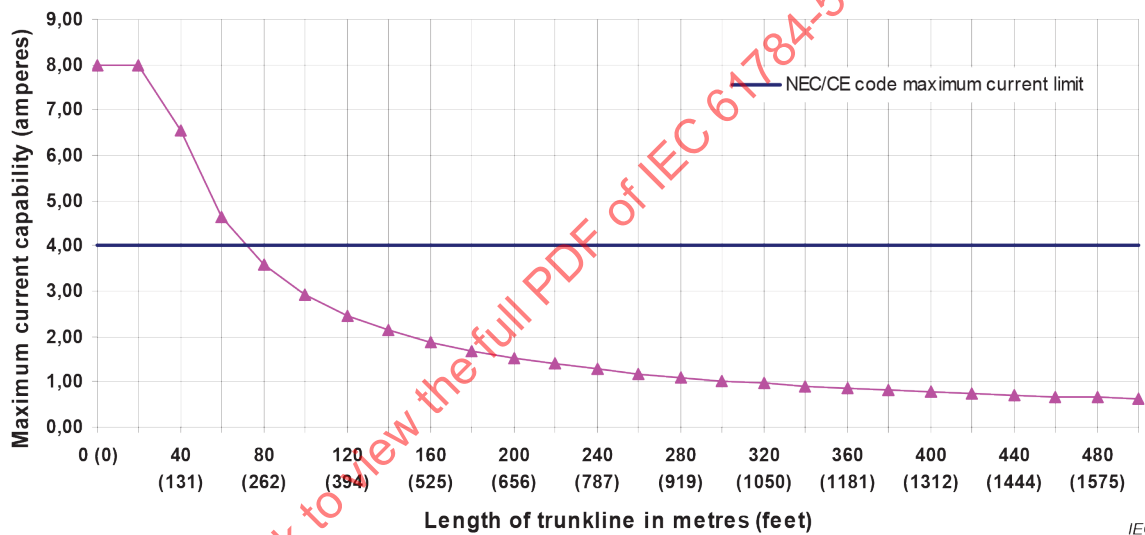
1,35 A is the minimum rating of power supply #2.

Reminder: Temperature derating requirements provided by the manufacturer shall be considered in the final calculations provided in the above Figure C.12 example.

**C.4.3.2.5.5 Examples of calculating network power**

Due to common mode offset limitations in the CAN transceiver (5,00 V) the voltage drop in V- between any two nodes is limited to 5,00 V. There are two factors that cause the voltage drop, DCR of the V- in the communications cabling and the current requirements of the devices. The voltage drop is partitioned as follows: 4,65 V in the trunk line and 0,35 V in the drop line. To work around this limitation, an additional power supply shall be added, or an existing power supply shall be moved closer to the larger current loads. In addition, the voltage between V+ and V- shall never fall below 11 V.

The graph specified in Figure C.13 and Table C.7 is an example of one power supply end connected using the look-up method.



NOTE It is assumed that all nodes are at the opposite end of the cable from the power supply.

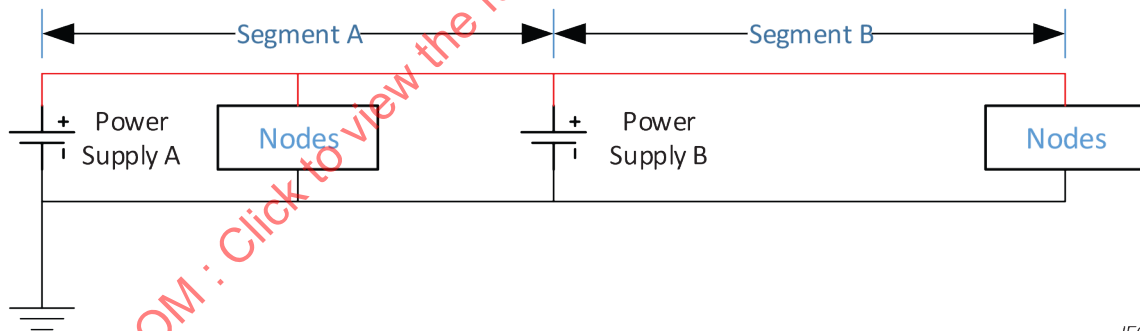
**Figure C.13 – Current limit for thick cable for one power supply**

**Table C.7 – Current versus cable length for one power supply thick cable**

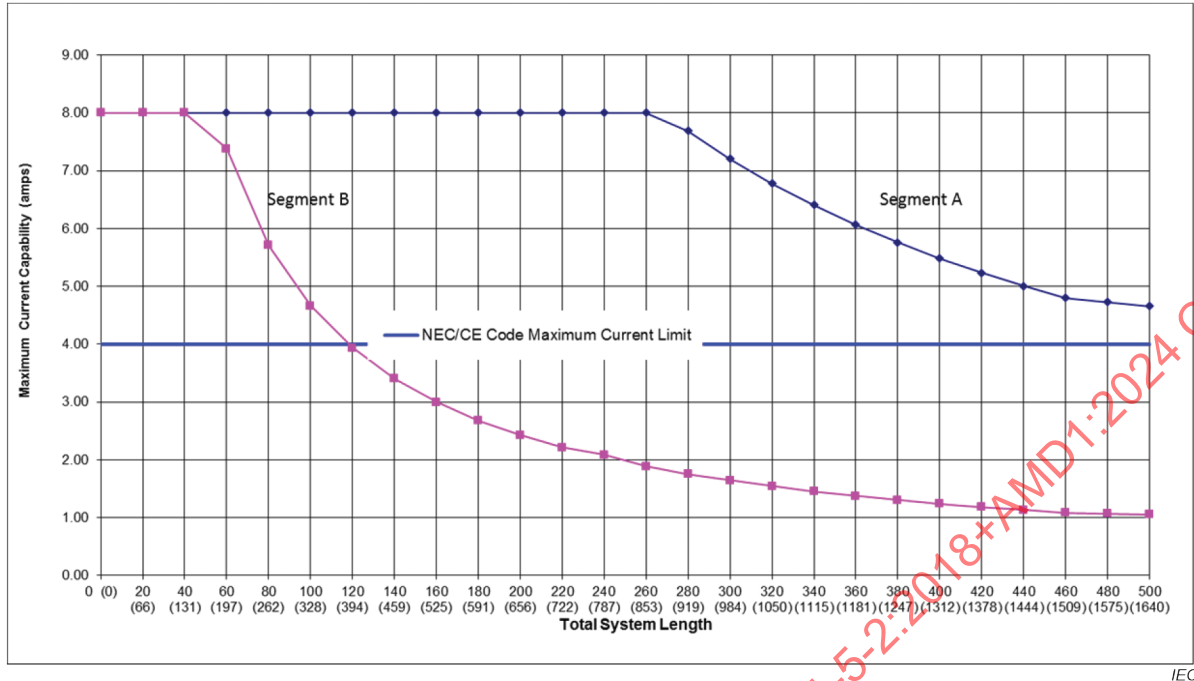
Network length m (ft.)	Maximum current A	Network length m (ft.)	Maximum current A
0 (0)	8,00	260 (853)	1,19
20 (66)	8,00	280 (919)	1,10
40 (131)	6,53	300 (984)	1,03
60 (197)	4,63	320 (1 050)	0,97
80 (262)	3,59	340 (1 115)	0,91
100 (328)	2,93	360 (1 181)	0,86
120 (394)	2,47	380 (1 247)	0,82
140 (459)	2,14	400 (1 312)	0,78
160 (525)	1,89	420 (1 378)	0,74
180 (591)	1,69	440 (1 444)	0,71
200 (656)	1,53	460 (1 509)	0,68
220 (722)	1,39	480 (1 575)	0,65
240 (787)	1,28	500 (1 640)	0,63

The graphs specified in Figure C.15 and Table C.8 are examples of current versus cable length for a two segment continuous V+.

The current requirements of Figure C.15 assume that there are two power supplies connected to a common V+. Power supply for Segment A is located at one end of the network and the second power supply is centred in the network. The nodes are at the centre of segment A and at the far end of segment B as detailed in Figure C.14.



**Figure C.14 – Example of a continuous power bus**



NEC and CE codes refer to National Electric Code and Canadian Electric Code used in some parts of North America. These limits impose power restrictions that shall be met by some cable constructions. The planner shall consult local codes for appropriate selection and application of cabling in installation.

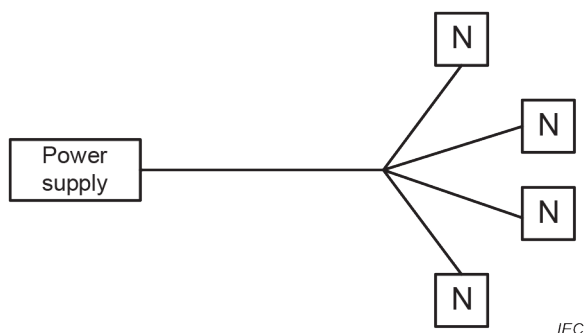
**Figure C.15 – Current limit for thick cable and two power supplies common V+**

**Table C.8 – Current versus length for two power supplies**

Power supply A, segment A				Power supply B, segment B			
Network length	Maximum current	Network length	Maximum current	Network length	Maximum current	Network length	Maximum current
m (ft)	A	m (ft)	A	m (ft)	A	m (ft)	A
0 (0)	8,00	260 (853)	8,00	0 (0)	8,00	260 (853)	1,89
20 (66)	8,00	280 (919)	7,69	20 (66)	8,00	280 (919)	1,76
40 (131)	8,00	300 (984)	7,21	40 (131)	8,00	300 (984)	1,64
60 (197)	8,00	320 (1 050)	6,78	60 (197)	7,38	320 (1 050)	1,54
80 (262)	8,00	340 (1 115)	6,41	80 (262)	5,71	340 (1 115)	1,46
100 (328)	8,00	360 (1 181)	6,07	100 (328)	4,66	360 (1 181)	1,38
120 (394)	8,00	380 (1 247)	5,76	120 (394)	3,94	380 (1 247)	1,31
140 (459)	8,00	400 (1 312)	5,49	140 (459)	3,40	400 (1 312)	1,24
160 (525)	8,00	420 (1 378)	5,24	160 (525)	3,00	420 (1 378)	1,18
180 (591)	8,00	440 (1 444)	5,01	180 (591)	2,68	440 (1 444)	1,13
200 (656)	8,00	460 (1 509)	4,80	200 (656)	2,43	460 (1 509)	1,08
220 (722)	8,00	480 (1 575)	4,73	220 (722)	2,22	480 (1 575)	1,07
240 (787)	8,00	500 (1 640)	4,66	240 (787)	2,08	500 (1 640)	1,05

To determine if there is adequate power for the devices in the cable system, the look-up method which is fully described here should be used. See the example in Figure C.16 and Figure C.17. There is enough power if the total load does not exceed the value shown by the curve in Figure C.15 or the values given in Table C.8.

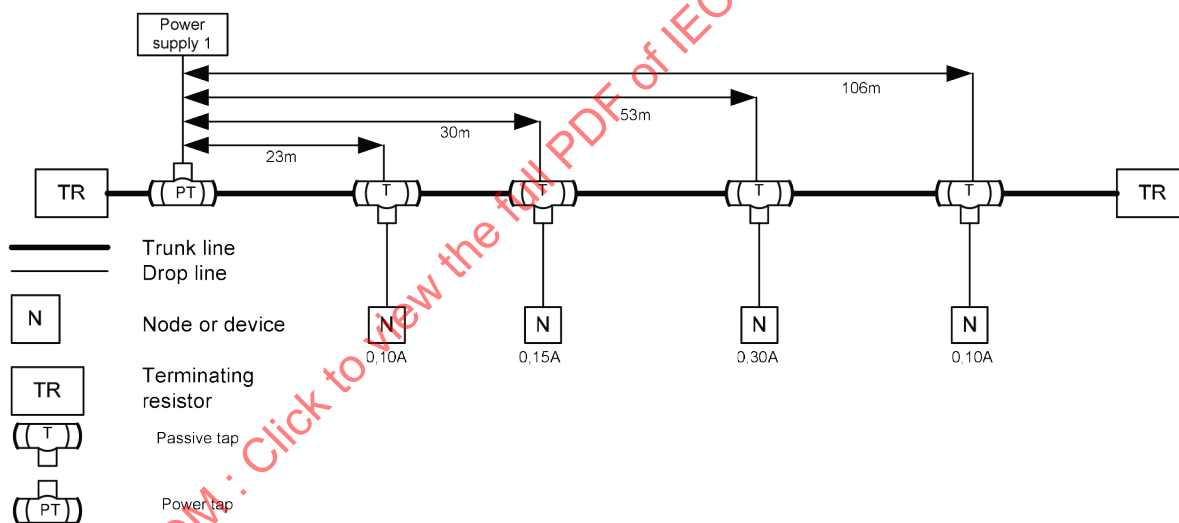
The worst-case scenario is when all of the nodes are together at one end of the cable and the power supply is at the opposite end (see Figure C.16), so all current flows over the longest distance of the trunk cable.



**Figure C.16 – Worst-case scenario**

Important: This method may underestimate the capacity of the network by as much as 4 to 1. See C.4.3.2.5.6 for the full calculation method if the current does not fit under the curve.

The following example uses the look-up method to determine the configuration for one end-connected power supply. One end connected power supply provides as much as 8 A near the power supply.



**Figure C.17 – Example using the lookup method**

a) Using the example in Figure C.17, the total length of the network is  
106 m

b) Add each device's current together to find the total current.  
 $0,10\text{ A} + 0,15\text{ A} + 0,30\text{ A} + 0,10\text{ A} = 0,65\text{ A}$

Important: Make sure that the required power is less than the rating of the power supply. Power supply derating may be necessary if it is in an enclosure or at elevated temperature.

c) Find the next largest network length using the values given in Table C.7 to determine the maximum current for thick round trunk cable allowed for the system (approximately).  
120 m (2,47 A)

Since the total current does not exceed the maximum allowable current, the system will operate properly (0,65 A is less than 2,47 A).

Important: If the application does not fit "under the curve" it will be necessary to either perform:

- the full-calculation method described later or;
- move the power supply to somewhere in the middle of the cable system and re-evaluate as per the previous procedure.

**C.4.3.2.5.6 Full-calculation method**

Use the full-calculation method if initial evaluation indicates that one section is overloaded or if the requirements of the configuration cannot be met by using the look-up method.

Important: Before construction of the cable system, repeat all calculations to avoid errors.

A supply that is not end-connected creates two sections of trunk line. Evaluate each section independently.

Use the following equation and Table C.9 to determine if the voltage drop for V- is within the specification limit of  $\leq 4,65$  V (trunk).

$$\text{Sum}\{[(L_n \times R_c) + (N_t \times 0,005)] \times I_n\} \leq 4,65 \text{ V}$$

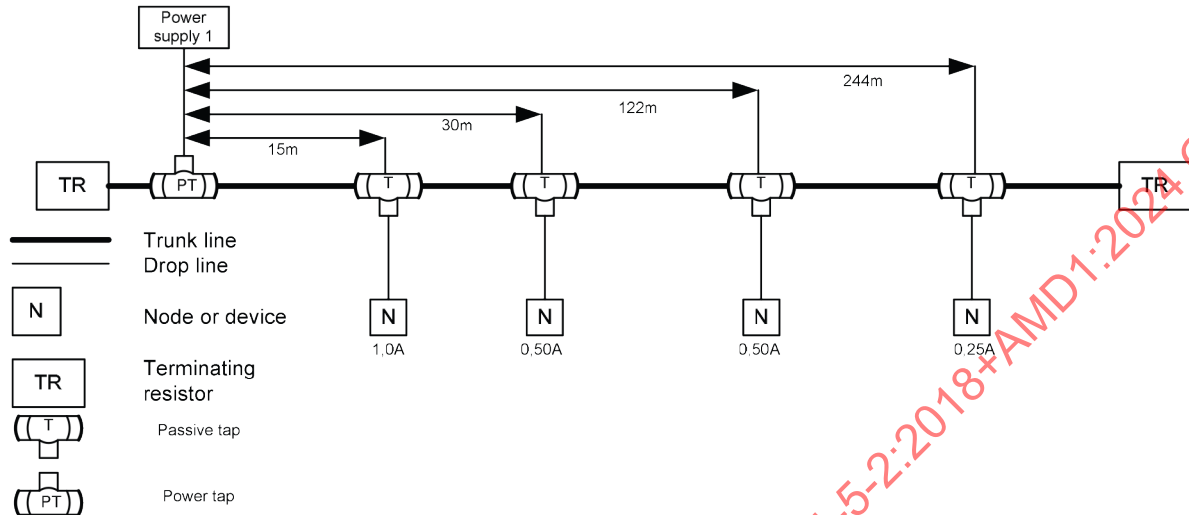
**Table C.9 – Definition of equation variables**

Term	Definition
$L_n$	$L$ = the distance (m) between the device and the power supply, excluding the drop line distance  $n$ = the number of a device being evaluated, starting with one for the device closest to the power supply and increasing by one for the next device. The equation sums the calculated drop for each device and compares it to 4,65 V
$R_c$	Thick cable --- 0,015 $\Omega$ /m Cable Type I --- 0,023 $\Omega$ /m Thin cable --- 0,069 $\Omega$ /m Flat cable --- 0,019 $\Omega$ /m
$N_t$	The number of taps between the device being evaluated and the power supply. For example: When a device is the first one closest to the power supply, this number is 1. When a device has one device between it and the power supply, this number is 2. When 10 devices exist between the evaluated device and the power supply, this number is 11.  For devices attached to a multi-port tap, treat the tap as one tap. The current for all devices attached to one of these taps shall be summed and used with the equation only once. For flat cable, $N_t = 1 +$ twice the number of intermediate splice kits.
0,005	The nominal contact resistance used for every connection to the trunk line
$I_n$	$I$ = the current drawn from the cable system by the device. For current within 90 % of the maximum, use the nominal device current. Otherwise, use the maximum rated current of the device. For multiport taps, sum the currents of all the attached devices, and count the tap as one tap  $n$ = the number of a device being evaluated, starting with one for the device closest to the power supply and increasing by one for the next device
4,65 V	The maximum voltage drop allowed on the DeviceNet trunk line in V- line. This is the total cable system (V-) voltage drop of 5,00 V minus 0,35 V reserved for the drop line voltage drop

**C.4.3.2.5.7 Example of one power supply (end-connected) using thick cable**

The example in Figure C.18 uses the full-calculation method to determine the configuration for one end-connected power supply on a thick cable trunk line:

- Device 1 and Device 2 cause the same voltage drop but Device 2 is twice as far from the power supply and draws half as much current.
- Device 4 draws the least amount of current but it is furthest from the power supply and causes the greatest incremental voltage drop.



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**Figure C.18 – One power supply end connected**

a) Find the voltages for each device using the equation for thick cable.

$$\text{SUM} \{ [(L_n \times 0,015) + (N_t \times 0,005)] \times I_n \} \leq 4,65 \text{ V.}$$

**A.**  $[(15 \times 0,015) + (1 \times 0,005)] \times 1,00 = 0,23 \text{ V}$

**B.**  $[(30 \times 0,015) + (2 \times 0,005)] \times 0,50 = 0,23 \text{ V}$

**C.**  $[(122 \times 0,015) + (3 \times 0,005)] \times 0,50 = 0,91 \text{ V}$

**D.**  $[(244 \times 0,015) + (4 \times 0,005)] \times 0,25 = 0,91 \text{ V}$

b) Add each device's voltage together to find the total voltage.

$$0,23 \text{ V} + 0,23 \text{ V} + 0,91 \text{ V} + 0,91 \text{ V} = 2,28 \text{ V}$$

Since the total voltage does not exceed 4,65 V, the system will operate properly (2,28 V < 4,65 V).

The percent loading is found by dividing the total voltage by 4,65 V.

$$\% \text{Loading} = \frac{2,28}{4,65} = 49 \%$$

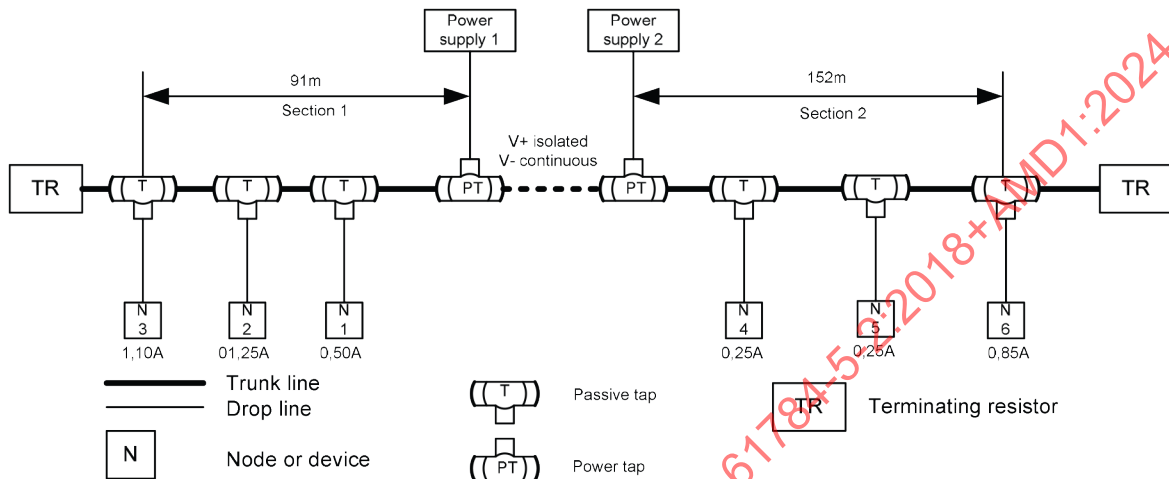
In some cases the network power will need to be segmented. Segmenting the network power requires cutting the V+ line to separate the power supplies. V- shall be continuous throughout the network. The power calculation for segmented power is the same as for single power supplies.

**C.4.3.2.5.8 Adjusting the power configuration**

To make the system operational, the designer can do one or more of the following:

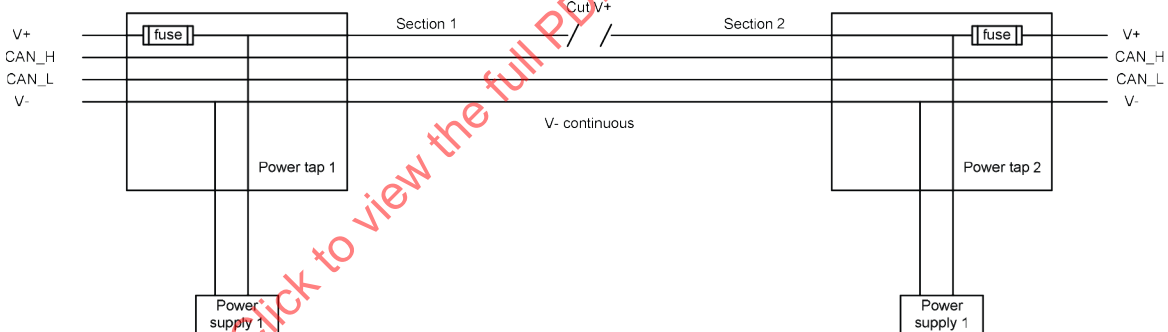
- move the power supply in the direction of the overloaded section;
- move higher current loads as close to the supply as possible;
- move devices from the overloaded section to another section;

- shorten the overall length of the cable system;
- perform the full-calculation method for the segment described in C.4.3.2.5.7 for the non-operational section;
- add a second power supply to the cable system as shown in the following example. Figure C.19 and Figure C.20 show how to segment the power bus to add an additional power supply. This example has the two power supplies in the centre of the network, which is convenient for power mains connection and reducing the number of enclosures needed.



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Figure C.19 – Segmenting power in the power bus



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Figure C.20 – Segmenting the power bus using power taps

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

**C.4.4 Selection and use of cabling components**

**C.4.4.1 Cable selection**

**C.4.4.1.1 Common description**

**C.4.4.1.2 Copper cables**

**C.4.4.1.2.1 Balanced cables for Ethernet-based CPs**

Not applicable.

**C.4.4.1.2.2 Copper cables for non-Ethernet-based CPs***Replacement:*

Table C.10 and Table C.11 provide values based on the template given in IEC 61918:2018, Table 4 and Table 5.

**Table C.10 – Information relevant to copper cable: fixed cables**

Characteristic	CP 2/3
Nominal impedance of cable (tolerance)	(120 ± 10 %) Ω
Balanced or unbalanced	Balanced
DCR of conductors	See Table C.13
DCR of shield	See Table C.13
Number of conductors	4 minimum, 5 with shield
Shielding	As needed (see Table C.13)
Colour code for conductor	Data WH & BU, Power RD & BK
Jacket colour requirements	User defined
Jacket material	To comply with local regulations and application/environment
Resistance to harsh environment (e.g.: UV, oil resist, LS0H)	Application dependent
Agency ratings	As required by local regulations

**Table C.11 – Information relevant to copper cable: cords**

Characteristic	CP 2/3
Nominal impedance of cable (tolerance)	(120 ± 10 %) Ω
Balanced or unbalanced	Balanced
DCR of conductors	See Table C.13
DCR of shield	See Table C.13
Number of conductors	4 minimum, 5 with shield
Length	See Table C.13
Shielding	See Table C.13
Colour code for conductor	Data WH & BU, Power RD & BK
Jacket colour requirements	User defined
Jacket material	To comply with local regulations and application/environment
Resistance to harsh environment (e.g.: UV, oil resist, LS0H)	Application dependent
Agency ratings	As required by local regulations

*Addition:*

The cables in Table C.12 are approved for DeviceNet networks. Table C.12 also provides connector compatibility and trunk lengths for each cable profile.

**Table C.12 – DeviceNet cables and connector support cross reference**

Parameter	Cable profiles									
	Thick	Thin	Flat	Flat II	Cable I	Cable II	Cable III	Cable IV	Cable V	Cable VI
Cable geometry	Round	Round	Flat	Flat	Round	Round	Round	Round	Round	Round
Number of conductors	4+1	4+1	4	4	4+1	4+1	4+1	4	4+1	4+1
Shielded	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes
<b>Max. trunk length (m)</b>										
125 kbit/s	500	100	420	265	100	500	300	0	420	75
250 kbit/s	250	100	200	150	100	250	250	0	200	66
500 kbit/s	100	100	75	75	100	100	100	0	75	50
Maximum current (A)	8	3	8	5	3	8	1,5	8	8	2,3
<b>Connector support</b>										
M8	No	No	No	No	No	No	No	No	No	Yes
M12	No	Yes	No	No	Yes	No	Yes	See NOTE	No	Yes
Mini	Yes	Yes	No	No	Yes	Yes	Yes	See NOTE	Yes	No
Open-style	Yes	Yes	No	No	Yes	Yes	Yes	See NOTE	Yes	Yes
Flat IDC	No	No	Yes	No	No	No	No	See NOTE	No	No
Flat IDC Type II	No	No	No	Yes	No	No	No	No	No	No
NOTE Connector support is vendor specific.										

**Addition:**

DeviceNet cables shall meet the following specifications. Table C.13 provides specifications for the three most common cable profiles.

NOTE See volume 3 of the ODVA specifications ([32]<sup>9</sup>) for other cable specifications.

<sup>9</sup> Numbers in square brackets refer to the Bibliography.

Table C.13 – DeviceNet cable profiles

	Cable profile		
	Thick	Thin	Flat
<b>Data pair</b>			
<b>Physical characteristics</b>	<b>Specification</b>		
Conductor pair size	18 AWG or 0,82 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	24 AWG or 0,20 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	16 AWG or 1,3 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)
Insulation diameter	3,8 mm (nominal)	120 mm (nominal)	2,8 mm (nominal)
Colours	LT BU/WH	LT BU/WH	LT BU/WH
Pair twist/m	9,8 (approximately)	16,4 (approximately)	–
Tape shield over pair	0,05 mm/0,025 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	0,025 mm/0,025 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	–
<b>Electrical characteristics</b>	<b>Specification</b>		
Impedance	(120 ± 10 %) Ω (at 1 MHz)	(120 ± 10 %) Ω (at 1 MHz)	(120 ± 10 %) Ω (at 500 kHz)
Propagation delay	4,46 ns/m (maximum)	4,46 ns/m (maximum)	5,25 ns/m (maximum)
Capacitance between conductors	39,37 pF/m at 1 kHz (nominal)	39,37 pF/m at 1 kHz (nominal)	48,23 pF/m at 500 kHz (maximum)
Capacitance between one conductor and other conductors connected to shield.	78,74 pF/m at 1 kHz (nominal)	78,74 pF/m at 1 kHz (nominal)	–
Capacitive unbalance	3 937 pF/ 1 000 m at 1 kHz (nominal)	3 937 pF/ 1 000 m at 1 kHz (nominal)	3 937 pF/ 1 000 m at 500 kHz (maximum) ASTM D4566-08e1
DCR at 20 °C	22,60 Ω /1 000 m (maximum)	91,9 Ω /1 000 m (maximum)	16,1 Ω /1 000 m (maximum)
Attenuation	0,43 dB/100 m at 125 kHz (maximum) 0,82 dB/100 m at 500 kHz (maximum) 1,31 dB/100 m at 1,00 MHz (maximum)	0,95 dB/100 m at 125 kHz (maximum) 1,64 dB/100 m at 500 kHz (maximum) 2,3 dB/100 m at 1,00 MHz (maximum)	0,43 dB/100 m at 125 kHz (maximum) 0,82 dB/100 m at 250 kHz (maximum) 1,31 dB/100 m at 500 kHz (maximum)
<b>Power pair</b>			
<b>Physical characteristics</b>	<b>Specification</b>		
Conductor pair size	15 AWG or 1,65 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	22 AWG or 0,33 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	16 AWG or 1,3 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)
Insulation diameter	2,5 mm (nominal)	1,4 mm (nominal)	2,8 mm (nominal)
Colours	Red, black	Red, black	Red, black
Pair twist/m	9,8 approximately	16,4 approximately	–
Tape shield over pair	0,025 mm/0,025 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	0,025 mm/0,025 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	–
<b>Electrical characteristics</b>	<b>Specification</b>		
DCR at 20 °C	11,81 Ω /1 000 m (maximum)	57,4 Ω /1 000 m (maximum)	16,1 Ω /1 000 m (maximum)
Allowable current	8 Amps	3 Amps	8 Amps

	Cable profile		
	Thick	Thin	Flat
<b>General specifications</b>			
<b>Physical characteristics</b>	<b>Specification</b>		
Geometry	Two shielded pairs, common axis with drain wire in centre	Two shielded pairs, common axis with drain wire in centre	–
Overall braid shield	65 % coverage 36 AWG or 0,012 mm <sup>2</sup> tinned Cu braid minimum (individually tinned)	65 % coverage 36 AWG or 0,012 mm <sup>2</sup> tinned Cu braid minimum (individually tinned)	–
Drain wire	18 AWG or 0,82 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	22 AWG or 0,33 mm <sup>2</sup> copper 19 strands minimum (individually tinned)	–
Outside diameter	10,4 mm (minimum) to 12,4 mm (maximum)	6,1 mm (minimum) to 7,1 mm (maximum)	See Figure C.24
Roundness	Radius delta to be within 15 % of 0,5 outer diameter	Radius delta to be within 20 % of 0,5 outer diameter	–
Jacket marking	Vendor name and part #, and additional markings	Vendor name and part # and additional markings	Vendor name and part # and additional markings
<b>Electrical characteristics</b>	<b>Specification</b>		
DCR (braid+tape+drain)	5,74 Ω /1 000 m (nom. at 20 °C)	10,5 Ω /1 000 m (nom. at 20 °C)	–
<b>Applicable environmental characteristics</b>	<b>Specification</b>		
Agency certifications (U.S. and Canada)	NEC (UL) type, CL2/CL3 (minimum)	NEC (UL) type CL2 (minimum)	NEC (UL) type CL2 (minimum)
Flexure	2 000 cycles at bend radius, 90°, 8,9 N pull force, 15 cycles per minute, tic-toc or rolling "C" track method	2 000 cycles at bend radius, 90°, 8,9 N pull force, 15 cycles per minute, tic-toc or rolling "C" track method	1,0 Mcycles at bend radius, 1,83 m minimum length, 15 cycles per minute, rolling "C" track method
Bend radius	Vendor specified	Vendor specified	10× thickness (fixed)
Operating ambient temperature	–20 °C to +60 °C at 8 A; derate current linearly to zero at 80 °C	–20 °C to +70 °C at 1,5 A; derate current linearly to zero at 80 °C	–25 °C to +75 °C at 8 A; derate current linearly to zero at 80 °C
Storage temperature	–40 °C to +85 °C	–40 °C to +85 °C	–40 °C to +85 °C
Pull tension	800 N maximum	280 N maximum	390 N maximum
Connector compatibility	Mini, open	Mini, micro, open	Flat
Topology compatibility	Trunk, drop	Trunk, drop	Trunk

**C.4.4.1.3 Cables for wireless installation**

**C.4.4.1.4 Optical fibre cables**

Not applicable.

**C.4.4.1.5 Special purpose balanced copper and optical fibre cables**

*Addition:*

Data communications and power bus cables that are part of hybrid cables shall comply with one of the profiles in Table C.13. Cable constructions that provide high flex performance and special chemical resistivity, oil resistant and UV shall comply with one or more of the profiles in Table C.13 and related material standards.

#### C.4.4.1.6 Specific requirements for CPs

Not applicable.

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

#### C.4.4.2 Connecting hardware selection

##### C.4.4.2.1 Common description

##### C.4.4.2.2 Connecting hardware for balanced cabling CPs based on Ethernet

Not applicable.

##### C.4.4.2.3 Connecting hardware for copper cabling CPs not based on Ethernet

*Modification:*

Table C.14 provides values based on the template given in IEC 61918:2018, Table 8.

**Table C.14 – Copper connectors for non-Ethernet based fieldbus**

	IEC 60807-2 or IEC 60807-3	IEC 610762-101			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
CP 2/3	No	Yes	No	No	No	Yes	Yes	Yes	Yes	See Table C.15

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.

*Addition:*

Table C.15 is an extension of Table C.14 that provides a list of available connectors for DeviceNet networks.

**Table C.15 – Additional connectors for CP 2/3 (DeviceNet)**

Connector	M8-5 B-coding	M12-5 A-coding	Mini 7/8-16 UN-2B THD / M18	Open	Flat
Standard	IEC 61076-2-104:2014 Figure 18 19	IEC 60947-5-2:2007, Figure D.2	ANSI/(NFPA) T3.5.29 R1-2007	ODVA (see [32])	ODVA (see [32])
Contacts	5	5	5	5	4
Current (A)	3	3	8	8	8
Sealed	Yes	Yes	Yes	No	Yes

**C.4.4.2.4 Connecting hardware for wireless installation**

**C.4.4.2.5 Connecting hardware for optical fibre cabling**

Not applicable.

**C.4.4.2.6 Specific requirements for CPs**

Not applicable.

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

**C.4.4.3 Connections within a channel/permanent link**

**C.4.4.3.1 Common description**

Not applicable.

**C.4.4.3.2 Balanced cabling connections and splices for CPs based on Ethernet**

Not applicable.

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

*Replacement:*

128 mated pairs in a trunk segment are allowed: this includes bulkheads and taps.

Copper splices are not allowed. All connections shall be made at a connection or on suitable terminal blocks.

Bulkhead connectors may be used as needed to provide modularity.

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

Not applicable.

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

Not applicable.

**C.4.4.3.6 Specification requirements for generic cabling in accordance with ISO/IEC 11801-3**

**C.4.4.4 Terminators**

**C.4.4.4.1 Common description**

**C.4.4.4.2 Specific requirements for CPs**

*Addition:*

The trunk line shall be terminated at each end of the network into its characteristic impedance of 121  $\Omega$ . The terminator can be an integral part of a plug or a resistor. The terminator shall conform to the values below:

- Value: 121  $\Omega$ ;
- Tolerance:  $\pm 1$  %;

- Power rating: ¼ W.

Physical: recommended axial lead or embedded in mini or micro connectors.

Terminators shall be placed across the data pair (white and blue) only. Terminators shall not be located inside an active device.

Copper splices are not allowed. All connections shall be made at a connector or on suitable terminal blocks.

#### **C.4.4.4.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **C.4.4.5 Device location and connection**

##### **C.4.4.5.1 Common description**

##### **C.4.4.5.2 Specific requirements for CPs**

*Addition:*

Devices shall be installed in accordance with the following:

- manufacturer's documentation;
- planner's documentation;
- cable routing.

##### **C.4.4.5.3 Specific requirements for wireless installation**

Not applicable.

#### **C.4.4.5.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **C.4.4.6 Coding and labelling**

#### **C.4.4.7 Earthing and bonding of equipment and devices and shielded cabling**

##### **C.4.4.7.1 Common description**

##### **C.4.4.7.2 Bonding and earthing of enclosures and pathways**

##### **C.4.4.7.2.1 Equalization and earthing conductor sizing and length**

*Addition:*

If the building does not have an adequate equipotential earthing system, then the star earthing method shall be used to mitigate earth potential offsets in the communications coverage area.

##### **C.4.4.7.2.2 Bonding straps and sizing**

*Modification:*

Equipotential bonding conductors should preferably be constructed of copper. Aluminium and steel constructions are not recommended for communications bonding straps.

Bonding plates and bus bars should preferably be of copper construction. Tin or zinc coating may be used to reduce corrosion. The plating minimum thickness shall be as detailed in IEC 61918:2018, Table 15 and Table 16.

**C.4.4.7.3 Earthing methods**

**C.4.4.7.3.1 Equipotential**

**C.4.4.7.3.2 Star**

**C.4.4.7.3.3 Earthing of equipment (device)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions.

The earthing of equipment shall not cause direct earthing of the shielded communications cable.

**C.4.4.7.3.4 Copper bus bars**

**C.4.4.7.4 Shield earthing**

**C.4.4.7.4.1 Non-earthing or parallel RC**

**C.4.4.7.4.2 Direct**

Not applicable.

**C.4.4.7.4.3 Derivatives of direct and parallel RC**

*Addition:*

DeviceNet shall be earthed at one location in the network only. This location is recommended to be at the power supply or power tap where the power supply connects to the trunk. In addition the V- is earthed at this location. This location shall provide an earth connection for the communications cable shield. Devices shall not connect V- or the shield directly to earth. Devices may connect the shield to earth through a 1 M $\Omega$  resistor in parallel with a 0,01  $\mu$ F capacitor or float the shield. The flat trunk cabling system has no shield, therefore it provides no earthing for devices.

**C.4.4.7.5 Specific requirements for CPs**

*Addition:*

DeviceNet V- and the communications shield may be earthed. To prevent noise loops when earthed, earthing shall only be at one location in the network. This location should be at the power supply or power tap, where the power supply connects to the trunk. If local standards require additional earthing of the shield, then it is mandatory that the earthing and bonding system in the communications coverage area provide equipotential earthing characteristics as described in IEC 61918:2018, 4.4.7.2.1, or a suitable star earthing system be installed as described in IEC 61918:2018, 4.4.7.2.2.

**C.4.4.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****C.4.4.8 Storage and transportation of cables****C.4.4.9 Routing of cables****C.4.4.9.1 Common description****C.4.4.9.2 Cable routing of assemblies****C.4.4.9.3 Requirements for cable routing inside enclosures****C.4.4.9.4 Cable routing inside buildings****C.4.4.9.5 Cable routing outside and between buildings****C.4.4.9.6 Installing redundant communication cables**

Not applicable.

**C.4.4.10 Separation of circuits****C.4.4.11 Mechanical protection of cabling components****C.4.4.11.1 Common description****C.4.4.11.2 Specific requirements for CPs**

Not applicable.

**C.4.4.11.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****C.4.4.12 Installation in special areas****C.4.4.12.1 Common description****C.4.4.12.2 Specific requirements for CPs**

*Addition:*

The cabling components shall be selected based on the environmental and application requirements. Highflex applications shall use cables designed to meet high flex. Cables expected to be subjected to weld splatter shall have the appropriate protection or jacket designs. Cables used in outdoor applications shall have the appropriate UV protection or jacketing design.

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

**C.4.5 Cabling planning documentation**

**C.4.6 Verification of cabling planning specification**

**C.5 Installation implementation**

**C.5.1 General requirements**

**C.5.1.1 Common description**

**C.5.1.2 Installations of CPs**

**C.5.1.3 Installation of generic cabling in industrial premises**

**C.5.2 Cable installation**

**C.5.2.1 General requirements for all cabling types**

**C.5.2.1.1 Storage and installation**

**C.5.2.1.2 Protecting communications cables against potential damage**

*Replacement:*

Table C.16 provides values based on the template given in IEC 61918:2018, Table 18.

**Table C.16 – Parameters for balanced cables**

Characteristic		Value
<b>Mechanical force</b>	Minimum bending radius, single bending (mm)	See Table C.13
	Bending radius, multiple bending (mm)	See Table C.13
	Pull forces (N)	840
	Permanent tensile forces (N)	–
	Maximum lateral forces (N)	–
	Temperature range during installation (°C)	20 to 60

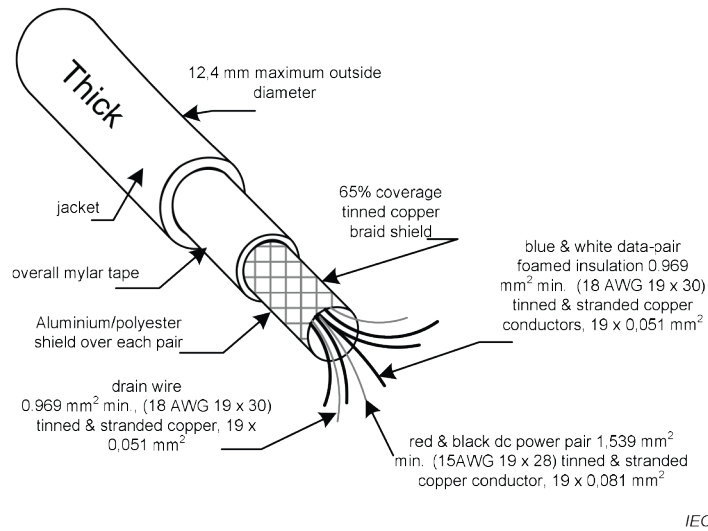
Tables 19 and 20 of IEC 61918:2018 are not applicable.

**C.5.2.2 Installation and routing**

**C.5.2.3 Specific requirements for CPs**

*Addition:*

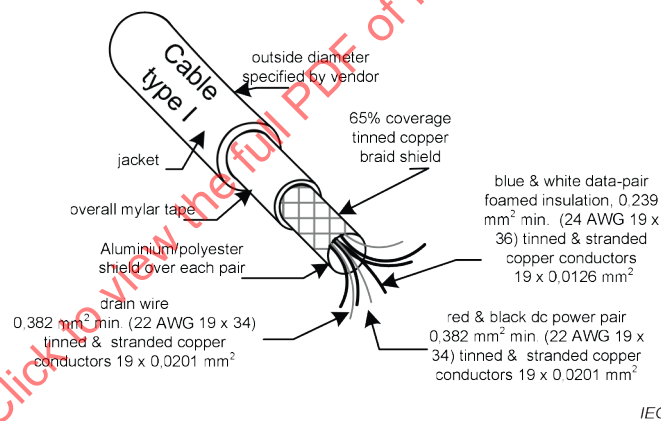
Thick cable is generally used as the trunk line on the DeviceNet network. Thick cable can also be used for drop lines. The cable construction is detailed in Figure C.21.



NOTE The mm<sup>2</sup> wire sizes in this and similar drawings are for information only. The wires are specified in AWG sizes.

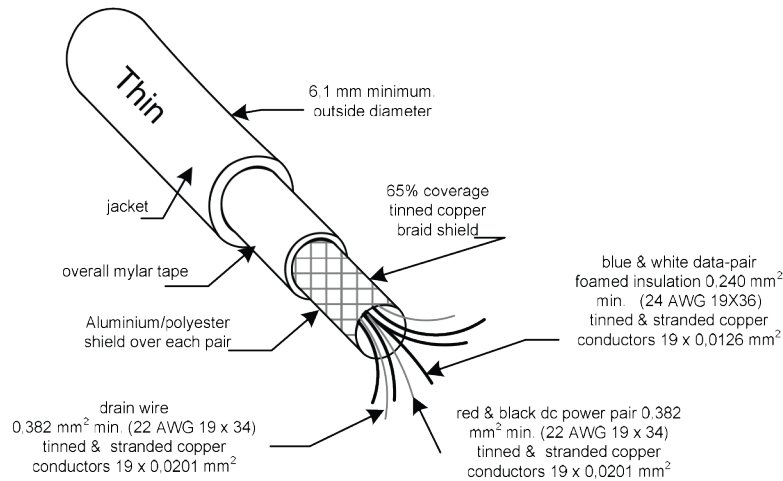
**Figure C.21 – Thick cable construction**

Cable Type I, with an outside diameter specified by the vendor, connects devices to the DeviceNet trunk line via taps. Cable Type I can be used for trunk lines and drop lines. The construction of the Cable Type I is detailed in Figure C.22.



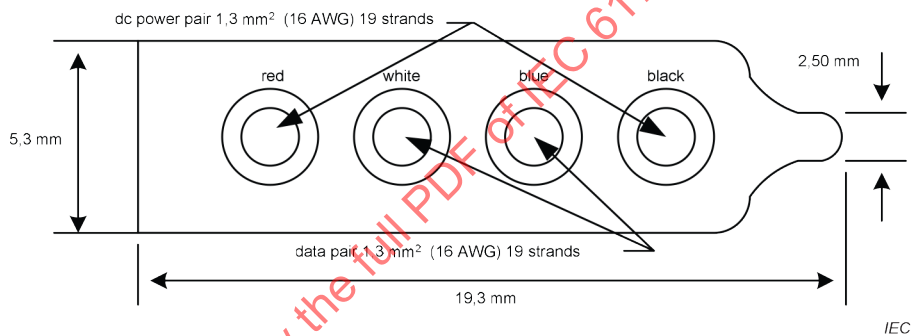
**Figure C.22 – Cable Type I construction**

Thin cable, with an outside diameter of 6,1 mm minimum, connects devices to the DeviceNet trunk line via taps. Thin cable can be used for trunk lines and drop lines. The construction of the thin cable is detailed in Figure C.23.



**Figure C.23 – Thin cable construction**

Flat cable is physically keyed to prevent wiring mishaps. Flat cable is unshielded and contains four parallel conductors. Flat cable is usually used only for the trunk line. The flat cable construction is detailed in Figure C.24.



**Figure C.24 – Flat cable construction**

It is common practice to use a special flat cable to power output, e.g. valves, actuators or indicators. This cable is called the auxiliary power cable. It is typically distinguished from the DeviceNet by the jacket colour; typically black for auxiliary power, typically grey for DeviceNet trunk.

**C.5.2.4 Specific requirements for wireless installation**

Not applicable.

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

**C.5.3 Connector installation**

**C.5.3.1 Common description**

**C.5.3.2 Shielded connectors**

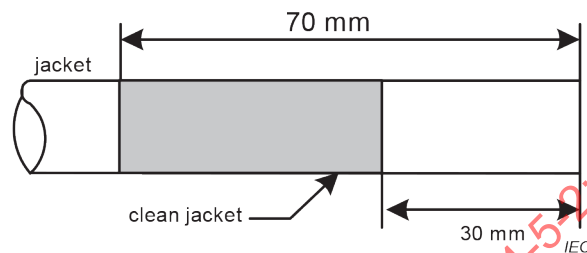
*Replacement:*

The following steps are required to install shielded connectors on round cables.

Trim the end of the cable segment to be terminated. The positions of the colour-coded conductors shall match the position at the face of the connectors. The M8 and M12 connector families are only suitable for installation onto the DeviceNet thin cables.

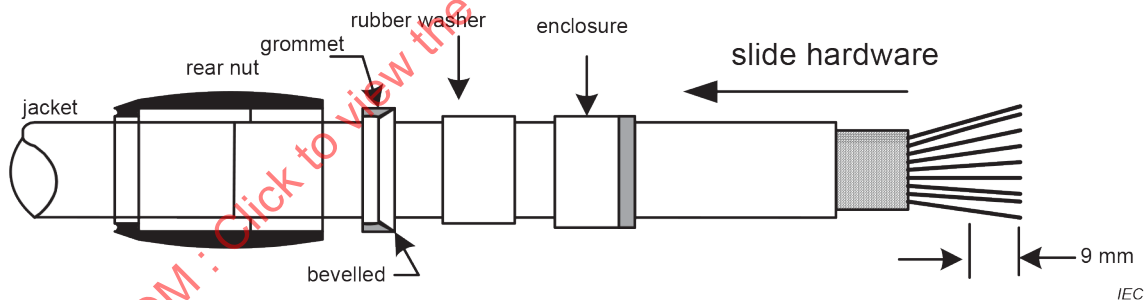
Before beginning, make sure that

- the DeviceNet cable system is inactive and all attached devices are turned off;
  - the power supply is turned off;
  - the manufacturer's instruction for stripping, crimping, and/or tightening are followed.
- a) Prepare the cable jacket by cleaning loose particles from the jacket as shown in Figure C.25.



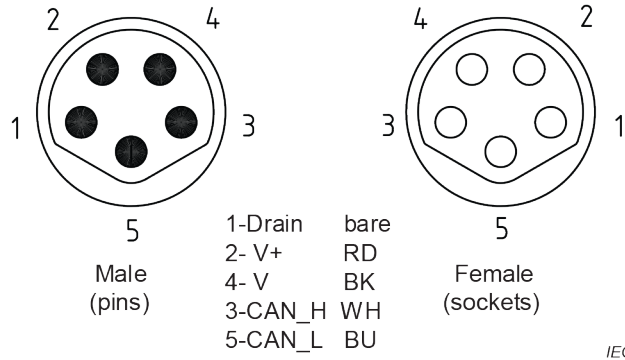
**Figure C.25 – Cable preparation**

- b) Strip 30 mm of the cable jacket from the end of the cable.
- c) Cut the braided shield and the foil shields surrounding the power and signal conductors.
- d) Trim the conductors to the same length.
- e) Slide the connector hardware onto the cable in the order shown in Figure C.26.

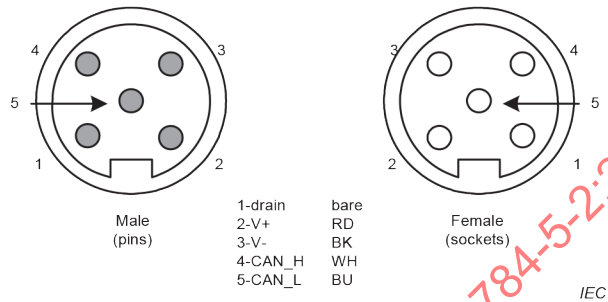


**Figure C.26 – Connector assembly**

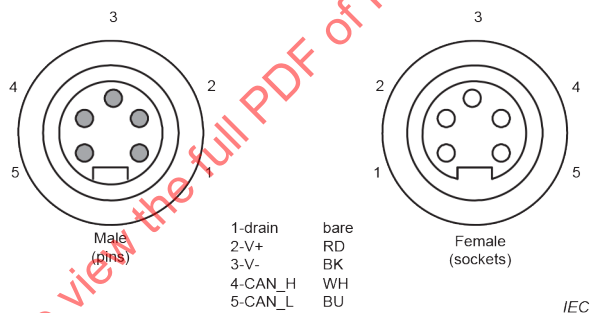
- f) Strip 9 mm of the insulation from the ends of all conductors except the bare drain wire.
- g) Tin the last 6,5 mm of the bare conductors or crimp a suitable ferrule on the conductors.
- h) Attach the wires to the connector using screw terminals as shown in the wiring diagrams in Figure C.27, Figure C.28 and Figure C.29.
- i) Attach the shield drain wire to the connector.



**Figure C.27 – M8 connector pin assignment**



**Figure C.28 – M12 connector pin assignment**



**Figure C.29 – Mini connector pin assignment**

- j) Screw the enclosure body to the connector.
- k) Screw the rear nut into the connector enclosure.

Important: Do not twist or pull the cable while tightening the rear nut.

### C.5.3.3 Unshielded connectors

#### Replacement:

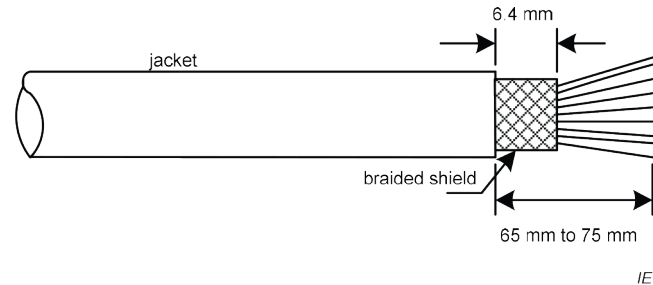
Trim the end of the cable segment to be terminated. The positions of the colour-coded conductors shall match the position at the face of the connectors.

Before beginning, make sure that

- the DeviceNet cable system is inactive and all attached devices are turned off;
- the power supply is turned off;
- the manufacturer's instruction for stripping, crimping, and/or tightening are followed.

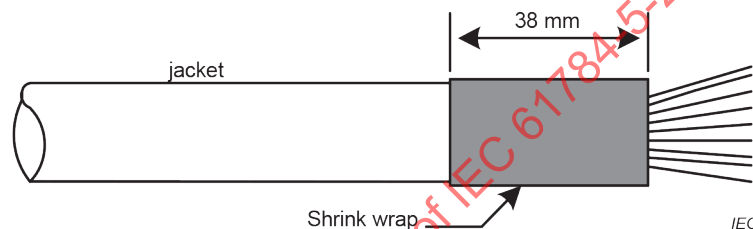
To attach a plug-in open-style connector to a round media (thick, Type I, or thin) trunk line, do the following.

- a) As detailed in Figure C.30, strip 65 mm to 75 mm of the outer jacket from the end of the cable, leaving no more than 6,4 mm of the braided shield exposed.



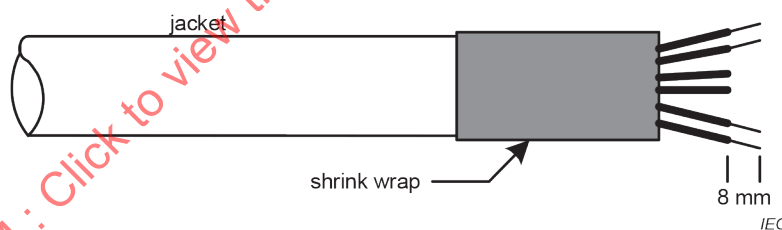
**Figure C.30 – Preparation of cable end**

- b) Wrap the end of the cable with 38 mm of shrink wrap, covering part of the exposed conductors and part of the trunk line insulation as shown in Figure C.31.



**Figure C.31 – Shrink wrap installation**

- c) Prepare the wire ends by stripping 8 mm of the insulation from the end of each of the insulated conductors as shown in Figure C.32.



**Figure C.32 – Wire preparation**

- d) Tin the last 6,5 mm of the bare conductors or crimp a suitable ferrule on the conductors.
- e) See Figure C.33, Figure C.34 and Table C.17 for the following steps.
- f) Insert each conductor into the appropriate clamping cavity of the open-style connector or the screw terminal on the device, according to the colour of the cable insulation.
- g) Tighten the clamping screws to secure each conductor. The male contacts of the device connector shall match the female contact of the connector.

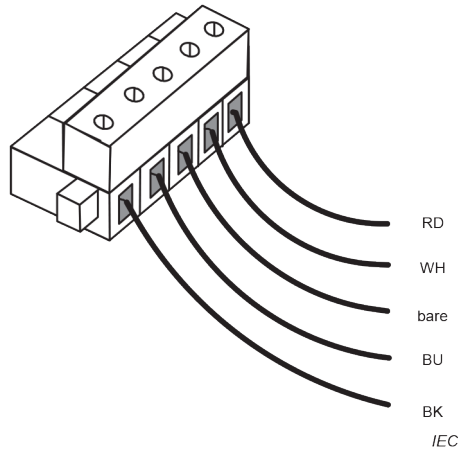


Figure C.33 – Open-style connector (female)

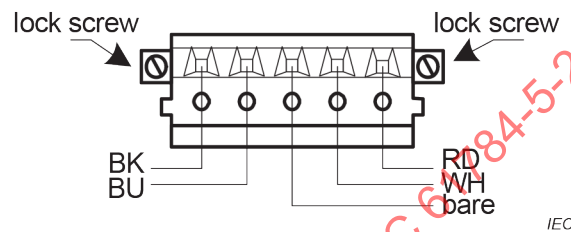


Figure C.34 – Open-style (male plug)

Table C.17 – Wire colour code and function

Wire colour	Wire identity	Usage
WH	CAN_H	Signal
BU	CAN_L	Signal
Bare	Drain	Shield
BK	V-	Power
RD	V+	Power

#### C.5.3.4 Specific requirements for CPs

Addition:

##### C.5.3.4.1 Installing IDC modules on flat cable

The flat IDC snap on to the interface provides the connection to the drop cable and is available with various connectivity options.

IDCs interface drop cables and devices to the flat cable trunk line. The hinged, two-piece base snaps around the flat cable at any point along the trunk. Contact is made with the cable conductors by tightening two screws that drive the contacts through the cable jacket and into the conductors.

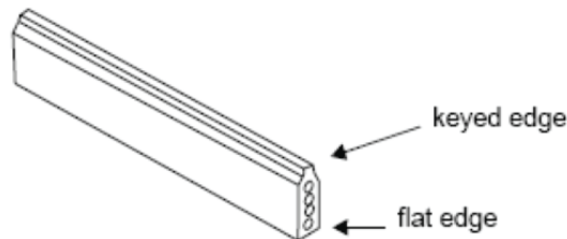
When used in flexing applications, the cable shall be secured to a solid reference with mounting hardware 10 cm to 15 cm from the connector.

The following guidelines should be followed.

- Installation of connectors is recommended only at temperatures of 0 °C to 75 °C.
- Make sure the cable is free of debris or scratches before attaching the connector to ensure a proper seal.
- The recommended distance between cable mounts is 3 m to 5 m.
- Special glands are available for running cable into an enclosure.

Follow these steps to properly install flat cable into a connector:

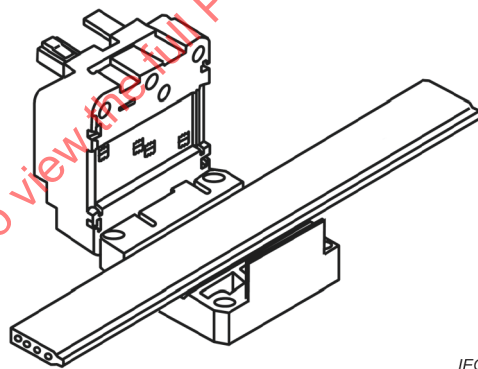
- a) Install flat cable with the wider flat edge of the cable on the bottom (see Figure C.35).



**Figure C.35 – Flat cable**

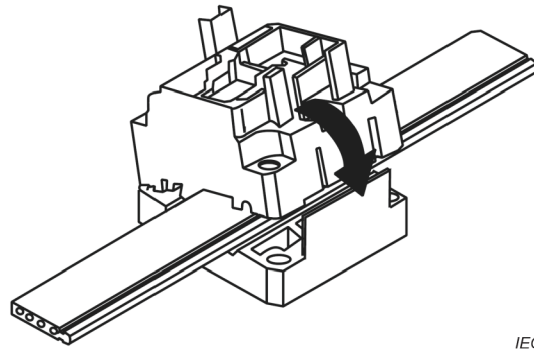
- b) As shown in Figure C.36, lay the cable in the hinged base, paying attention to the keyed profile; the unkeyed edge is closer to the hinge, the keyed edge is toward the latch.

Prior to closing the connector, make sure the IDC blades do not protrude from the housing. If the blades are exposed, gently push them back into the base. In the event that the blades do not retract easily (or retract only partially), verify that the IDC screws are not partially driven.



**Figure C.36 – Aligning the cable**

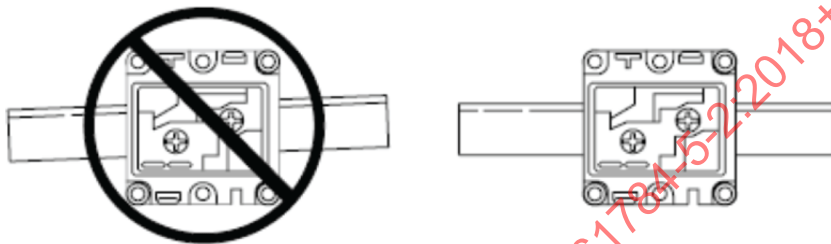
- c) Close the hinged assembly (see Figure C.37), applying pressure until the latch locks into place. The latch has two catches. The first catch loosely holds the connector on the cable. The second catch needs more pressure applied to close the connector tightly. If the cable is not in the correct position the connector will not close.



IEC

**Figure C.37 – Closing the assembly**

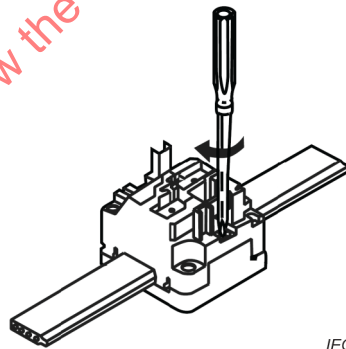
- d) Make sure the cable is straight as shown in Figure C.38 before moving on to step e).



IEC

**Figure C.38 – Proper orientation of cable**

- e) See Figure C.39 and locate the latch screws and tighten down the two screws at the centre points of the hinge and latch sides of the base; tighten down the latch side first. Take care to avoid stripping, apply torque as per the manufacturer's specifications. Mount the base to the panel by driving screws through the corner holes.



IEC

**Figure C.39 – Locking the assembly**

- f) See Figure C.40 and drive the IDC contacts into the cable by tightening down the two screws in the centre of the base assembly. Care shall be taken to ensure that the screws are tight, excessive force shall be avoided to prevent damage to the threads.

Once the IDC contacts are driven into the cable, the module should not be removed. If the module is removed, it shall be discarded and proper cable healing techniques shall be used to protect the waterproofing to IP67.

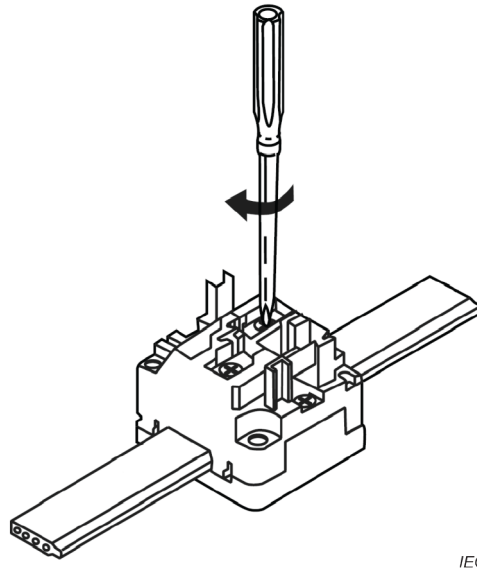


Figure C.40 – Driving the IDC contacts in to the cable

#### C.5.3.4.2 End cap installation

Each flat cable terminator module needs an end cap designed to cover the exposed end of the cable.

To install the end cap:

- a) See Figure C.41 and fit the end cap on the cable as keyed. Align the end cap posts with the receptacles in the lower IDC base and press down until the end cap is firmly seated as shown in Figure C.42 (the upper surface of the posts will be flush with the upper surface of the base).

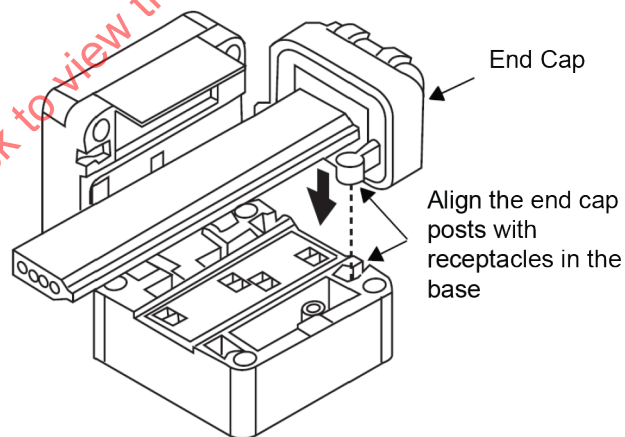
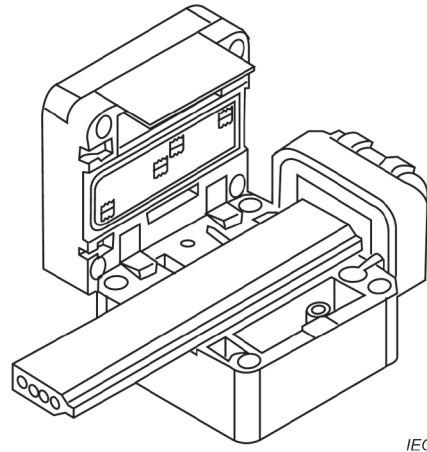
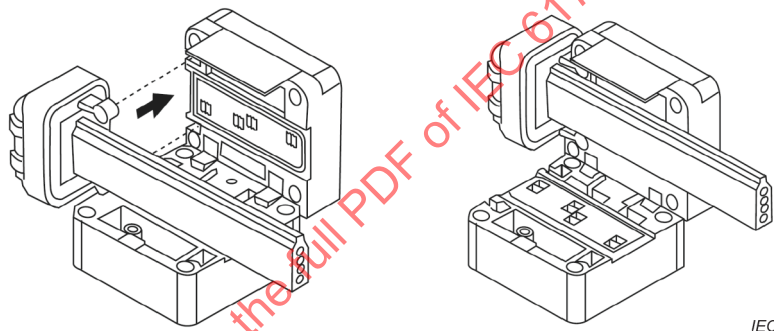


Figure C.41 – End cap placement



**Figure C.42 – End cap seated**

- b) Close the IDC base and continue with the connection process.
- c) When installing an end cap on the other end of the cable, the guide receptacles are on the upper portion of the IDC base (see Figure C.43). Seat the end cap in the upper half of the IDC module. Repeat the end cap installation process as outlined previously. Close the IDC base and continue with the connection.

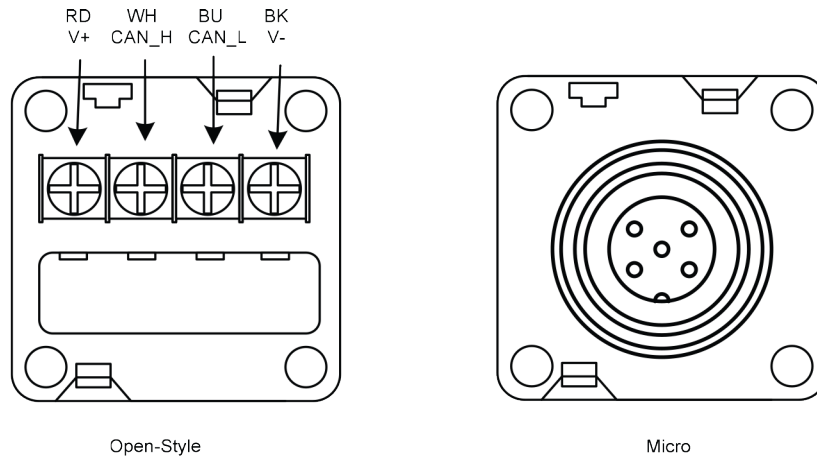


**Figure C.43 – End cap installation on alternate side of cable**

#### **C.5.3.4.3 Flat interface connector installation**

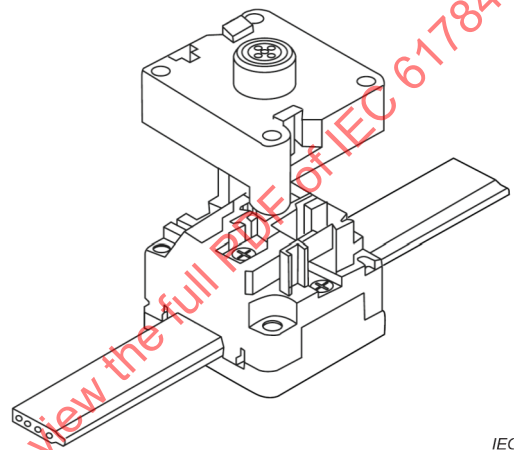
There are currently two modules available, one is an open-style screw terminal, the other is an M12 A-coding connector. The module snaps onto the previously installed IDC modules, both providing connectivity to the trunk.

Examples of the snap-on interface connectors are shown in Figure C.44.



**Figure C.44 – Flat cable IDC connectors**

See Figure C.45 and line up the keyed rectangular holes of the micro/open/terminator module by driving screws through the two remaining mounting holes as shown in Figure C.45.



**Figure C.45 – Installing the connectors**

#### C.5.3.4.4 Wiring to an open-style module

Install the flat cable open-style connector to the flat media using the directions in C.5.3.4.1. Prepare the drop cable following the directions in C.5.3.3. Shielded or unshielded drop cables can be used for flat media connections (see Figure C.46 for wiring).

Cut or heat shrink the drain wire when using shielded drop cable as shown in Figure C.46.

Determine the exact placement of the connector before engaging the IDC contacts.

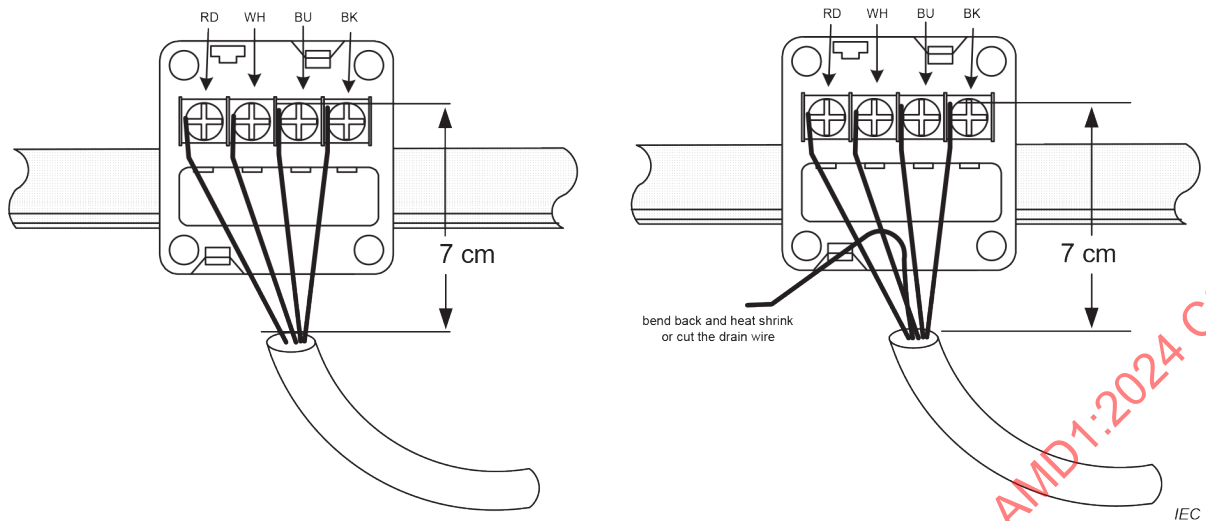


Figure C.46 – Cable wiring to open-style terminals

### C.5.3.4.5 Installing auxiliary power cables

#### C.5.3.4.5.1 Flat cable system

Install auxiliary power cables the same way as installing the network cable. See C.5.3.4.1 for installation instructions. The flat power cable is detailed in Figure C.47. This profile is the same as the flat DeviceNet communications cable with the exception of the colour. The auxiliary power cable typically has a black jacket. The colour code and wire identity for the auxiliary power cable are detailed in Table C.18.

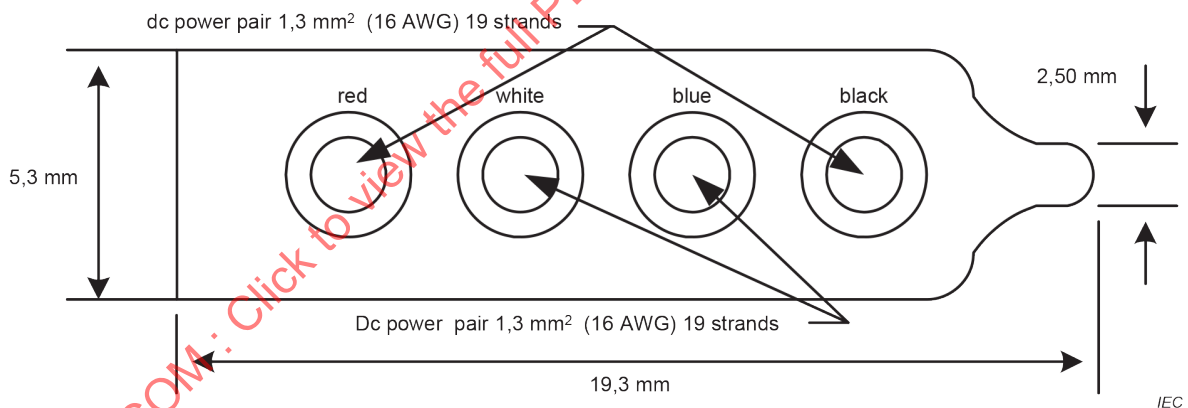


Figure C.47 – Auxiliary power cable profile

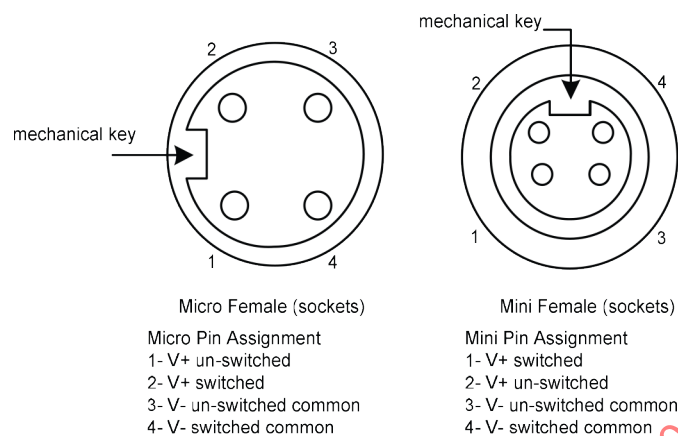
Table C.18 – Auxiliary power cable colour code

Wire colour code	Wire identity	Use
WH	User defined	User defined
BU	User defined	User defined
BK	V-	Output power
RD	V+	Output power

When routing cable into an enclosure, use a flat cable gland at the bulkhead.

**C.5.3.4.5.2 Round cable system**

Pin out diagrams for the micro and mini connections to the auxiliary power cable are shown in Figure C.48.



**Figure C.48 – Pin out auxiliary power connectors**

**C.5.3.4.6 Connecting the power supply to the network**

DeviceNet requires a 24 V power supply for the bus power and auxiliary power bus. The network power supply shall meet the requirements of Table C.5. Power supplies used to power auxiliary circuits shall meet the requirements of Table C.19. The power supply shall be earthed in accordance with local, national and international standards. The V- and communications shield shall be earthed at only one location in the network. This location is usually at the power supply or power tap.

**Table C.19 – Auxiliary power supply requirements**

Specification	Parameter
Initial tolerance	24 volts $\pm$ 1 % or adjustable power supplies with output range of 22 V DC to 27,2 V DC
Line regulation	0,5 % maximum
Load regulation	1,5 % maximum
Temperature coefficient	0,05 % per °C maximum from 20 °C to 50 °C
Output ripple	480 mV p-p maximum
Temperature range	Operating 0 °C to 60 °C Non-operating -25 °C to 65 °C
Inrush current limit	Less than 65 A peak
Over voltage protection	36 Vdc maximum
Over current protection	Yes (current limit to 160 % maximum)
Turn-on time (with full load)	1 000 ms maximum within 5 % of final value
Turn-on overshoot	3,5 % maximum
Stability	0 % to 100 % load (all conditions)
Isolation	Output isolated from AC and chassis earth
Output voltage	(24 $\pm$ 1 %) V
Output current	Per application and per local regulations and codes
Surge current capability	10 % reserve capability

### C.5.3.4.7 Connecting power supplies to round media

The power supply placement will be determined by the planner and should be documented in the installation planning documentation. The power tap placement shall be determined by the planner and should be within 3 m of the power supply. If this is not possible then the conductor cross sectional area shall be increased in accordance with Figure C.49. Connect the power supply to the power taps after installing the power taps in the network. See C.4.3.2.5 for further instructions.

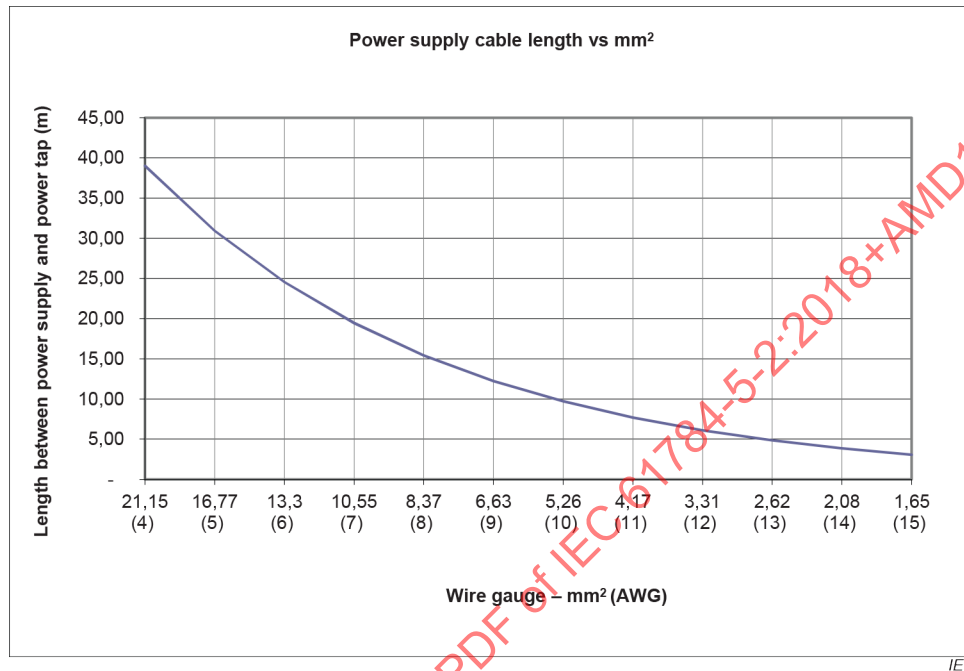


Figure C.49 – Power supply cable length versus wire size

The following are rules for connecting a power supply to the network:

- Devices are not allowed between the power supply and the power tap. This includes smart power supplies.
- The AC and DC power source remains off during installation.
- If the cable used to connect the power supply to the network contains the signal conductors and they are connected at the network, then the cable shall be considered in the drop cable budget.

To install a power supply:

- a) Mount the power supply securely allowing for proper ventilation, connection to the AC or DC power source, and protection from environmental conditions according to the specifications for the supply.
- b) Connect the power supply using the following rules and guidelines:
  - a cable that has one pair of 12 AWG (3,3 mm<sup>2</sup>) conductors is recommended or a DeviceNet thick cable may be used. If a DeviceNet thick cable is used, only the V+ (red) and V- (black) should be connected, unless the power supply is designed to communicate on the network and therefore requires all conductors. If there are no terminals for CAN\_H and CAN\_L, cut and insulate CAN\_H (white) and CAN\_L (blue) at the power supply and power tap. The length of the power cable shall be included in the cumulative drop length calculation if the CAN\_H and CAN\_L conductors are connected to the trunk line;

- the cable length between the power tap and the power supply should be 3 m (10 ft) or less however it can be increased beyond 3 m (10 ft) in accordance with Figure C.49 if necessary;
- the manufacturer's recommendations for connecting the cable to the supply should be observed.

The power supply V- and shield should be earthed at the power tap.

#### **C.5.3.4.8 Connecting power supplies to flat cable**

Use a flat cable tap to connect power to the network. Choose a tap that is suitable for the expected current.

Because these taps have no overcurrent protection, protection shall be provided. Use either a fuse or a circuit breaker externally or use a current-limited power supply.

The power supply placement should be determined and the power supply installed before the power taps are installed. The power supply shall be earthed. Connect the power supply to the power taps after installing the power taps on to the network cable. See C.4.3.2.5 for further instructions.

Make sure the AC and DC power source remains off during installation.

- a) Mount the power supply securely allowing for proper ventilation, connection to the AC or DC power source connections, and protection from environmental conditions according to the specifications for the supply.
- b) Connect the power supply using the following rules and guidelines:
  - devices are not allowed between the power supply and the power tap. This includes smart power supplies;
  - a cable that has one pair of 12 AWG (3,3 mm<sup>2</sup>) conductors is recommended or in accordance with Figure C.49;
  - the cable length between the power tap and the power supply should be 3 m (10 ft) or less however it can be increased beyond 3 m (10 ft) in accordance with Figure C.49 if necessary;
  - the manufacturer's recommendations for connecting the cable to the supply should be observed.

#### **C.5.3.5 Specific requirements for wireless installation**

Not applicable.

#### **C.5.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

### **C.5.4 Terminator installation**

#### **C.5.4.1 Common description**

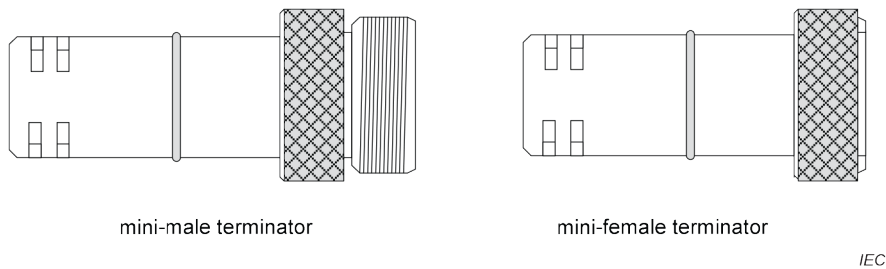
#### **C.5.4.2 Specific requirements for CPs**

*Addition:*

##### **C.5.4.2.1 General**

Terminators are used to minimize reflections from the ends of the cables. Each segment shall be terminated at each end with a 121  $\Omega$  1 % 1/4 W low inductance resistor. The terminators shall be connected directly across the BU (CAN\_L) and WH (CAN\_H) wires of the DeviceNet cable. Terminators are available as sealed and open-style (discrete resistor).

Male and female sealed terminators are available in mini and micro versions. Figure C.50 is an example of a sealed terminator.

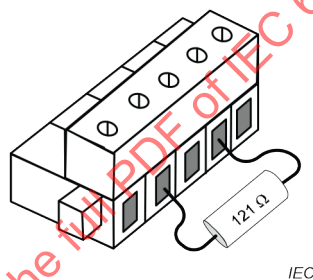


**Figure C.50 – Sealed terminator**

#### C.5.4.2.2 Unsealed open-style terminators for round and flat media

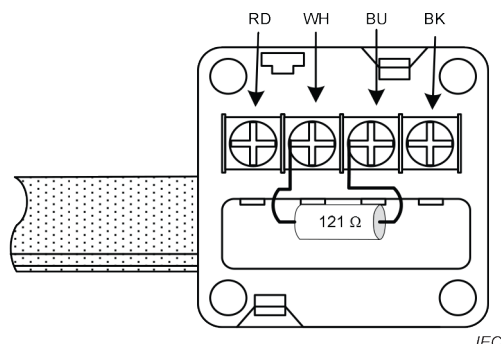
An open-style terminator is suitable for use with:

- multi-port taps (open-style taps only);
- open-style plugs or taps (see Figure C.51);
- flat cable open-style insulation displacement connectors (see Figure C.52 for installation of the terminator on the flat cable open-style connector).



**Figure C.51 – Open-style terminator**

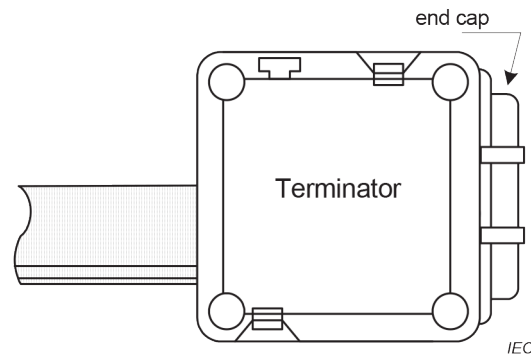
An open-style connector option with a terminator may be installed when sealing is not required. Figure C.52 shows the location of the resistor. The resistor shall meet the requirements of Clause C.5.



**Figure C.52 – Open-style IDC terminator**

#### C.5.4.2.3 Sealed terminators for flat media

Sealed terminators shall be used when sealing to IP67 is required. The terminator is installed as shown in Figure C.53.



**Figure C.53 – Sealed terminator IDC cable**

### **C.5.5 Device installation**

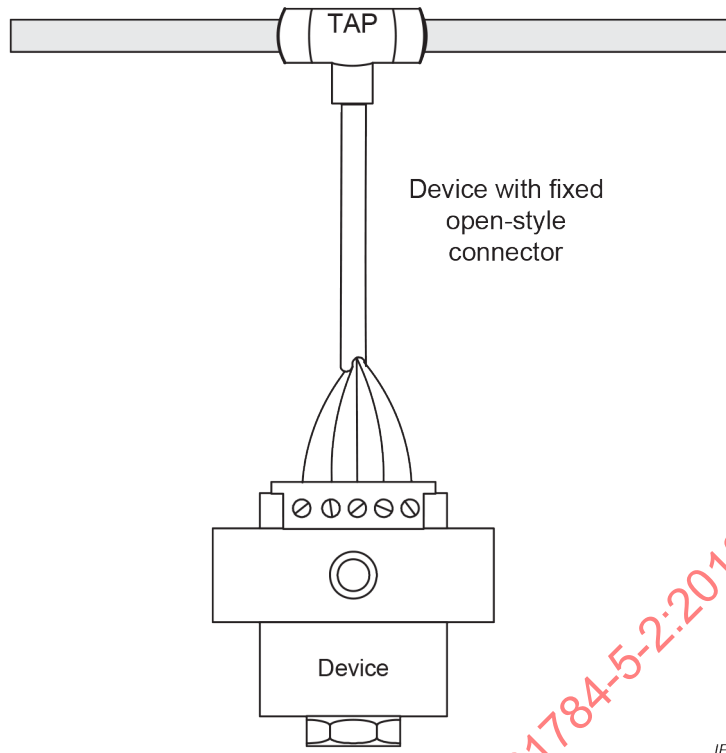
#### **C.5.5.1 Common description**

#### **C.5.5.2 Specific requirements for CPs**

*Addition:*

Direct connection of devices is possible by using open-style connectors on a device. Connect devices directly to the trunk line only if removal of the devices without disturbing communications on the cable system is possible.

**Important:** If a device provides only fixed-terminal blocks for its connection, it shall be connected to the cable system by a drop line. Doing this allows removal of the device at the tap without disrupting communications on the cable system. Figure C.54 is an example of how to make a direct connection to the trunk using a "T" and a drop line with an open-style connection at the device. For correct wiring of the open-style connection see Figure C.55 (5 positions) and Figure C.56 (10 positions).

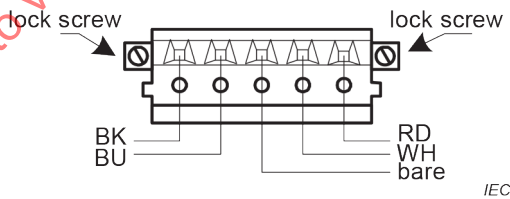


**Figure C.54 – Direct connection to the trunk**

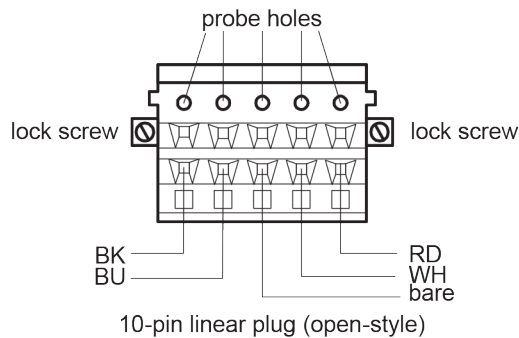
Open-style connectors come in two primary varieties:

- five-position (5-pin linear plug), Figure C.55;
- ten-position (10-pin linear plug), Figure C.56.

Ten-position (2×5) connectors provide easier daisy chaining because there is an independent wire chamber for each wire (entering cable and exiting cable).



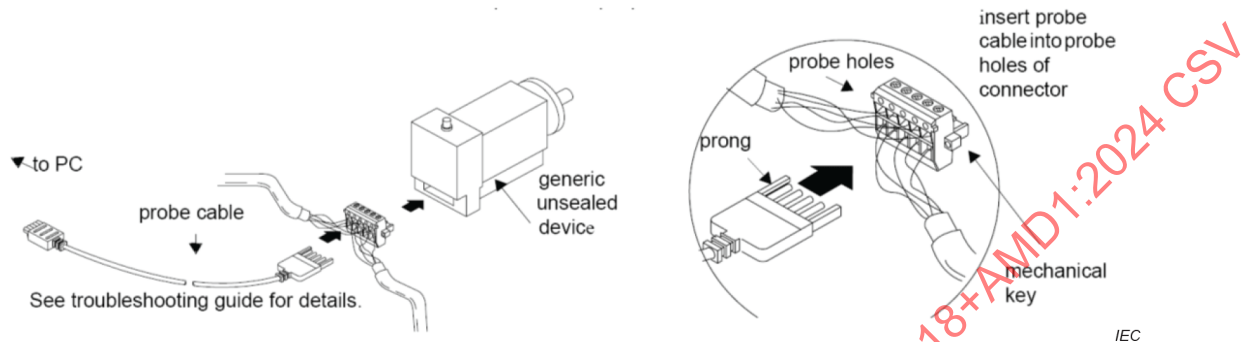
**Figure C.55 – Wiring of open-style connector**



**Figure C.56 – Wiring of open-style 10-position connector**

Some open-style connectors provide a temporary connection, for a PC or other configuration tool, using probe holes. Both the 5-pin linear plug in Figure C.55 and 10-pin linear plug and Figure C.56 provide probe contacts.

For connection, insert the prongs of a probe cable into the probe holes of a connector (see Figure C.57). Mechanical keys on the connector prevent improper insertion.



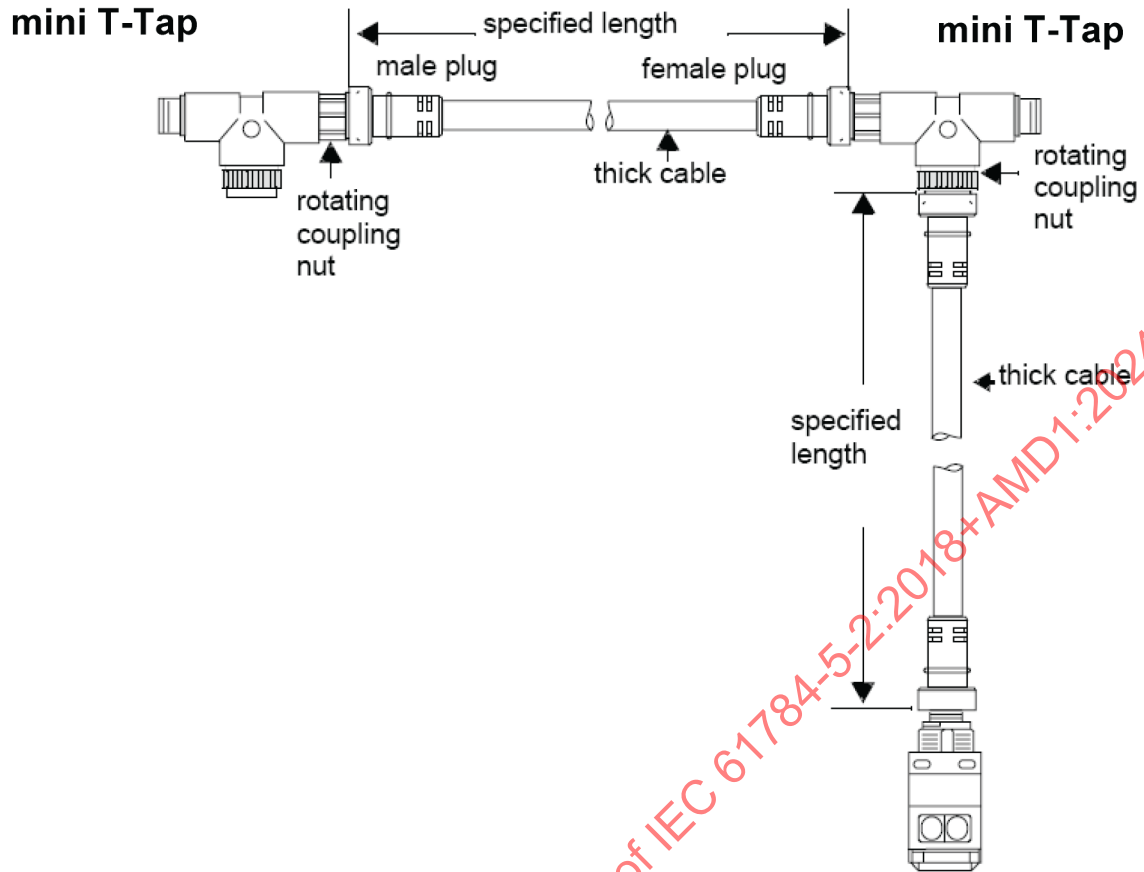
**Figure C.57 – Diagnostic temporary connections**

Connections may also be made using preterminated cables.

Using a preterminated cable assembly saves time and effort of stripping and wiring the connectors to the cable ends and also reduces wiring errors as the cable assemblies are normally factory tested.

Thick cable preterminated is available in several lengths with mini connectors at each end. Thick cable that is 6 m or shorter can also be used as drop lines (see Figure C.58).

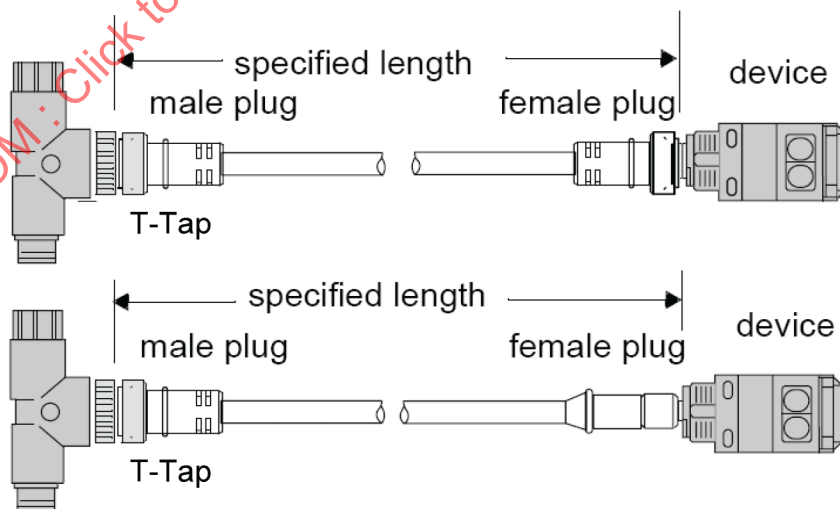
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Figure C.58 – Thick cable preterminated cables (cord sets)

Preterminated thin cable assemblies for use as a drop line are available with various connectors in several lengths. Preterminated thin cable assemblies (Figure C.59) can also be used as trunk lines up to a total of 100 m in a system.



IEC

Figure C.59 – Thin cable preterminated cables (cord sets)

**C.5.6 Coding and labelling****C.5.7 Earthing and bonding of equipment and devices and shield cabling****C.5.7.1 Common description****C.5.7.2 Bonding and earthing of enclosures and pathways****C.5.7.3 Earthing methods****C.5.7.3.1 Equipotential**

*Addition:*

The earthing method shall be in accordance with the planner's documentation. If there is an earth potential off-set in the communication coverage area, equalization conductors shall be installed to mitigate the offset. The cross sectional area of these conductors shall be in accordance with IEC 61918:2018, 4.4.7.2.1, Table 14.

**C.5.7.3.2 Star**

*Addition:*

In addition to the requirements of C.4.4.7.3.2, the following shall be observed.

Cable shields for the communications equipment shall be referenced only to the signal earth (functional earth). Other equipment such as motors or motor controllers shall not be referenced to the functional earth. The star earth of the two systems (functional earth and protective earth) shall converge at one point within the building as shown in IEC 61918:2018, Figure 18. Earthing connections for the cabinets shall not be daisy chained.

**C.5.7.3.3 Earthing for equipment (devices)**

*Replacement:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions and the planner's documentation.

**C.5.7.4 Shield earthing methods****C.5.7.4.1 General****C.5.7.4.2 Parallel RC**

*Addition:*

The network shield shall be earthed at one location in the network. This location should be preferably at the power supply. The network V- shall be earthed at the same location as the network shield. The active devices are either isolated or make use of a parallel RC internal to the device that terminates the shield to the local earth. The shield shall not be directly connected to earth thereby defeating or bypassing the parallel RC.

**C.5.7.4.3 Direct**

Not applicable.

**C.5.7.4.4 Derivatives of direct and parallel RC**

Not applicable.

### **C.5.7.5 Specific requirements for CPs**

Not applicable.

### **C.5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

### **C.5.8 As-implemented cabling documentation**

## **C.6 Installation verification and installation acceptance test**

### **C.6.1 General**

### **C.6.2 Installation verification**

#### **C.6.2.1 General**

#### **C.6.2.2 Verification according to cabling planning documentation**

*Addition:*

There are several different types of diagnostic and troubleshooting tools available to aid in the initial commissioning of the network, further troubleshooting during operation and as an ongoing means of monitoring its health. The broadest category of tools are those which are general purpose (e.g. a voltmeter, oscilloscope, time domain reflectometer). These analytical tools can confirm connections, verify cable lengths and the proper installation of terminations as well as being able to measure voltages and confirm signal levels. This category of tools requires a user with advanced knowledge of both the measuring tool and the DeviceNet specification.

The second category of tools are protocol-specific and include a variety of both passive and active handheld meters. Passive instruments are designed to locate short circuits, opens, confirm terminations and cable lengths. Active handheld devices are designed to give "dial in" measurements of the physical layer voltages such as common mode voltage as well as data packet characteristics such as node error count or rate and bandwidth utilization. These protocol-aware measuring tools are more user friendly in that they typically use plug-play network connections.

Lastly there are a variety of software tools available to monitor network traffic which can aid in commissioning and diagnostics. For instance, some configuration tools can monitor traffic and errors produced in the network. More sophisticated software tools such as protocol analyzers parse out and decode DeviceNet messages to get into refined issues such as device communications and timing. These tools require a higher level of sophistication and are not designed specifically to address physical layer issues.

Prior to making measurements use the check list below to verify that the physical media system has been installed properly:

- total device network current draw does not exceed power supply current limit;
- number of DeviceNet nodes does not exceed 64 on one network. The practical limit of DeviceNet nodes is 61 slave devices. Allowance for the scanner, the computer interface module, and an open node at node 63 is recommended;
- drop length shall not be greater than 6 m in length (20 ft);
- cumulative drop line budget does not exceed the maximum allowable per the network baud rate and cable type;
- total network trunk length does not exceed the maximum allowable per the network data rate and cable type;

- trunk V- does not exceed 4,65 V between any two points in the trunk and that any drop line V- does not exceed 0,35 V between the trunk tap and end of the drop line;
- terminating resistors are on each end of the trunk line;
- earth V-, drain and (for shielded media) communications shield at only one location;
- check the physical media prior to applying power:
  - all connections are inspected for loose wires or coupling nuts,
  - check for opens or shorts,
  - check the proper value of the terminating resistors,
  - confirm the media topology and connections.

The following measurement procedures are suggested prior to commissioning the network.

- a) Use a time domain reflectometer, DVM or handheld network media checker to verify cable lengths, cable types, termination and connection integrity. These tests shall be conducted prior to connection of devices and power on the network.
- b) Insure that both termination resistors are connected to the network. Measure and record DC resistance between CAN\_H and CAN\_L at the middle and the ends of the network. Table C.20 provides resistance values for proper and improper termination of the network. Follow the action based on the measurement value.

**Table C.20 – Signal wire verification**

Measured value	Action
< 50 Ω	Check for a short circuit between CAN_H and CAN_L wiring. Check for more than two terminating resistors Check nodes for faulty receivers
50 Ω to 70 Ω	Normal
71 Ω to 125 Ω	Check for open circuit in CAN_H and CAN_L wiring. Check for only one terminating resistor
> 125 Ω	Add termination resistors

- c) Perform the measurements in Table C.21, and follow the action based on the measured value. At the completion of this step, record the measured value in the installation documentation.
- d) At the network earth point, temporarily disconnect from earth connection and measure between earth and the disconnected earth.

**Table C.21 – Shield to earth**

Measured value	Action
$\frac{950 \text{ k}\Omega}{\text{number of nodes on the network}}$	Normal
$< \frac{950 \text{ k}\Omega}{\text{number of nodes on the network}}$	Troubleshoot for short

- e) Measure the network's electrical characteristics with the following as the recommended minimum to make and record:
  - bus power;
  - shield voltage;
  - common mode voltage.

Record all the above in the attached "Baseline and Test Report".

- f) After scanner(s) and any other connection originators have been configured and are operating normally, measure the following network traffic statistics:
- error rate;
  - error counter;
  - % network bandwidth;
  - network message rate/second.

Record all the above in the attached "Baseline and Test Report".

**C.6.2.3 Verification of earthing and bonding**

**C.6.2.4 Verification of shield earthing**

**C.6.2.5 Verification of cabling system**

**C.6.2.5.1 Verification of cable routing**

**C.6.2.5.2 Verification of cable protection and proper strain relief**

**C.6.2.6 Cable selection verification**

**C.6.2.6.1 Common description**

**C.6.2.6.2 Specific requirements for CPs**

Not applicable.

**C.6.2.6.3 Specific requirements for wireless installation**

Not applicable.

**C.6.2.7 Connector verification**

**C.6.2.7.1 Common description**

**C.6.2.7.2 Specific requirements for CPs**

Not applicable.

**C.6.2.7.3 Specific requirements for wireless installation**

Not applicable.

**C.6.2.8 Connection verification**

**C.6.2.8.1 Common description**

**C.6.2.8.2 Number of connections and connectors**

**C.6.2.8.3 Wire mapping**

*Replacement:*

Connector wiring (wire map) shall be checked prior to commissioning the network. The wire map can be tested using a suitable network tester or DVM. DeviceNet only supports straight through type wiring. Therefore wire map testing shall always yield a direct pin 1 to pin 1, pin 2 to pin 2 wiring. Cables that convert one connector to another are an exception to this rule. See Table C.22 for connector pin and function name.

**Table C.22 – Connector pin out**

Connector	Drain (bare)	V+ (RD)	V- (BK)	CAN_H (WH)	CAN_L (BU)
Open-style	3	5	1	4	2
Micro	1	2	3	4	5
Mini	1	2	3	4	5

Most connection errors occur because the screws are not tight. Confirm that all contact screws are torqued according to the connector manufacturer's instructions.

### **C.6.2.9 Terminator verification**

#### **C.6.2.9.1 Common description**

#### **C.6.2.9.2 Specific requirements for CPs**

*Addition:*

See Table C.20 in C.6.2.2.

### **C.6.2.10 Coding and labelling verification**

#### **C.6.2.11 Verification report**

See C.8.4.

### **C.6.3 Installation acceptance test**

#### **C.6.3.1 General**

#### **C.6.3.2 Acceptance test of Ethernet-based cabling**

Not applicable.

#### **C.6.3.3 Acceptance test of non-Ethernet-based cabling**

##### **C.6.3.3.1 Copper cabling for non-Ethernet-based CPs**

###### **C.6.3.3.1.1 Common description**

###### **C.6.3.3.1.2 Specific requirements for copper cabling for non-Ethernet-based CPs**

*Addition:*

See the network validation check sheet in Annex D.

###### **C.6.3.3.2 Optical fibre cabling for non-Ethernet-based CPs**

Not applicable.

###### **C.6.3.3.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

###### **C.6.3.4 Specific requirements for wireless installation**

Not applicable.

### **C.6.3.5 Acceptance test report**

## **C.7 Installation administration**

Subclause 7.8 is not applicable.

## **C.8 Installation maintenance and installation troubleshooting**

### **C.8.1 General**

### **C.8.2 Maintenance**

### **C.8.3 Troubleshooting**

### **C.8.4 Specific requirements for maintenance and troubleshooting**

*Replacement:*

Once the network has been installed and has been successfully commissioned and baseline measurements recorded, periodic measurements can improve network availability. The most obvious place to begin this checkup is by comparing the network's operating characteristics against the established baseline. Checkup frequency and thoroughness is the key to early detection of deteriorating network properties. A continuous monitoring of these baseline parameters is ideal, however, a quick protocol-aware checkup every few weeks would be adequate to detect any deteriorations of network performance.

### **Analyzing symptoms**

Use the following to analyze the most common symptoms and their likely sources.

Most devices have LEDs, some have alphanumeric or oth

er displays. If any of these show error codes or messages, read the manufacturer's data sheets to interpret the codes.

### **Bus lengths problems**

#### **SYMPTOMS:**

- Nodes at the end of the trunk stop communicating after operating normally.
- The network communicates only when the number of nodes is decreased or the trunk length is reduced.
- Properly configured slaves are not detected by the scanner.

#### **CHECKS:**

- Check the communications at the end of the network.
- Check the common mode voltage.

#### **SUGGESTED ACTIONS:**

- Move nodes from overloaded section to less overloaded section.
- Shorten the overall length of the network cable.
- Move the power supply in the direction of the overloaded section of the network.
- Move the high current nodes (e.g. valve banks) close to the power supply.

- Add a second power supply.
- Break the network into two (2) separate networks.

### Bus errors

#### SYMPTOMS:

- Nodes intermittent – they drop off suddenly and unexpectedly.
- LEDs or other displays indicate "bus off" errors.

#### CHECKS:

- Use protocol-aware tool to measure bus error rate.

#### SUGGESTED ACTIONS:

- Make sure that all nodes are set to the same baud rate.
- Replace the suspected faulty device and re-check the error rates.
- Intermittent cables – check by shaking/bending/twisting the suspected cable or connection while looking at the error rates.

### Bus traffic problems

#### SYMPTOMS:

- Nodes stop communicating and devices time out. No communication from a device.

#### CHECKS:

- Check the bandwidth using a protocol-aware device.

#### SUGGESTED ACTIONS:

- Check scanner configuration as scan rate may be set incorrectly.
- Increase inter-scan delay/scan interval to clear device timeouts.
- Decrease inter-scan delay/scan interval to increase network performance.
- Check Change-of-State devices consuming excessive bandwidth – increase production inhibit time or change these devices to poll, strobe or cyclic communications.
- Look for nodes using excessive network bandwidth.

### Bus power problems

#### SYMPTOMS:

- Nodes near end of trunk stop communicating after operating normally.
- Network communicates only when the number of nodes is reduced or the trunk length is reduced.

#### CHECKS:

- Check the network power voltage at the node and the common mode voltage at the ends of the network.

#### SUGGESTED ACTIONS:

- Check for output devices (e.g. contactors) powered from the network.
- Check for network cables routed too close to interferences from the high voltage and RF lines.

- Check the power supply ripple increasing over time against the baseline.
- Intermittent cables – check by shaking/bending/twisting the suspected cable or connector while watching the peak-peak voltage changes.

### Shield voltage problems

#### SYMPTOMS:

- Nodes intermittently dropping out.
- Properly configured slaves are not detected by the scanner.

#### CHECKS:

- Check shield voltage.

#### SUGGESTED ACTIONS:

- Check for additional V- and/or shield connections in the network.
- Check for loose connections, especially field attachable connections.
- Confirm that the cable shield and V- are connected together to earth at the power supply and only at the power supply.

### Common faults

If experiencing difficulty with the network check the following most common network problems:

- More or less than two (2) terminators.
- Relaxed connector pin – especially those which use a soft brass contact on the female socket. The DeviceNet specification requires that connectors are good for at least 1 000 insertions. Phosphor-bronze contacts are more likely to meet this requirement.
- Excessive drop line cable length – greater than 6 m for any single drop cable.
- Too many drop cables – cumulative drop length exceeded.
- Excessive trunk line length – especially with thin cable.
- Improper shield and earth connections at the power supply.
- Shorts and opens in manually-wired connectors.
- Failure to perform power distribution calculations for new installations and again when adding nodes i.e. the power budget has been exceeded.
- Using a typical device current rather than maximum current for power distribution calculations.
- Scan interval configured faster than the network can handle.

### Flat cable shorts

Incorrectly installed flat cable taps can cause short circuits. These can be difficult to find because the taps are not designed to allow removal. A time domain reflectometer or handheld network media checker can indicate the approximate distance to a short. In some cases where several taps are located within a short distance of each other, the tool may not be accurate enough to correctly locate the short. The following technique can be used to identify the shorted tap more precisely.

Disconnect all devices by removing all of the snap-on connection interfaces. Use two open-style connection interfaces for the test. Use one of these to inject about 100 mA DC into the shorted pair of conductors. Use the other with a multimeter to measure mV across the shorted pair. Move the measurement point to different taps – the voltage should decrease as it gets nearer to the short. If there is no change, the short is probably on the other side of the current

injection point. If there is no change on either side, the short is probably at the current injection point. Move the current injection point to another tap and repeat the test. The lowest voltage measured should be at the shorted tap.

The 100 mA current can be generated by a low-voltage DC power supply and a resistor. Be careful if using the 24 V DC network supply for this – the resistor (240  $\Omega$ ) would dissipate 2,4 W and would get hot. It should have at least a 5 W rating. It is better to use a 1,5 V cell and a 15  $\Omega$  resistor, which will only dissipate about 0,15 W.

Once the shorted tap is identified, the flat cable shall be cut on either side and the faulty tap removed. Use a splice kit to repair the cable. The splice kit consists of two taps with end caps for sealing, and two connection interfaces permanently joined by a short length of cable.

Never attempt to re-use a flat cable tap.

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**Annex D**  
(informative)

**Additional information**

**D.1 Network validation check sheet for CP 2/3 (DeviceNet)**

The following three pages show a Network validation check sheet for CP 2/3 (DeviceNet).

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### DeviceNet baseline & test report

Tested by	Company	
Phone	e-mail	
Measurement Date	Measurement Time	Network Identification
Network Location (Company name & Address)		

#### Network Characteristics

Single Master # \_\_\_   
  Multi Master # \_\_\_ . \_\_\_ . \_\_\_ . \_\_\_   
  Single power supply   
  Multiple power supplies (No. \_\_\_)

125Kbaud   
  250Kbaud   
  500Kbaud   
  Network uses Thick media

Network uses Thin media   
  Network uses Mid media   
  Network uses Flat media   

#### Media Testing

Trunk checked for short circuits   
  Trunk checked for opens   
  Wiring of trunk checked

Drops checked for opens   
  Check termination values   
  Shield and V- chnnected to ground at single point on network-at power supply

#### Node List

(According to network administrator, or "Network Who" scan)

0     1     2     3     4     5     6     7     8     9     10     11     12     13     14     15

16     17     18     19     20     21     22     23     24     25     26     27     28     29     30     31

32     33     34     35     36     37     38     39     40     41     42     43     44     45     46     47

48     49     50     51     52     53     54     55     56     57     58     59     60     61     62     63

### Basic Observation & Symptoms

#### Reported Symptoms

No problems reported   
  Intermittent problem ( \_\_\_ min, \_\_\_ hrs, \_\_\_ days)   
  Multiple power supplies (No. \_\_\_)

All nodes affected   
  Some nodes affected

Error codes   
  Error codes per node

#### Node Network Status LEDS

(LED indications refer to Network Status or Combined Module/Network Status LEDs)




All nodes active (green)   
  Some nodes active (green)   
  Some nodes inactive (blink green)

Some nodes faulted (red)   
  All nodes occasionally inactive (green/blink green)   
  Some nodes occasionally inactive (green/blink green)

All nodes with no power (LED off)   
  Some nodes with no poer (LED off)

**Physical Layer Measurements**

( NetMeter™  DeviceNet Detective™  Multimeter  Oscilloscope  
 Connected to network in proximity to node # \_\_\_\_).

Use NetMeter to take all of the following measurements (NetMeter switch positions are shown beside each measurement). It is possible to collect a limited number of measurements using other tools such as the DeviceNet Detective  multimeter  and/or oscilloscope  (indicated by icons in the table).

This document shows some measurements that are only practical with specific proprietary test instruments. All measurements are theoretically possible with general-purpose instrumentation such as oscilloscopes, but some would be very tedious. Proprietary instruments make it easy to perform the tests for which they are designed. This page indicates instruments that are believed to have such capabilities, do not assume that it is complete or accurate. Consult the instrument manufacturers for more information about each instrument's capabilities.

**Autosearch Results**

(record measurements as indicated by NetMeter Autosearch function and check for ☺ and/or ☹ with each reported problem)

No faults found ☺ NetMeter gathered data at (H:M:S) \_\_\_\_:\_\_\_\_:\_\_\_\_

Measurement	Min	Max
[2] Bus error rate (/S)		☺ ☺ ☺
[4] Bus power, DC (V)	☺ ☺ ☺	☺ ☺ ☺
[5] Shield Voltage (V)	☺ ☺ ☺	☺ ☺ ☺
[7] CANH/L Recessive Diff.	☺ ☺ ☺	☺ ☺ ☺
[9] CANH Recessive (V)	☺ ☺ ☺	☺ ☺ ☺
[11] CANL Recessive (V)	☺ ☺ ☺	☺ ☺ ☺

Measurement	Min	Max
[3] Bus traffic, bandwidth	☺ ☺ ☺	☺ ☺ ☺
[4] Bus power, P-P (V)		☺ ☺ ☺
[6] Common Mode Voltage		☺ ☺ ☺
[8] CANH/L Dominant Diff.	☺ ☺ ☺	☺ ☺ ☺
[10] CANH Dominant (V)	☺ ☺ ☺	☺ ☺ ☺
[12] CANL Dominant (V)	☺ ☺ ☺	☺ ☺ ☺

**Overall Subnet Measurement**

(only important for baseline performance, or for more detail if NetMeter Autosearch indicates problems)

Measurement	"Live"	Min	Max
[2] Bus error rate (/S)			
[3] Bus traffic, bandwidth (%)			
[4] Bus power, DC (V)			
[5] Shield Voltage (V)			
[7] CANH/L Recessive Diff. (V)			
[9] CANH Recessive (V)			
[11] CANL Recessive (V)			

Measurement	"Live"	Min	Max
[2] Bus error count			
[3] Bus traffic, message rate (/S)			
[4] Bus power, P-P (V)			
[6] Total Common Mode Voltage			
[8] CANH/L Dominant Diff. (V)			
[10] CANH Dominant (V)			
[12] CANL Dominant (V)			

Measurement	Network idle	Network active (normal operation)
CAN_H average (V)		
CAN_L average (V)		

"Network idle" means all scanners and other connection originators are inactive, disabled or disconnected. In this state the average voltages should be in the range 2,5 V to 3,5 V. This will vary with position on the network. Repeated measurements should be taken at the same point for valid comparisons. When the network is active and a DC meter is being used to measure a complex high frequency waveform, the measurements will only be approximate. Different meters may give different results. Repeated measurements should be taken with the same instrument at the same point for valid comparisons. CAN\_H average should be about 0,5 V to 1 V higher than when idle. CAN\_L average should be about the same amount lower than when idle. Because multimeters are not intended for this sort of waveform it is possible that they might cause errors on an active network. Experience suggests that this is rare with modern, high-impedance instruments; if this problem is encountered, construct a pair of probes with 100 kΩ resistors and heat-shrink sleeving. This is much higher than the network



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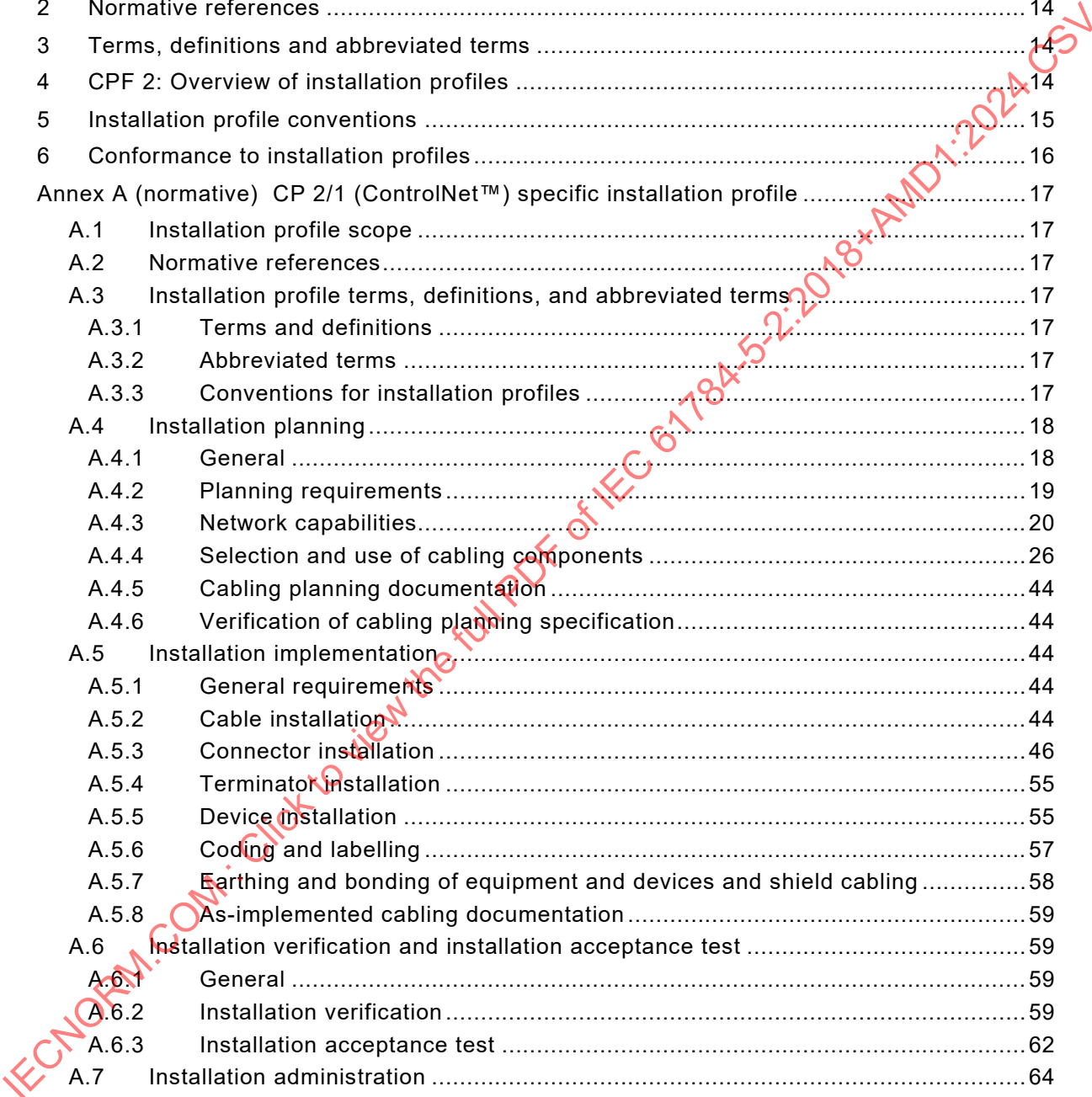
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**INDUSTRIAL COMMUNICATION NETWORKS –  
PROFILES –****Part 5-2: Installation of fieldbuses –  
Installation profiles for CPF 2****FOREWORD**

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**IEC 61784-5-2 edition 4.1 contains the fourth edition (2018-08) [documents 65C/924/FDIS and 65C/925/RVD] and its amendment 1 (2024-03) [documents 65C/1283/FDIS and 65C/1297/RVD].**

**This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.**

International Standard IEC 61784-5-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This document is to be used in conjunction with IEC 61918:2018, IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024.

This fourth edition cancels and replaces the third edition published in 2013. This edition constitutes a technical revision.

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

- a) references to ISO/IEC 24702 have been replaced with references to ISO/IEC 11801-3 in Table B.1;
- b) errors have been corrected;
- c) Tables B11 and B13 have been added in support of 1,000 Mb/s 4 Pair Ethernet;
- d) Clarification of dual power supplies for Annex C.

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

A list of all parts of IEC 61784-5 series, under the general title *Industrial communication networks – Profiles – Installation of fieldbuses*, can be found on the IEC website.

The committee has decided that the contents of this document and its amendment will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://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

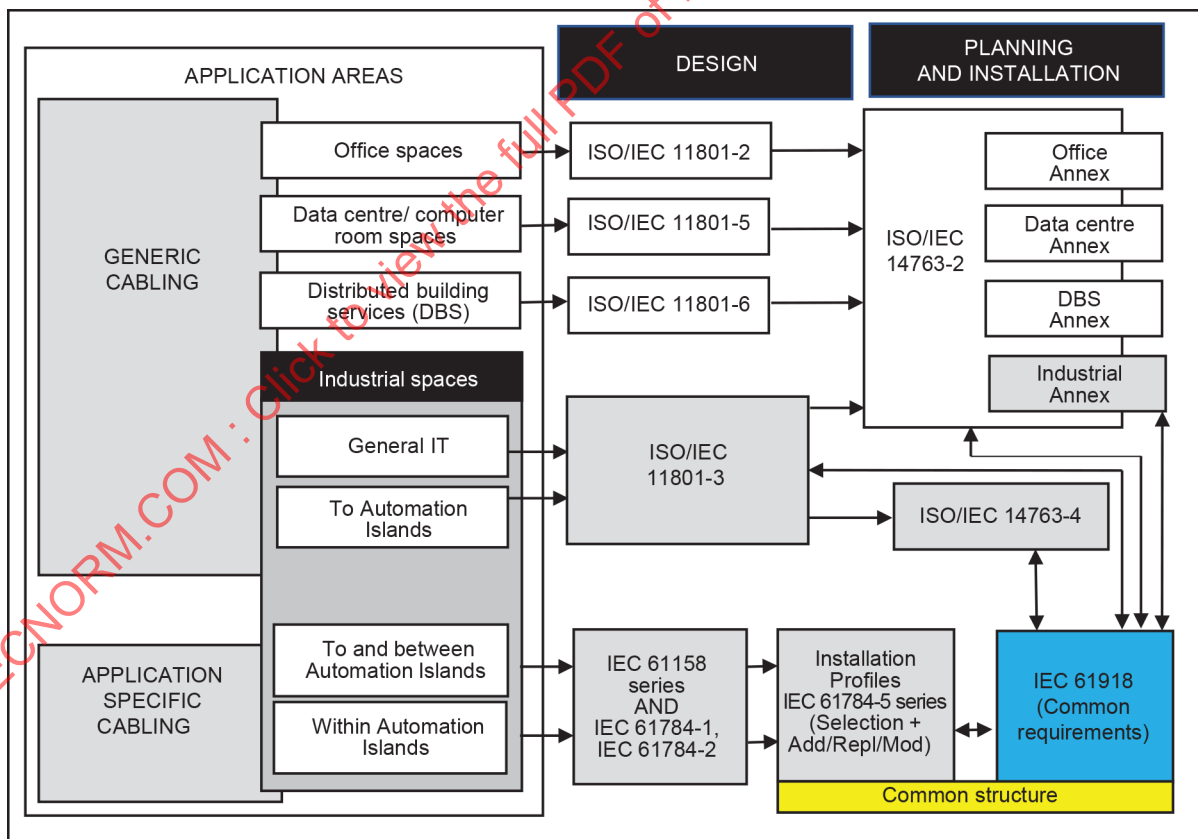
This document is one of a series produced to facilitate the use of communication networks in industrial control systems.

IEC 61918:2018, IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024 provide the common requirements for the installation of communication networks in industrial control systems. This installation profile standard provides the installation profiles of the communication profiles (CP) of a specific communication profile family (CPF) by stating which requirements of IEC 61918 fully apply and, where necessary, by supplementing, modifying, or replacing the other requirements (see Figure 1).

For general background on fieldbuses, their profiles, and relationship between the installation profiles specified in this document, see IEC 61158-1.

Each CP installation profile is specified in a separate annex of this document. Each annex is structured exactly as the reference standard IEC 61918 for the benefit of the persons representing the roles in the fieldbus installation process as defined in IEC 61918 (planner, installer, verification personnel, validation personnel, maintenance personnel, administration personnel). By reading the installation profile in conjunction with IEC 61918, these persons immediately know which requirements are common for the installation of all CPs and which are modified or replaced. The conventions used to draft this document are defined in Clause 5.

The provision of the installation profiles in one standard for each CPF (for example IEC 61784-5-2 for CPF 2) allows readers to work with standards of a convenient size.



IEC

Figure 1 – Standards relationships

## INTRODUCTION to Amendment 1

This Amendment 1 includes the following significant technical changes with respect to IEC 61784-5-2:2018:

- a) Updated references of IEC 61918:2018 to include additions of IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024,
- b) Added references for consideration of security to Subclause B.4.2.2,
- c) Updated optical fiber specifications and references in Subclauses B.4.3.3.2 and B.4.4.1.4,
- d) Added definition of electromagnetic compatibility options for conformance to Subclause B.4.4.1.2.1,
- e) Added support of mesh bonding systems to Subclause B.4.4 and Clause B.5,
- f) Added acceptance of end-to-end link verification and certification testing to Clause B.6.

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## INDUSTRIAL COMMUNICATION NETWORKS – PROFILES –

### Part 5-2: Installation of fieldbuses – Installation profiles for CPF 2

#### 1 Scope

This part of IEC 61784-5 specifies the installation profiles for CPF 2 (CIP™<sup>1</sup>).

The installation profiles are specified in the annexes. These annexes are read in conjunction with IEC 61918:2018, IEC 61918:2018/AMD1:2022 and IEC 61918:2018/AMD2:2024.

#### 2 Normative references

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

IEC 61918:2018<sup>2</sup>, *Industrial communication networks – Installation of communication networks in industrial premises*  
IEC 61918:2018/AMD1:2022  
IEC 61918:2018/AMD2:2024

NOTE For profile specific normative references, see Clauses A.2, B.2, and C.2.

#### 3 Terms, definitions and abbreviated terms

For the purpose of this document, the terms, definitions and abbreviated terms given in IEC 61918:2018 Clause 3, IEC 61918:2018/AMD1:2022, Clause 3, and Clauses A.3, B.3, C.3 of this document, 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>

#### 4 CPF 2: Overview of installation profiles

CPF 2 consists of three basic communication profiles as specified in IEC 61784-1 and IEC 61784-2. These profiles share a common upper layers protocol named CIP™ (Common Industrial Protocol).

<sup>1</sup> CIP™ (Common Industrial Protocol) is a trade name of ODVA, Inc. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this document does not require use of the trade name CIP™. Use of the trade name CIP™ requires permission of ODVA, Inc.

<sup>2</sup> The normative references of IEC 61918:2018, Clause 2, IEC 61918:2018/AMD1:2022, Clause 2 and IEC 61918:2018/AMD2:2024, Clause 2, apply.

The installation requirements for CP 2/1 (ControlNet™<sup>3</sup>) are specified in Annex A.

The installation requirements for CP 2/2 (EtherNet/IP™<sup>4</sup>) are specified in Annex B.

The installation requirements for CP 2/3 (DeviceNet™<sup>5</sup>) are specified in Annex C.

## 5 Installation profile conventions

The numbering of the clauses and subclauses in the annexes of this document corresponds to the numbering of IEC 61918 main clauses and subclauses.

The annex clauses and subclauses of this document supplement, modify, or replace the respective clauses and subclauses in IEC 61918.

Where there is no corresponding subclause of IEC 61918 in the normative annexes in this document, the subclause of IEC 61918 applies without modification.

The annex heading letter represents the installation profile assigned in Clause 4. The annex (sub)clause numbering following the annex letter shall represent the corresponding (sub)clause numbering of IEC 61918.

EXAMPLE "Subclause B.4.4" in IEC 61784-5-2 means that CP 2/2 specifies the Subclause 4.4 of IEC 61918:2018.

All main clauses of IEC 61918 are cited and apply in full unless otherwise stated in each normative installation profile annex.

If all subclauses of a (sub)clause are omitted, then the corresponding IEC 61918 (sub)clause applies.

If in a (sub)clause it is written "Not applicable.", then the corresponding IEC 61918 (sub)clause does not apply.

If in a (sub)clause it is written "*Addition*:", then the corresponding IEC 61918 (sub)clause applies with the additions written in the profile.

If in a (sub)clause it is written "*Replacement*:", then the text provided in the profile replaces the text of the corresponding IEC 61918 (sub)clause.

NOTE A replacement can also comprise additions.

If in a (sub)clause it is written "*Modification*:", then the corresponding IEC 61918 (sub)clause applies with the modifications written in the profile.

---

<sup>3</sup> ControlNet™ is a trade name 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 to this profile does not require use of the trade name ControlNet™. Use of the trade name ControlNet™ requires the permission of ODVA, Inc.

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<sup>5</sup> DeviceNet™ is a trade name 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 to this document does not require use of the trade name DeviceNet™. Use of the trade name DeviceNet™ requires the permission of ODVA, Inc.

If all (sub)clauses of a (sub)clause are omitted but in this (sub)clause it is written "(Sub)clause *x* has "addition:" (or "replacement:") or "(Sub)clause *x* is not applicable.", then (Sub)clause *x* becomes valid as declared and all the other corresponding IEC 61918 (sub)clauses apply.

## 6 Conformance to installation profiles

Each installation profile within this document includes part of IEC 61918:2018. It may also include defined additional specifications.

A statement of compliance to an installation profile of this document shall be stated as either

Compliance with IEC 61784-5-2:2018 and IEC 61784-5-2:2018/AMD1:2024 for CP 2/m <name> or

Compliance with IEC 61784-5-2 (Ed.4.1) for CP 2/m <name>.

where the name within the angle brackets < > is optional and the angle brackets shall not be included. The m within CP 2/m shall be replaced by the profile number 1 to 3.

NOTE The name can be the name of the profile, e.g. ControlNet, EtherNet/IP or DeviceNet.

If the name is a trade name then the permission of the trade name holder shall be required.

Product standards shall not include any conformity assessment aspects (including quality management provisions), neither normative nor informative, other than provisions for product testing (evaluation and examination).

## Annex A (normative)

### CP 2/1 (ControlNet™) specific installation profile

#### A.1 Installation profile scope

*Addition:*

This annex specifies the installation profile for Communication Profile CP 2/1 (ControlNet). The CP 2/1 is specified in IEC 61784-1.

The installation profiles are specified in the annexes. These annexes are read in conjunction with IEC 61918:2018.

#### A.2 Normative references

*Addition:*

IEC 60096-2:1961<sup>6</sup>, *Radio-frequency cables – Part 2: Relevant cable specifications*

#### A.3 Installation profile terms, definitions, and abbreviated terms

##### A.3.1 Terms and definitions

##### A.3.2 Abbreviated terms

*Addition:*

DVM	Digital voltmeter
HMI	Human machine interface
I/O	Input/Output
IS	Intrinsic safety
MM	Multi mode
NAP	Network access port (local access to a device, i.e. not via the bus)
OTDR	Optical time domain reflectometer
PLC	Programmable logic controller
PVC	Polyvinyl chloride
RG6	Coaxial cable
SM	Single mode
TDR	Time domain reflectometer

##### A.3.3 Conventions for installation profiles

Not applicable.

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<sup>6</sup> This document has been withdrawn but for the purposes of this document, the edition cited is applicable.

## A.4 Installation planning

### A.4.1 General

#### A.4.1.1 Objective

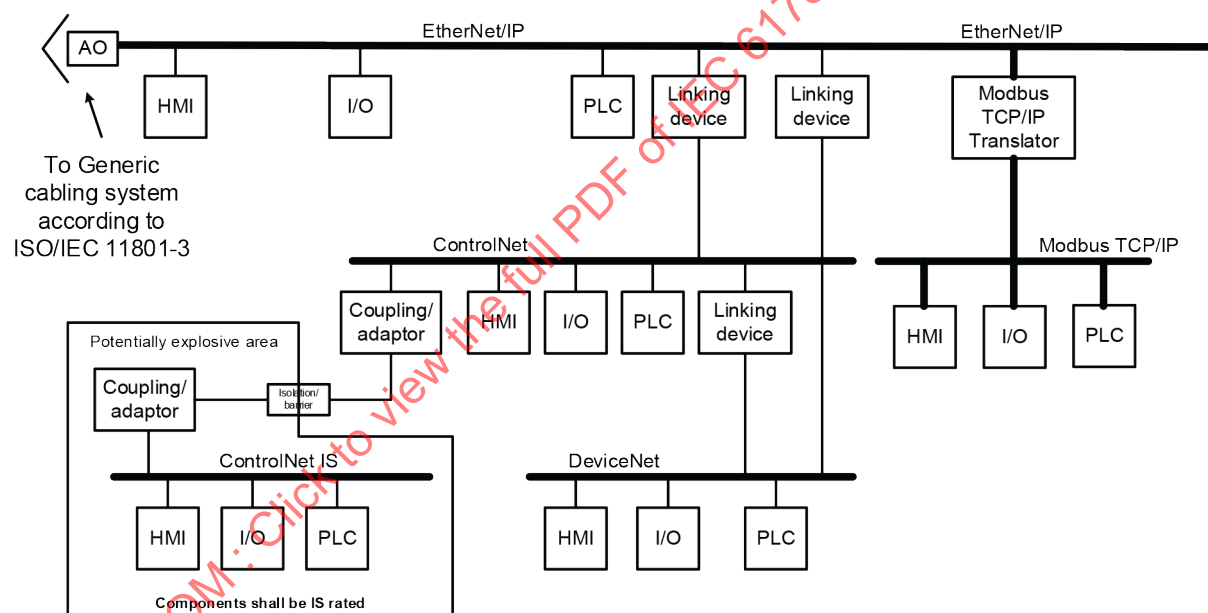
#### A.4.1.2 Cabling in industrial premises

*Addition:*

CP 2/1 networks can be connected to generic cabling via a converter/adaptor as mentioned in IEC 61918:2018, 4.1. Connection to the generic cabling system can also be facilitated through EtherNet/IP and the AO as shown in Figure A.1.

CP 2/1 is designed to be deployed within the automation island and between automation islands as detailed in IEC 61918:2018, 4.1.2, Figure 4, Figure 5 and Figure 6. The network is constructed of passive Taps <sup>[T]</sup> and Repeaters <sup>[R]</sup> interconnected by coaxial cable. Links are connected by Bridges <sup>[B]</sup>. The network can span an entire factory floor.

The interconnection of CP 2/1 with CP 2/2 and CP 2/3 can be accomplished through an appropriate converter/adaptor (linking device) as shown in Figure A.1.



**Figure A.1 – Interconnection of CPF 2 networks**

The CP 2/1 coaxial media system is made up of the components found in Figure A.2. These parts are as follows:

- coaxial cable and associated connectors (BNC/TNC);
- passive taps (non-sealed and sealed) with fixed 1 m drop cable BNC/TNC connector on the end of the drop cable, which shall not be extended under any circumstances;
- trunk line terminators BNC/TNC;
- repeaters (linear, ring and star) fibre and copper;
- various coaxial couplers, bulkhead, jack-to-jack and plug-to-plug (BNC/TNC).

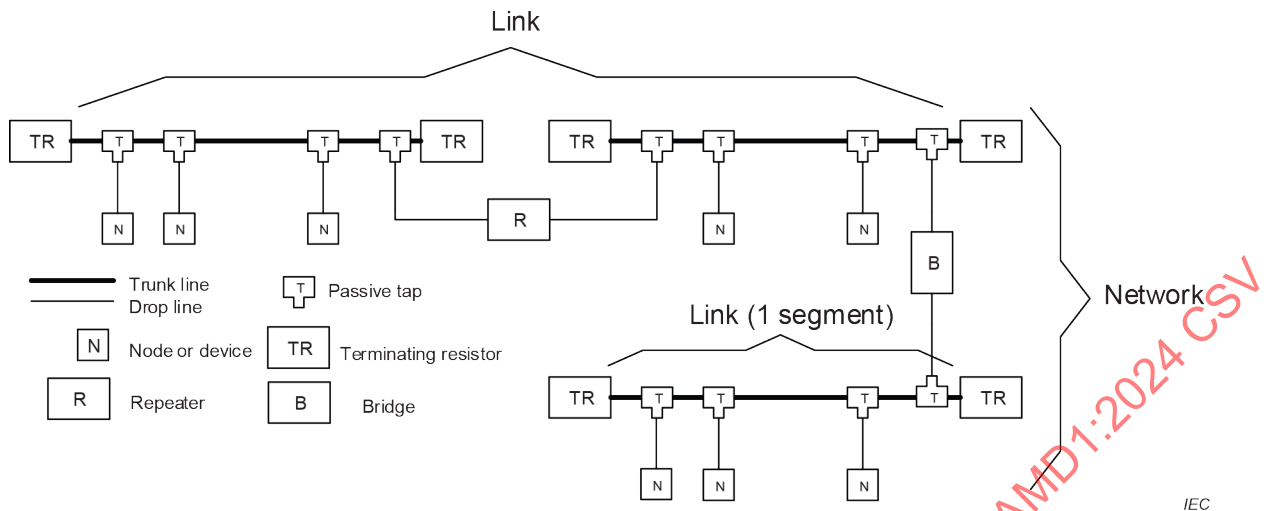


Figure A.2 – Overview of CPF 2/1 networks

**A.4.2 Planning requirements**

**A.4.2.1 Safety**

**A.4.2.1.1 General**

**A.4.2.1.2 Electrical safety**

**A.4.2.1.3 Functional safety**

Not applicable.

**A.4.2.1.4 Intrinsic safety**

Not applicable.

**A.4.2.1.5 Safety of optical fibre communication systems**

**A.4.2.2 Security**

**A.4.2.3 Environmental considerations and EMC**

**A.4.2.3.1 Description methodology**

*Addition:*

The configuration of the low-voltage power distribution system shall comply with local regulations. In some cases and geographical areas, additional earthing and bonding is necessary to control noise currents and provide a low noise functional earth for the low signal communications devices. This may be achieved through methods described in IEC 61918:2018, 4.4.7 and A.4.4.7.3 of this document.

This network uses a parallel RC between earth and the shield of the coaxial cable. The shields shall not directly reference to earth at any point in the system, as doing so will allow noise currents to flow in the shields causing high error rates in the network.

**A.4.2.3.2 Use of the described environment to produce a bill of material****A.4.2.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

Not applicable.

**A.4.3 Network capabilities****A.4.3.1 Network topology****A.4.3.1.1 Common description****A.4.3.1.2 Basic physical topologies for passive networks**

*Modification:*

ControlNet supports passive bus topologies. Passive star topologies are not supported.

**A.4.3.1.3 Basic physical topologies for active networks**

*Modification:*

ControlNet supports active linear, star and ring topologies.

**A.4.3.1.4 Combination of basic topologies**

*Addition:*

ControlNet supports both series connected and parallel connected linear passive bus topologies. In addition, ControlNet supports network redundancy using both series connected and parallel connected linear passive bus topologies. Both networks shall have the same number of active nodes in the same order on the network.

**A.4.3.1.5 Specific requirements for CPs**

*Addition:*

**A.4.3.1.5.1 General**

CP 2/1 supports both coaxial and fibre media in the trunk segments. Drop cables shall be coaxial. The network is an amplitude and delay limited network. In general, for the coaxial variant, amplitude is the limiting factor. Fibre trunk segments have much less loss, so delay limits can be readily exceeded. In either case, the amplitude and delay limits shall be observed. The maximum delay for any network construction (cabling and repeaters) shall be limited to 242  $\mu$ s round trip or 121  $\mu$ s each way.

ControlNet can be configured as a redundant network for both active star and active linear topologies in copper and fibre. See A.4.4.9.6 for specific design considerations. When configured as a redundant network, the number of nodes and addressing shall be the same for both networks.

The following Subclauses A.4.3.1.5.2 to A.4.3.1.5.8 describe the various components and topology constructions possible.

**A.4.3.1.5.2 Taps (coaxial media)**

Taps connect each node on a network to the coax media system via a fixed 1 m drop cable as shown in Figure A.3.

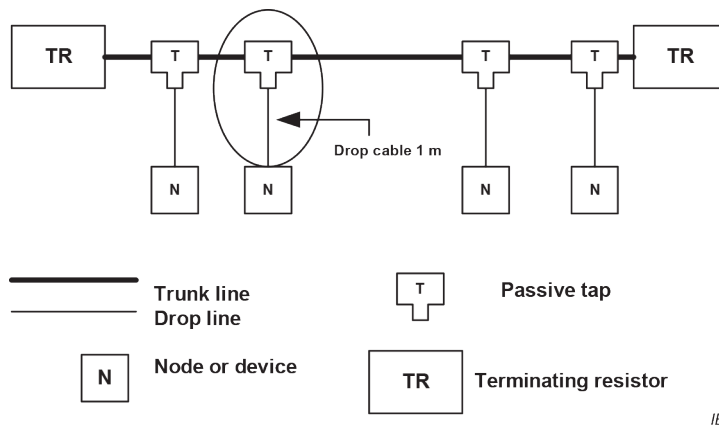


Figure A.3 – Drop cable requirements

#### A.4.3.1.5.3 Trunk cable

The trunk cable is the bus or central part of the CP 2/1 coax media system. The trunk cable is composed of multiple sections of cable. The standard cable that can be used to construct trunk cable sections is defined in A.4.4.1.2.1.

#### A.4.3.1.5.4 Trunk line connectors

BNC/TNC plugs are used to connect the coaxial cables to the taps. Devices are connected to the tap through a 1 m cable attached to the tap with the appropriate BNC/TNC plug. Each trunk cable section shall have a BNC or TNC plug installed on each end as shown in Figure A.4.

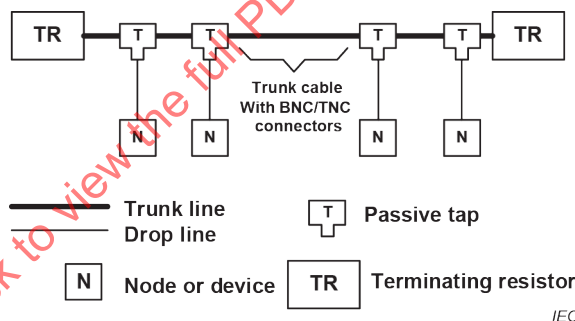
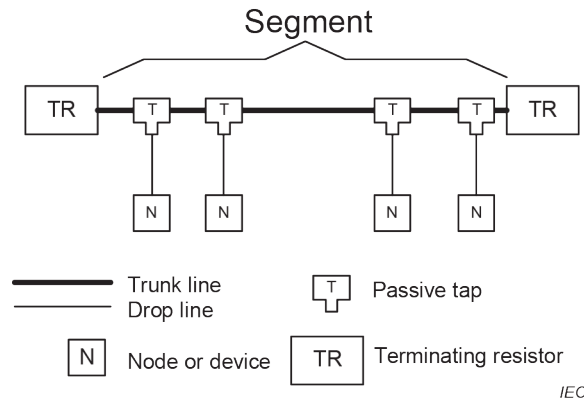


Figure A.4 – Placement of BNC/TNC plugs

#### A.4.3.1.5.5 Terminators

To minimize reflections, the network segment(s) shall be terminated with the appropriate 75  $\Omega$  coaxial terminators (see A.4.4.4.2).

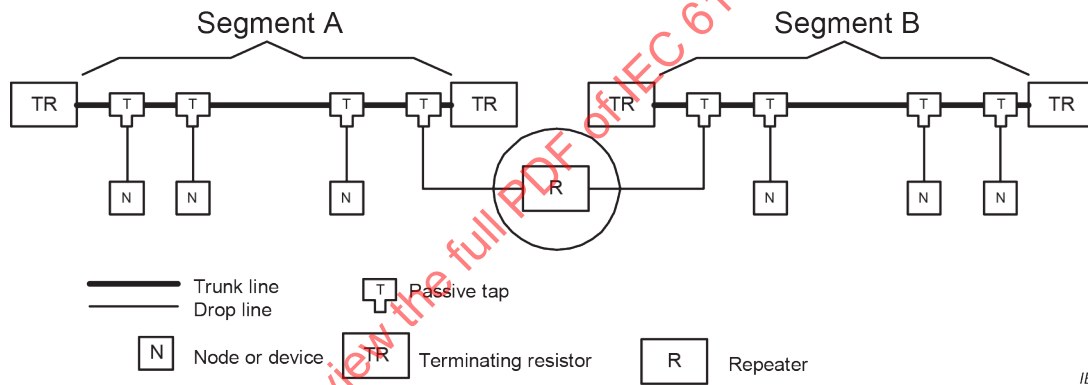
Figure A.5 details the location of the 75  $\Omega$  coaxial terminators. The designer shall specify the placement of the 75  $\Omega$  coaxial terminators in the design documentation. The terminators are generally installed on the outside port of the tap located at each end of a segment. The terminator is fully described in A.4.4.4.



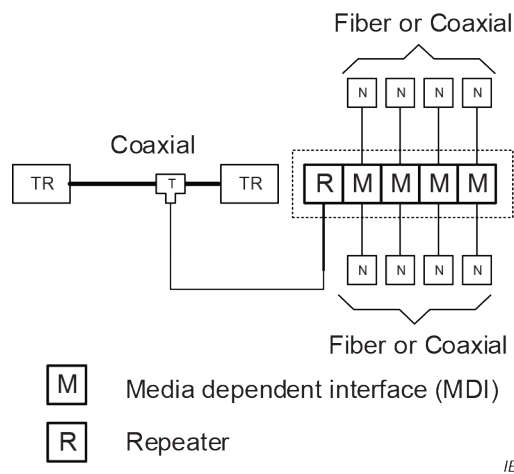
**Figure A.5 – Placement of terminators**

**A.4.3.1.5.6 Repeaters**

Repeater adapters shall be used to increase the number of taps, extend the total length of the network (see Figure A.6), or create an active star configuration as shown in Figure A.7. The number of repeaters and cable length total is limited depending on the network topology. See A.4.4.3.3.2 for information on limitations of length and number of nodes per segment. A repeater creates a new segment allowing additional cable or taps or both.



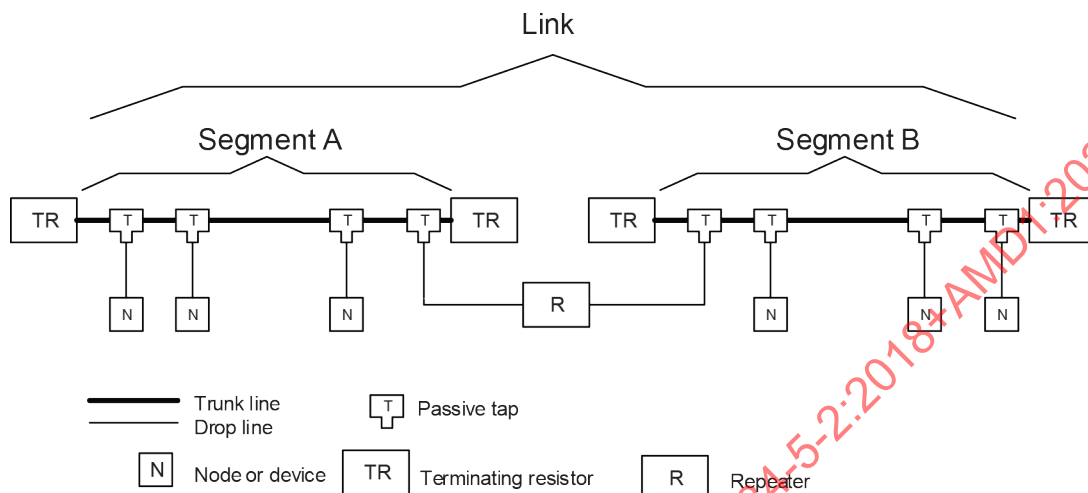
**Figure A.6 – Extending a network using repeaters**



**Figure A.7 – Extending a network using active star topology**

**A.4.3.1.5.7 Links**

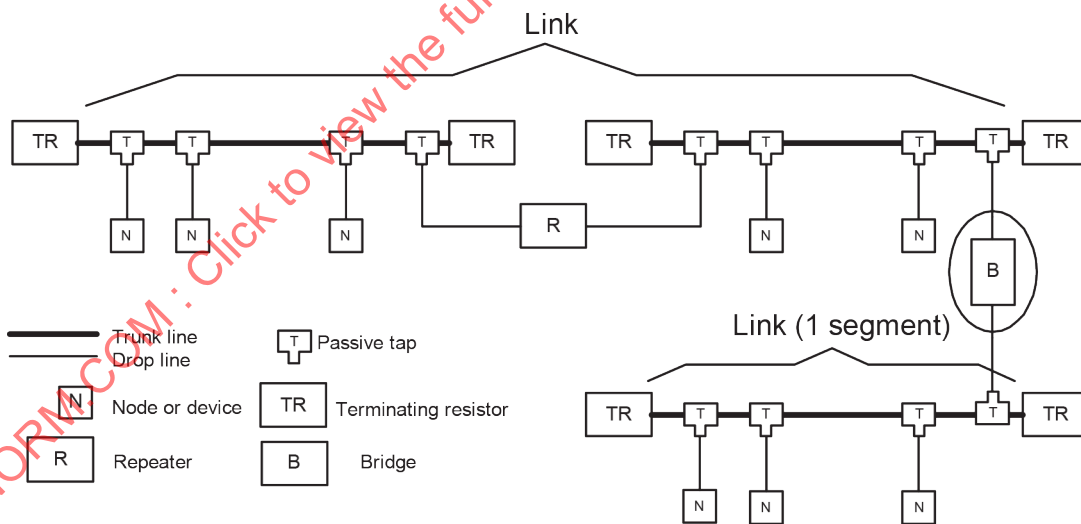
A link is formed by connecting multiple segments together through repeaters (see Figure A.8). A link may consist of only one segment. Each node in a link shall have a unique address in the range of 0 to 99. Node address 0 shall be reserved for devices that are auto address nodes or nodes without address switches.



**Figure A.8 – Links**

**A.4.3.1.5.8 Bridges**

Bridges may be used to connect links together and to extend the network addressing beyond 99 nodes. A bridge connects links together as shown in Figure A.9.



**Figure A.9 – Extending the network beyond 99 nodes**

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

#### A.4.3.2 Network characteristics

##### A.4.3.2.1 General

##### A.4.3.2.2 Network characteristics for balanced cabling not based on Ethernet

*Replacement:*

ControlNet is a coaxial based system, balanced cabling is not supported.

Table A.1 provides values based on the template given in IEC 61918:2018, Table 1.

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

Characteristics	CP 2/1
<b>Basic transmission technology</b>	Linear bus
<b>Length / transmission speed</b>	
Transmission speed	Segment length m
5 Mbit/s	Segment: 1 000 m maximum (see Figure A.10) Link: 20 km maximum <sup>a</sup>
<b>Maximum capacity</b>	<b>Max. no.</b>
Devices / segment	48
Devices / link	99
Devices / network	Unlimited
<sup>a</sup> The total link length is limited to 20 km due to delay limitations of 242 $\mu$ s round trip (121 $\mu$ s one-way trip).	

##### A.4.3.2.3 Network characteristics for balanced cabling based on Ethernet

Not applicable.

##### A.4.3.2.4 Network characteristics for optical fibre cabling

*Replacement:*

The allowable fibre segment lengths and wavelengths are detailed in Table A.2 for CP 2/1 based on the template given in IEC 61918:2018, Table 3.

**Table A.2 – Network characteristics for optical fibre cabling**

CP 2/1		
Optical fibre type	Description	
Single mode silica	Bandwidth (MHz) or equivalent at $\lambda$ (nm)	20 MHz 1 310 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	20 000 <sup>b</sup>
	Maximum channel Insertion loss/optical power budget (dB)	10,5
	Connecting hardware	See A.4.4.2.5
Multimode silica	Modal bandwidth (MHz × km) at $\lambda$ (nm)	20 MHz 1 300 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	M = 3 000 <sup>c</sup> L = 10 000 <sup>c</sup> XL = 10 000 <sup>c</sup>
	Maximum channel Insertion loss/optical power budget (dB)	M = 13,3 L = 15 XL = 10,5
	Connecting HW	See A.4.4.2.5
POF	Modal bandwidth (MHz × km) at $\lambda$ (nm)	–
	Minimum length (m)	–
	Maximum length <sup>a</sup> (m)	–
	Maximum channel Insertion loss/optical power budget (dB)	–
	Connecting HW	–
Hard clad silica	Modal bandwidth (MHz × km) at $\lambda$ (nm)	20 MHz 650 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	300
	Maximum channel Insertion loss/optical power budget (dB)	4,2 <sup>d</sup>
	Connecting HW	See A.4.4.2.5
<sup>a</sup> This value is reduced by connections, splices and bends in accordance with Formula (1) in 4.4.3.4.1 of IEC 61918:2018. <sup>b</sup> Extra Long Repeaters Only. <sup>c</sup> M = Medium distance capable modules, L = Long distance capable modules and XL = Extra long distance capable modules. <sup>d</sup> Short distance modules only.		

**A.4.3.2.5 Specific network characteristics**

*Addition:*

CP 2/1 supports active fibre rings, active line and active star topologies.

Fibre redundancy is only available for active linear and active star topologies, see A.4.4.9.6 for the design and limitations of redundant networks.

Fibre ring is inherently redundant and does not require duplicate hardware.

**A.4.3.2.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****A.4.4 Selection and use of cabling components****A.4.4.1 Cable selection****A.4.4.1.1 Common description****A.4.4.1.2 Copper cables****A.4.4.1.2.1 Balanced cables for Ethernet-based CPs**

Not applicable.

**A.4.4.1.2.2 Copper cables for non-Ethernet-based CPs**

*Replacement:*

The selection of connector and installation tools shall be compatible with coaxial cable (referred to as RG6). If these are not properly matched, network failures may result.

The coaxial cable electrical requirements, on which the standard topology is based, can be found in Table A.3. The mechanical properties for the standard coaxial cable are described in Table A.4. These parameters (electrical and mechanical) can be used to procure the proper cable for standard installations. Speciality cables as described in Table A.5 may require different mechanical and/or electrical properties and therefore shall be accounted for in the network length limits and tools used for connector installation. Since the network is designed to be a 75  $\Omega$  system, substitution of the cable impedance is not allowed.

The electrical parameters detailed in Table A.3 shall be met in order to maintain standard network configurations as described in this installation profile.

**Table A.3 – RG6 coaxial electrical properties**

Specification	Limits/Characteristics
Shielding	Quad shield
Impedance	$(75 \pm 3) \Omega$
Delay	$(4,1 \pm 0,1) \text{ ns/m}$
Frequency	Attenuation (dB/100 m)
1 MHz	1,15
2 MHz	1,25
5 MHz	1,48
10 MHz	1,94
20 MHz	2,82
50 MHz	4,49
Structural return loss	23 dB minimum from 5 MHz to 50 MHz
Conductor DC resistance	92 $\Omega$ /km nominal
Shield DC resistance	24 $\Omega$ /km nominal
Capacitance	53,2 pF/m

The physical parameters listed in Table A.4 shall be met in order to maintain noise immunity and connector compatibility.

**Table A.4 – RG6 coaxial physical parameters**

Specification	Characteristics
Centre conductor material and diameter	18 AWG solid bare copper covered steel $0,823 \text{ mm}^2 \pm 0,020 \text{ 4 mm}^2$
Dielectric material and diameter	$4,65 \text{ mm} \pm 0,13 \text{ mm}$
Shield construction 4 layers	Layer 1: foil Layer 2: 60 % braid Layer 3: foil Layer 4: 40 % braid
Jacket diameter	$7,67 \text{ mm} \pm 0,13 \text{ mm}$

*Addition:*

CP 2/1 uses 75  $\Omega$  RG6 quad shield coaxial cables compliant with IEC 60096-2.

Specific cable designs shall be selected based on the application and the environment. The MICE concept can be used to help determine the environmental conditions and to select components and/or appropriate mitigation. Table A.5 provides guidance for application-specific cables.

**Table A.5 – Cable type selection**

Application type	Example cable type <sup>a</sup>
Light industrial applications	Standard – PVC CM-CL2
Industrial applications	Lay-on armoured and interlocking armour
High and low temperature application, as well as corrosive area (harsh chemicals – see manufacturing data sheets for chemical resistivity)	Plenum-FEP CMP-CL2P
Festooning or flexing applications (rolling "C" track and robotic tic-toc)	High flex
Moisture resistant applications; direct burial, with flooding compound, fungus resistant	Flood burial
<sup>a</sup> See the local cable distributor for cable availability.	

All coaxial cables used in the ControlNet system shall meet the electrical requirements of this Clause A.4. In addition, they shall be constructed with quad shields (single, dual and tri shields are not allowed). It is important that the attenuation be met over the frequencies listed in this Clause A.4. If the attenuation is greater than listed in this Clause A.4, additional length derating shall be determined by using the equations in this Clause A.4. If the segment attenuation is too high, the segment shall be divided using repeaters.

The cabling components shall be selected based on the environmental and application requirements. Highflex applications shall use cables designed to meet high flex. Cables expected to be subjected to weld splatter shall have the appropriate protection or jacket designs. Cables used in outdoor applications, shall have the appropriate UV protection or jacketing design.

#### **A.4.4.1.3 Cables for wireless installation**

#### **A.4.4.1.4 Optical fibre cables**

*Addition:*

For optical fibre, cabling shall conform to the requirements given in Table A.2. In addition the planner shall consider the following.

The planner shall define the maximum cable length allowed between any two devices. When installing optical fibre cables, this maximum cable length shall not exceed the lengths as defined in Table A.2. Using special cables or optical fibre splices can further reduce cable lengths. Reliable data transmission may be ensured up to this certified length if the cables and the connections have been installed correctly.

The properties of an optical fibre transmission system are mainly characterized by:

- the output power of the optical interface;
- the type of cable used;
- the quality of installation and the plug configuration.

Planner and installer shall observe the insertion loss requirements (cables and connectors) to insure proper functioning segment. In addition, the instructions of the cable, plug connector and device manufacturer shall be observed. For optical fibre cables of an industrial network the planner shall use the data defined in Table A.6.

Some additional information that shall be considered by the installer and maintenance personnel are given in the relevant clauses of this document.

Table A.6 provides values based on the template given in IEC 61918:2018, Table 6.

**Table A.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	OS1	OM1, OM2 or OM3 1 300 nm	OM1, OM2 or OM3 1 300 nm	–	–
Attenuation per km (650 nm)	–	–	–	–	≤ 6,0 dB
Attenuation per km (820 nm)	–	–	–	–	–
Attenuation per km (1 310 nm)	≤ 1,0 dB or OS1	≤ 2,5 dB or OM1	≤ 3,5 dB or OM1	–	–
Number of optical fibres	2	2	2	–	2
Connector type (e.g. duplex or simplex)	BFOC 2,5	BFOC 2,5	BFOC 2,5	–	V-Pin
Jacket colour requirements	User defined	User defined	User defined	–	User defined
Jacket material	Application specific	Application specific	Application specific	–	Application specific
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	Yes <sup>a</sup>	Yes <sup>a</sup>	Yes <sup>a</sup>	–	Yes <sup>a</sup>
NOTE Duplex and simplex cords/cables are supported.					
<sup>a</sup> If application requires.					

**A.4.4.1.5 Special purpose balanced and optical fibre cables**

**A.4.4.1.6 Specific requirements for CPs**

Not applicable.

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

**A.4.4.2 Connecting hardware selection**

**A.4.4.2.1 Common description**

**A.4.4.2.2 Connecting hardware for balanced cabling CPs based on Ethernet**

Not applicable.

**A.4.4.2.3 Connecting hardware for copper cabling CPs not based on Ethernet**

*Replacement:*

The connectors used in this network are limited to those shown in Table A.7.

**Table A.7 – Copper connectors for ControlNet**

CP 2/1	Coaxial IEC 61169-8	Others
Characteristics for CP 2/1 (ControlNet)	BNC	TNC RJ45 (NAP)

*Addition:*

The centre conductor contact shall be plated in conformance with one of the following specifications:

- 0,75  $\mu\text{m}$  gold minimum over 1,25  $\mu\text{m}$  nickel minimum over base metal;
- 0,05  $\mu\text{m}$  to 0,2  $\mu\text{m}$  gold flash over 1,25  $\mu\text{m}$  palladium nickel minimum over 1,25  $\mu\text{m}$  nickel minimum over base metal.

The connector characteristic impedance shall be 75  $\Omega$  nominal, 45  $\Omega$  minimum and 80  $\Omega$  maximum, from DC to 50 MHz.

For network reliability, the cables, connectors and installation tools shall be mechanically compatible. The cable and connector manufacturer's data sheets shall be consulted for compatibility and installation tool requirements.

Passive taps are used to connect the trunk sections together and provide a connection point for each node. A tap is required for each active device connected to the network. There are two variants of the taps available:

- sealed meeting IP67 minimum, using TNC connectors;
- non-sealed meeting IP65 maximum, using BNC connectors.

For reliability reasons, the number of connections in a segment shall be minimized.

The cabling components shall be selected based on the environmental and application requirements.

**A.4.4.2.4 Connecting hardware for wireless installation****A.4.4.2.5 Connecting hardware for optical fibre cabling***Replacement:*

Table A.8 provides values based on the template given in IEC 61918:2018, Table 9.

**Table A.8 – 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	VPIN
<b>CP 2/1 (ControlNet)</b>	Yes	No	No	No	No	Yes
NOTE The 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.						

To minimize noise coupling into the sensitive receiver, connectors with plastic or ceramic ferrules are recommended.

Table A.9 provides values based on the template given in IEC 61918:2018, Table 10.

**Table A.9 – Relationship between FOC and fibre types (CP 2/1)**

FOC	Fibre type					
	9..10/125 $\mu\text{m}$ single mode silica	50/125 $\mu\text{m}$ multimode silica	62,5/125 $\mu\text{m}$ multimode silica	980/1 000 $\mu\text{m}$ step index POF	200/230 $\mu\text{m}$ step index hard clad silica	Others
BFOC/2,5	No	Yes	Yes	No	No	No
SC	No	No	No	No	No	No
SC-RJ	No	No	No	No	No	No
LC	No	No	No	No	No	No
F-SMA	No	No	No	No	No	No
V-PIN	No	No	No	No	Yes	No

Insertion loss correction factors shall be used when using MMF fibres smaller than 62,5/125  $\mu\text{m}$ .

**A.4.4.2.6 Specific requirements for CPs**

Not applicable.

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

**A.4.4.3 Connections within a channel/permanent link**

**A.4.4.3.1 Common description**

Not applicable.

**A.4.4.3.2 Balanced cabling connections and splices for CPs based on Ethernet**

Not applicable.

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

**A.4.4.3.3.1 Common description**

**A.4.4.3.3.2 Connections minimum distance**

*Replacement:*

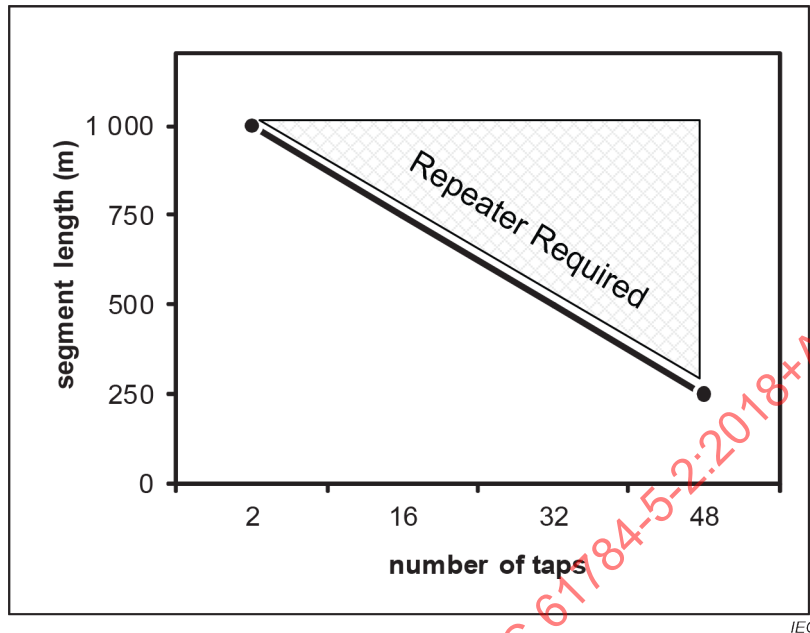
**a) General**

The shortest path for routing the cable shall be selected to minimize the amount of cable needed. The specific details of planning cabling route depend upon the needs of the network.

When determining the cable length of trunk-cable sections, it is important to measure the actual cable path as it is routed in the network. Vertical dimensions as well as horizontal dimensions shall be considered. The three-dimensional routing path distance shall always be calculated when determining cable lengths.

The total allowable length of a segment containing standard RG6 quad shield depends on the requirements of Table A.1 and Table A.3, and of the number of taps in the segment. There is no minimum trunk-cable section or segment length requirement. The maximum allowable total length of a segment is 1 000 m with two taps installed. Each additional tap decreases the

maximum length of the segment by 16,3 m. The maximum number of taps allowed on a segment is 48. With 48 taps the maximum segment length is limited to 250 m. Figure A.10 details the relationship between the number of taps allowed in a segment and the segment length. If the network design falls in the grey area, then a repeater is required.



**Figure A.10 – Maximum allowable taps per segment**

Maximum allowable segment length = 1 000 m – 16,3 m × [number of taps – 2]

#### EXAMPLE 1

The following is an example of how to calculate the number of taps allowed for different segment lengths.

If the segment requires 10 taps, then the maximum segment length is:

$$1\,000\text{ m} - 16,3\text{ m} \times [10 - 2]$$

$$1\,000\text{ m} - 130,4\text{ m} = 869,6\text{ m}$$

The amount of high flex RG6 cable that can be used in a system is less than the amount of standard RG6 cable. The designer is encouraged to keep the length of high flex cable use to a minimum. BNC bullet connectors or isolated bulkhead connectors shall be used to isolate areas that require high flex RG6 cable from areas that require standard RG6 cable; this allows the high flex RG6 section to be replaced before flex life is exhausted. An allowable total length of RG6 flex cable segment in the application can be determined using the equation below. Each additional tap decreases the maximum length of the segment. The maximum segment length depends on the attenuation of the high flex cable used. The maximum allowable segment length is then as follows:

$$\text{Segment}_{\text{Length}} = \frac{[20,29\text{ dB} - (\text{Number}_{\text{taps}} \times 0,32\text{ dB})]}{\text{Cable}_{\text{Attenuation@10MHz}}}$$

Important: The cable attenuation at 10 MHz per unit length is defined as the signal loss measured at 10 MHz per 100 m of cable.

Cable attenuation for ControlNet cables are listed in the manufacturers' data sheets.

#### EXAMPLE 2

The cable selected for this example is high flex cable. The attenuation for this high flex coaxial cable is 2,36 dB per 100 m at 10 MHz. For a segment that requires 3 taps using high flex cable, the maximum segment length is:

$$\text{Segment}_{\text{Length}} = \left[ \frac{[20,29 \text{ dB} - (3 \times 0,32 \text{ dB})]}{2,36 \text{ dB}} \right] \times 100\text{m}$$

or

$$\text{Segment}_{\text{Length}} = \left[ \frac{19,33 \text{ dB}}{2,36 \text{ dB}} \right] \times 100 \text{ m} = 820 \text{ m}$$

The total trunk-cable length or number of taps (connections) can be increased by breaking up the segment into smaller segments.

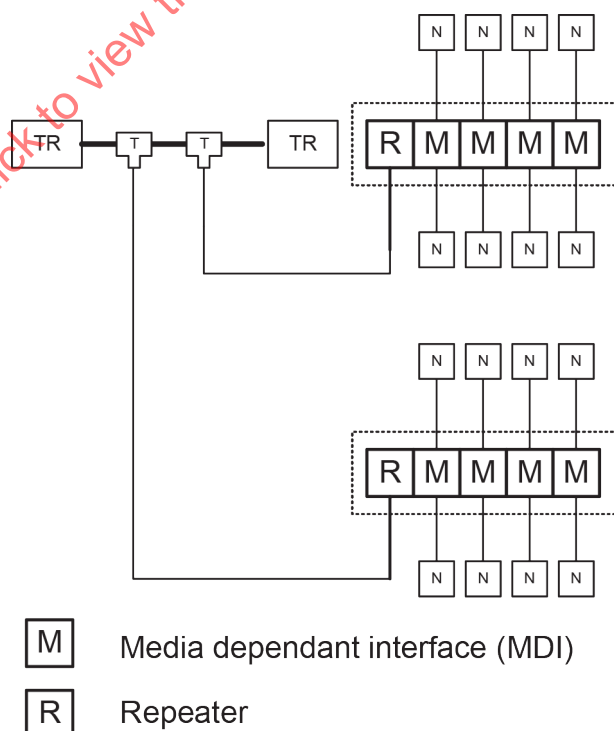
### b) Repeaters

ControlNet supports copper and fibre repeaters. Regardless of the media, the repeaters can be configured in the following topologies.

A link may be configured in one of five ways:

- series up to 20 repeaters;
- star topology (see Figure A.11);
- parallel up to 48 repeaters (see Figure A.12);
- combination of series and parallel (see Figure A.13);
- ring up to 20 repeaters (see Figure A.14).

The total link length is limited to 20 km due to delay limitations of 121 μs each way (242 μs round trip).



IEC

Figure A.11 – Example of repeaters in star configuration

The appropriate repeater module is required for the specific repeater topology needed. For example ring capable repeaters are required for fibre ring topologies.

A repeater can be connected to a segment at any tap location along the trunk. Fibre repeaters may be connected in series through the fibre ports.

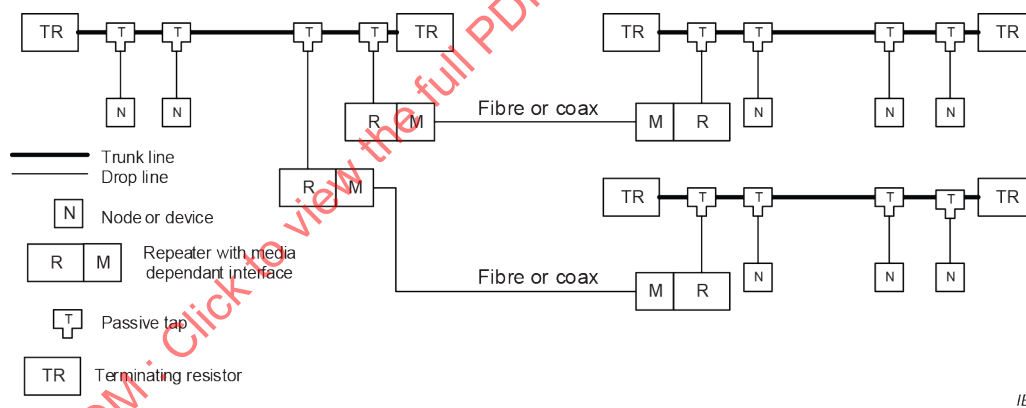
The maximum link length is based on the distance between any two nodes. The maximum distance between any two nodes in a link is limited by the delay between the nodes. The maximum delay is limited to 121  $\mu$ s end-to-end or 242  $\mu$ s round trip.

### c) Series connected repeaters

When installing repeaters in series, ControlNet network management software should be used to verify that the system is an allowable configuration. The system size is based on the maximum number of repeaters (20) in series and length of the media used between any two nodes. The total network delay described above in b) shall not be exceeded. See the installation instructions that were shipped with the repeater for an example series topology drawing and configuration instructions.

### d) Parallel connected repeaters

When installing repeaters in parallel, a maximum of 48 repeaters (the maximum number of taps per 250 m segment) on any one segment is allowed. If the link is configured using repeaters in parallel, one shall count one of the repeater taps for one segment and the other repeater tap for the parallel segment that the repeater is connecting to the backbone network. See Figure A.12 for an example of repeaters in parallel. For further instructions on repeaters in series and parallel, see the instructions that were shipped with the repeater.



IEC

Figure A.12 – Repeaters in parallel

### e) Repeaters in a combination of series and parallel

Repeaters can be installed in a combination of series and parallel connections to form a link. The guidelines listed for each type shall be followed. For mixed topologies (series and parallel), the maximum number of repeaters and media should be verified by using the appropriate network configuration software. See the installation instructions that were shipped with the repeater for an example combination series/parallel topology drawing. There shall not be more than one communication path to a node on a network. Ring repeaters have two paths by definition.

When the network is configured using repeaters in combination of series and parallel as shown in Figure A.13, it is important to count the taps and repeaters in all segments.

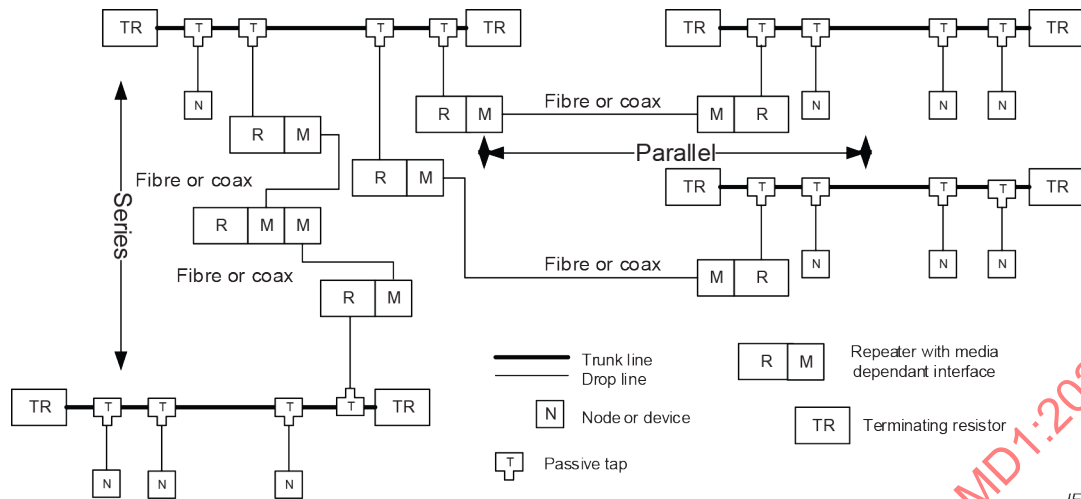


Figure A.13 – Repeaters in combination series and parallel

**f) Ring repeaters**

For a ring topology, the network designer shall use the appropriate ControlNet fibre ring repeaters. See Figure A.14 for an example of a fibre ring. See the installation instructions that were shipped with the repeater for instructions on setting up the ring. ControlNet supports both linear redundancy and ring topologies.

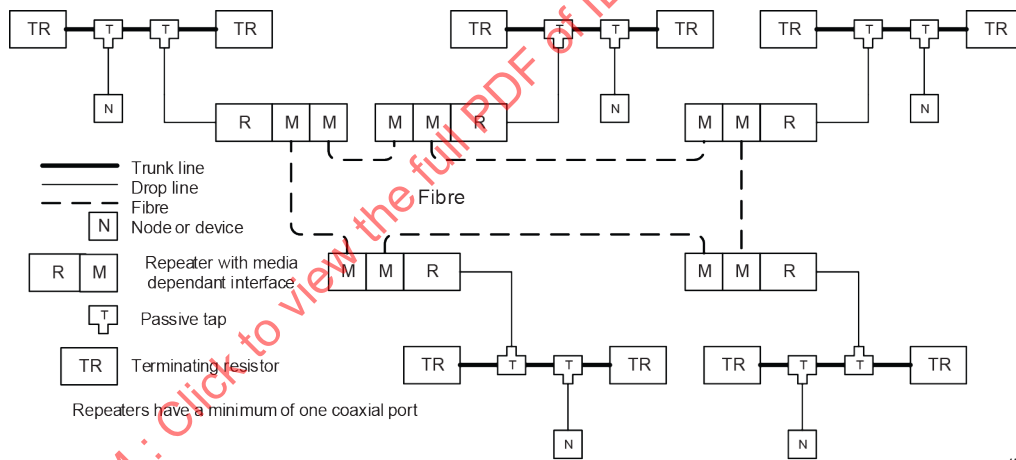


Figure A.14 – Ring repeater

**A.4.4.3.3.3 Copper cabling splices**

*Addition:*

The planner shall specify J-J BNC or TNC couplers when splices are necessary.

**A.4.4.3.3.4 Copper cabling bulkhead connections**

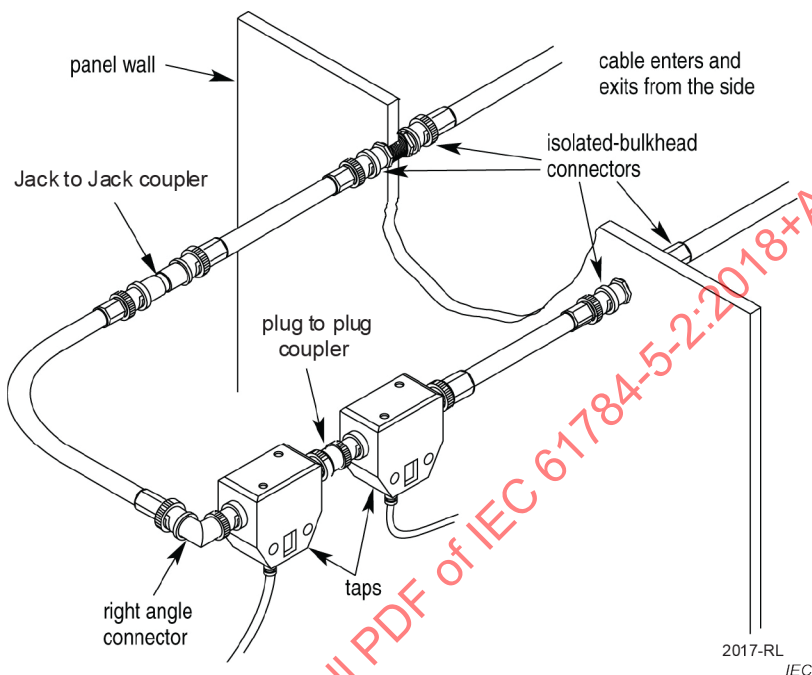
*Replacement:*

Copper bulkheads shall be isolated from earth. Copper bulkheads shall be constructed of back-to-back BNC jacks, TNC jacks or a combination of BNC and TNC jacks. They shall provide environmental isolation. Examples of how bulkheads are used in this profile are shown in Figure A.15.

When copper adaptors are used they shall have a nominal characteristic impedance of 75  $\Omega$ , 45  $\Omega$  minimum and 80  $\Omega$  maximum, from DC to 50 MHz.

In this example, ControlNet cable:

- enters and exits the panel enclosure from the side using isolated-bulkhead connectors;
- contains two adjacent taps connected by a barrel connector;
- reserves one future tap location with a bullet.



**Figure A.15 – Installing bulkheads**

#### **A.4.4.3.3.5 Copper cabling J-J couplers (J-J adaptors)**

*Replacement:*

When extending a trunk section, the appropriate BNC or TNC J-J coupler connector shall be used (see Figure A.15).

Copper adaptors shall have a nominal characteristic impedance of 75  $\Omega$ , 45  $\Omega$  minimum and 80  $\Omega$  maximum, from DC to 50 MHz

#### **A.4.4.3.4 Optical fibre cabling connections and splices for CPs based on Ethernet**

Not applicable.

#### **A.4.4.3.5 Optical fibre cabling connections and splices for CPs not based on Ethernet**

*Addition:*

The designer is encouraged to minimize the number of mechanical connections to minimize the risk of failure.

Each connection adds losses that shall be accounted for in the power budget found in Table A.2.

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

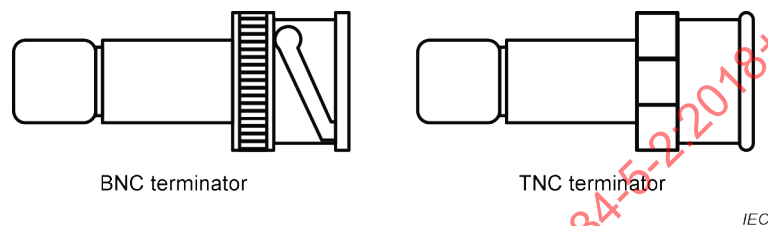
**A.4.4.4 Terminators**

**A.4.4.4.1 Common description**

**A.4.4.4.2 Specific requirements for CPs**

*Addition:*

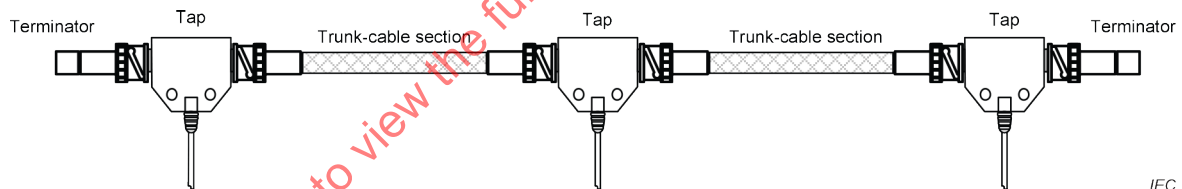
Terminators are required for ControlNet in order to minimize reflections in the trunk system. Figure A.16 shows examples of BNC and TNC coaxial terminators. A 75 Ω terminator shall be placed at the end of each segment for the ControlNet cable system (see Figure A.17 for placement).



**Figure A.16 – Coaxial BNC and TNC terminators**

The number of required terminators is determined by multiplying the number of segments by two.

The terminators shall be coaxial 75 Ω 1 %, 0,5 W low inductance BNC or TNC.



**Figure A.17 – Terminator placement in a segment**

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

Not applicable.

**A.4.4.5 Device location and connection**

**A.4.4.5.1 Common description**

**A.4.4.5.2 Specific requirements for CPs**

*Addition:*

Devices shall be installed in accordance with the following:

- manufacturer's documentation;
- planner's documentation;
- cable routing;

- location of the taps. Taps have a 1 metre maximum drop length.

#### **A.4.4.5.3 Specific requirements for wireless installation**

Not applicable.

#### **A.4.4.5.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **A.4.4.6 Coding and labelling**

#### **A.4.4.7 Earthing and bonding of equipment and devices and shielded cabling**

##### **A.4.4.7.1 Common description**

##### **A.4.4.7.2 Bonding and earthing of enclosures and pathways**

##### **A.4.4.7.2.1 Equalization and earthing conductor sizing and length**

*Addition:*

ControlNet supports both earthing schemes, Star and Equipotential earthing systems. If the building does not have an adequate equipotential earthing system, then the star earthing system shall be used to mitigate earth potential offsets within the communications coverage area. Equipotential earthing system can be installed in accordance with IEC 61918:2018.

##### **A.4.4.7.2.2 Bonding straps and sizing**

##### **A.4.4.7.3 Earthing methods**

##### **A.4.4.7.3.1 Equipotential**

##### **A.4.4.7.3.2 Star**

##### **A.4.4.7.3.3 Earthing of equipment (devices)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions.

##### **A.4.4.7.3.4 Copper bus bars**

##### **A.4.4.7.4 Shield earthing**

##### **A.4.4.7.4.1 Non-earthing or parallel RC**

*Modification:*

ControlNet coaxial shields are connected to earth via a parallel RC circuit that is integral to the active devices as modelled in Figure A.18. The coaxial shields shall not be directly bonded to earth as this will introduce noise in the network.

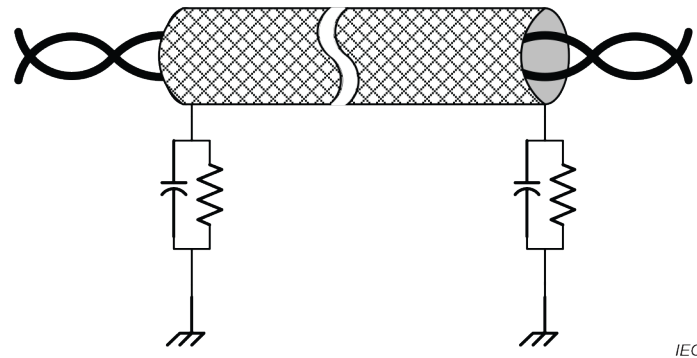


Figure A.18 – RC Shield Termination in Active Devices

**A.4.4.7.4.2 Direct**

Not applicable.

**A.4.4.7.4.3 Derivatives of direct and parallel RC**

Not applicable.

**A.4.4.7.5 Specific requirements for CPs**

Not applicable.

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

**A.4.4.8 Storage and transportation of cables**

**A.4.4.9 Routing of cables**

**A.4.4.9.1 Common description**

**A.4.4.9.2 Cable routing of assemblies**

**A.4.4.9.3 Requirements for cable routing inside enclosures**

*Addition:*

Cable sections that run inside protective equipment enclosures are relatively short. For wiring external to enclosures, the maximum separation shall be maintained between ControlNet cable and Category-1 conductors. The minimum separation from other circuits is defined in Table 17 of IEC 61918:2018. When running cable inside an enclosure, the installer shall route the conductors external to all pathways in the same enclosure, or in a pathway separate from Category-1 conductors.

**A.4.4.9.4 Cable routing inside buildings**

**A.4.4.9.5 Cable routing outside and between buildings**

**A.4.4.9.6 Installing redundant communication cables**

*Addition:*

A second trunk cable is used between ControlNet nodes for redundant media. With redundant media, nodes send signals on two separate segments. The receiving node compares the quality of the two signals and accepts the better signal to permit use of the best signal. This

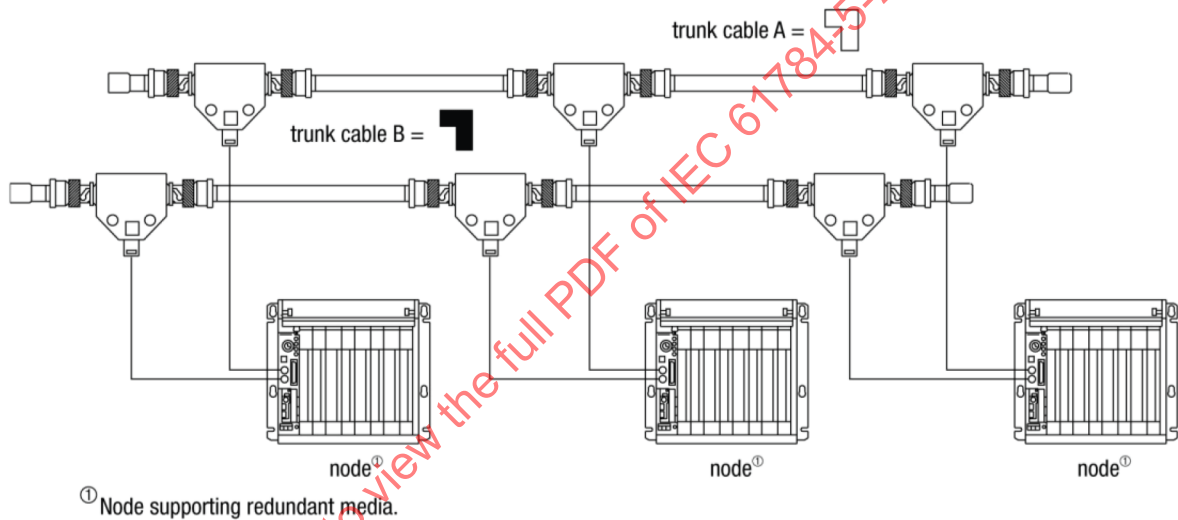
also provides a backup cable if one cable fails. Trunk cables on a redundant cable link are defined by the segment number and the redundant trunk-cable letter.

ControlNet products are labelled with the icons in Figure A.19. The light-coloured icon should be placed on drop cables connected to port A of the devices. The dark-coloured icon should then be placed on redundant node ports marked B. See Figure A.20 for redundant coax media example. Figure A.21 is an example of a redundant network using repeaters to extend the network. The difference in length of redundant network A and network B shall not exceed the limits in Figure A.22 for coax repeaters and Figure A.23 for fibre repeaters.



**Figure A.19 – Redundant network icons**

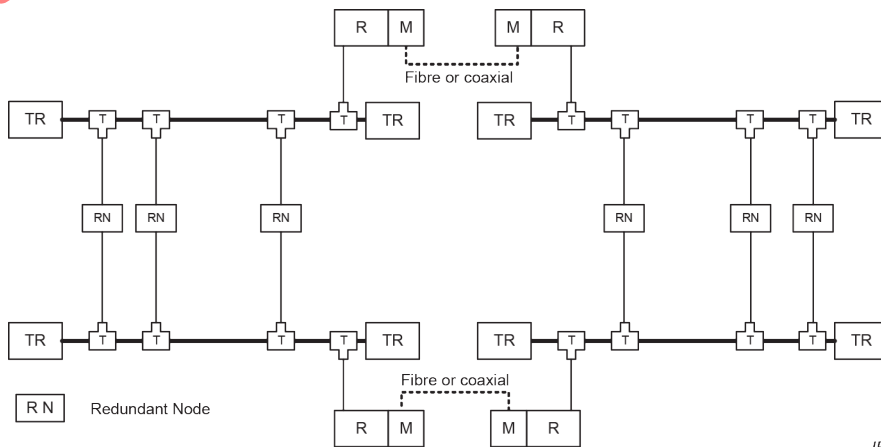
In Figure A.20, trunk cable A is denoted by the light icon and trunk cable B is denoted by the dark icon. The cabling system should be marked accordingly with the proper icon or letter. Redundant nodes are connected to trunk cable A and trunk cable B as shown in Figure A.20



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**Figure A.20 – Redundant coax media**

Fibre media can be used to extend a redundant network as shown in Figure A.21.



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**Figure A.21 – Redundant fibre media**

The following guidelines shall be observed when planning a redundant media system.

- The two trunk cables (trunk cable A and trunk cable B) shall be routed differently to reduce the chance of both cables being damaged at the same time.
- Each node on a redundant-cable link shall support redundant coax connections and be connected to both trunk cables at all times. Any nodes connected to only one side of a redundant-cable link will result in media errors on the unconnected trunk cable.
- The cabling system shall be installed so that the trunk cables at any physical device location can be easily identified and labelled with the appropriate icon or letter. Each redundant ControlNet device is labelled so that it can be connected to the corresponding trunk cable.
- Both trunk cables (trunk cable A and trunk cable B) of a redundant-cable link shall have the same configurations. Each segment shall contain the same number of taps, nodes and repeaters. Nodes and repeaters shall be connected in the same relative sequence on both trunk cables.
- Cable shall be installed on each side of a redundant cable system so that each cable is about the same length. As the number of repeaters in a network increases, the allowable difference in length of the two redundant cabling systems is decreased as shown in Figure A.22.
- The difference in length between the two paths (trunk cable A and trunk cable B) shall not exceed the worst-case limit line as detailed in Figure A.22 for coax media when using repeaters.
- The difference in length between the two paths (trunk cable A and trunk cable B) shall not exceed the worst-case limit line as detailed in Figure A.23 for fibre media when using repeaters.
- When there are no repeaters in a redundant network, the difference between the redundant paths (trunk cable A and trunk cable B) shall not exceed that detailed for zero repeaters in Figure A.22 or Figure A.23.
- Both redundant connections of a node shall not be connected to the same network; doing so will cause erratic operation. In addition, all nodes with redundant ports shall be connected to a redundant network at the same physical location within the network. See Figure A.24 and Figure A.25 for both proper and improper connection of redundant nodes.
- The two networks shall not be connected together.
- ControlNet supports linear redundancy and ring topology. Dual redundant rings are not supported and will result in multiple communications paths and lead to network instabilities.

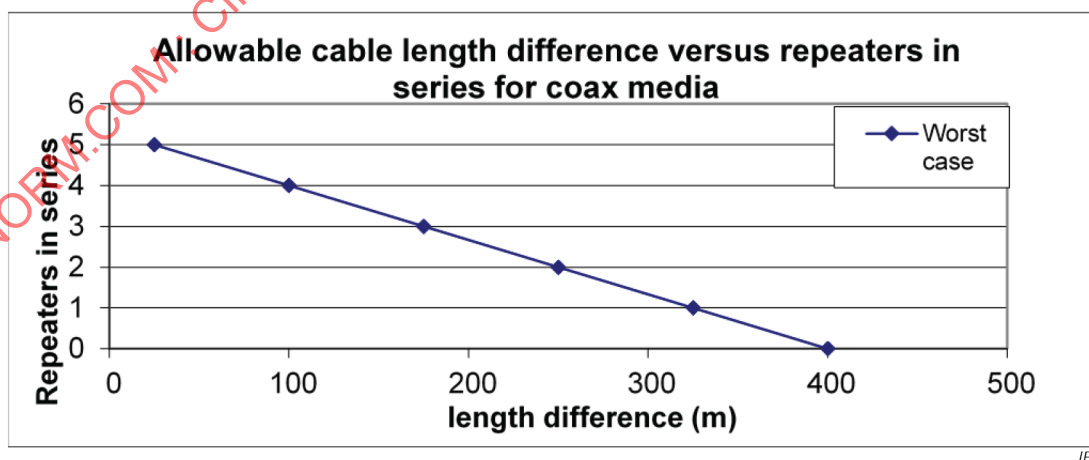
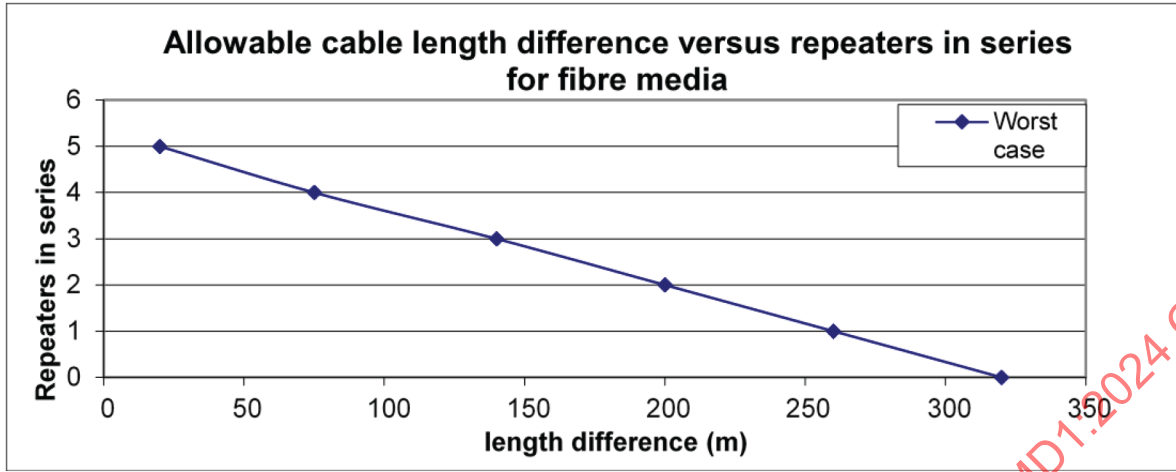
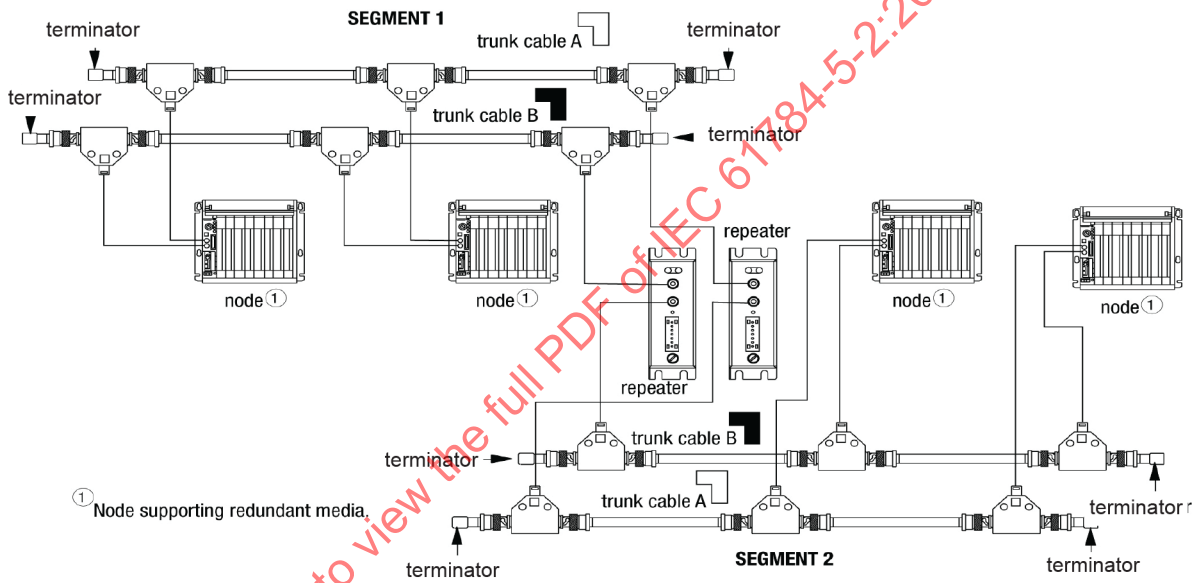


Figure A.22 – Repeaters in series versus length difference for coax media



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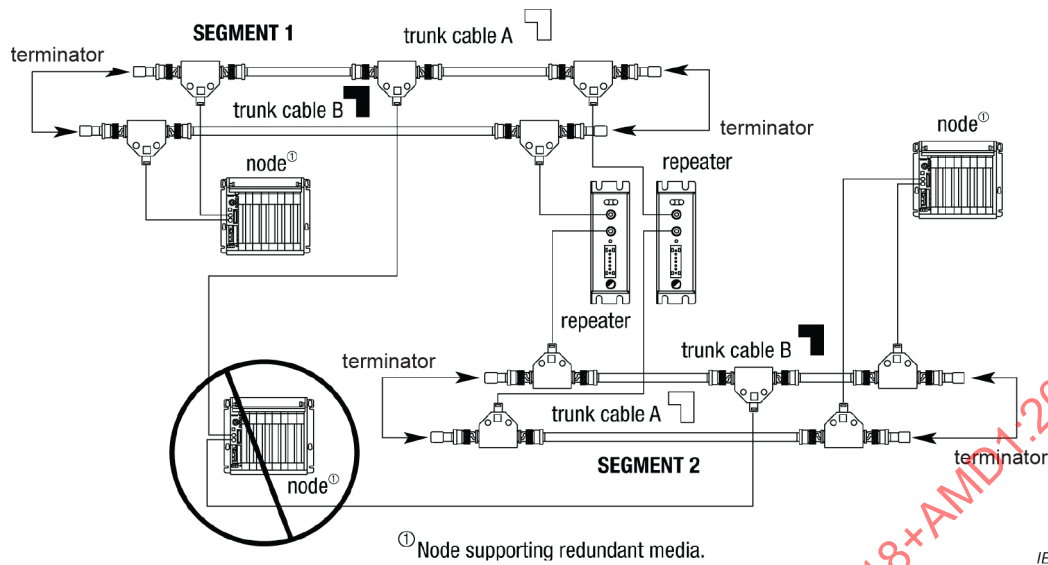
Figure A.23 – Repeaters in series versus length difference for fibre media



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Figure A.24 – Example of redundant coax network with repeaters

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**Figure A.25 – Example of improper redundant node connection**

The allowable difference in length of trunk cable A and B can be found by counting the number of repeaters needed for the network and looking in the graph for coax repeaters above. When one repeater is used, the allowable difference in length between network cable A and B is limited to 325 m (see Figure A.22 and Figure A.24).

A node supporting redundant trunk-cable connections will function even if trunk cable A is connected to the B connector on the node and vice-versa. However, doing so is not recommended because this makes cable fault indications (on the hardware or in the software) difficult to interpret and this makes locating a bad cable segment very difficult.

#### A.4.4.10 Separation of circuits

*Addition:*

These additional guidelines shall be followed for wiring all ControlNet cables:

- if cables are required to cross power lines, they should do so at right angles;
- cable shall be routed at least 1,5 m (5 ft.) from high-voltage enclosures, or sources of rf/microwave radiation.

If the conductor is in a metal wireway or conduit, each section of the wireway or conduit shall be bonded to each adjacent section so that it has electrical continuity along its entire length, and shall be bonded to the enclosure at the entry point.

#### A.4.4.11 Mechanical protection of cabling components

##### A.4.4.11.1 Common description

Specific requirements for CPs.

Not applicable.

**A.4.4.11.2 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****A.4.4.12 Installation in special areas****A.4.4.12.1 Common description****A.4.4.12.2 Specific requirements for CPs**

*Addition:*

The cabling components shall be selected based on the environmental and application requirements. Highflex applications shall use cables designed to meet high flex. Cables expected to be subjected to weld splatter shall have the appropriate protection of jacket designs. Cables used in outdoor applications shall have the appropriate UV protection or jacketing design.

**A.4.5 Cabling planning documentation****A.4.6 Verification of cabling planning specification****A.5 Installation implementation****A.5.1 General requirements****A.5.1.1 Common description****A.5.1.2 Installation of CPs****A.5.1.3 Installation of generic cabling in industrial premises**

Not applicable.

**A.5.2 Cable installation****A.5.2.1 General requirements for all cabling types****A.5.2.1.1 Storage and installation****A.5.2.1.2 Protecting communications cables against potential mechanical damage**

*Addition:*

When pulling the RG6 type coax cable through multiple conduit bends, the specifications detailed in Table A.10 shall be followed.

**Table A.10 – Parameters for coaxial RG6 cables**

Characteristic		Value	
		PVC	FEP
<b>Mechanical force</b>	Minimum bending radius, single bending (mm)	77	70
	Bending radius, multiple bending (mm)	See manufacturer's data sheet	See manufacturer's data sheet
	Pull forces (N)	400	600
	Permanent tensile forces (N)	See manufacturer's data sheet	See manufacturer's data sheet
	Maximum lateral forces (N/cm)	See manufacturer's data sheet	See manufacturer's data sheet
	Temperature range during installation (°C)	See manufacturer's data sheet	See manufacturer's data sheet

When pulling the RG6 type coax cable outside of the conduit, the specifications detailed in Table A.11 shall be followed. Table A.12 and Table A.13 provide values based on the template given in IEC 61918:2018, Table 19 and Table 21.

**Table A.11 – Bend radius for coaxial cables outside conduit**

For this coax cable	The bend radius shall not exceed
PVC	38 mm
FEP	36 mm
Tap drop-cable	26 mm

**Table A.12 – Parameters for silica optical fibre cables**

Characteristic		Value	
		GI Single mode	GI Multi mode
<b>Mechanical force</b>	Minimum bending radius, single bending (mm)	See manufacturer's data sheet	See manufacturer's data sheet
	Bending radius, multiple bending (mm)	See manufacturer's data sheet	See manufacturer's data sheet
	Pull forces (N)	See manufacturer's data sheet	See manufacturer's data sheet
	Permanent tensile forces (N)	See manufacturer's data sheet	See manufacturer's data sheet
	Maximum lateral forces (N/cm)	See manufacturer's data sheet	See manufacturer's data sheet
	Temperature range during installation (°C)	See manufacturer's data sheet	See manufacturer's data sheet

**Table A.13 – Parameters for hard clad silica optical fibre**

Characteristic		Value
		200 µm SI MM Fibre
<b>Mechanical force</b>	Minimum bending radius, single bending (mm)	See manufacturer's data sheet
	Bending radius, multiple bending (mm)	See manufacturer's data sheet
	Pull forces (N)	See manufacturer's data sheet
	Permanent tensile forces (N)	See manufacturer's data sheet
	Maximum lateral forces (N/cm)	See manufacturer's data sheet
	Temperature range during installation (°C)	See manufacturer's data sheet

**A.5.2.2 Installation and routing****A.5.2.3 Specific requirements for CPs**

Not applicable.

**A.5.2.4 Specific requirements for wireless installation**

Not applicable.

**A.5.2.5 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3****A.5.3 Connector installation****A.5.3.1 Common description****A.5.3.2 Shielded connectors****A.5.3.3 Unshielded connectors**

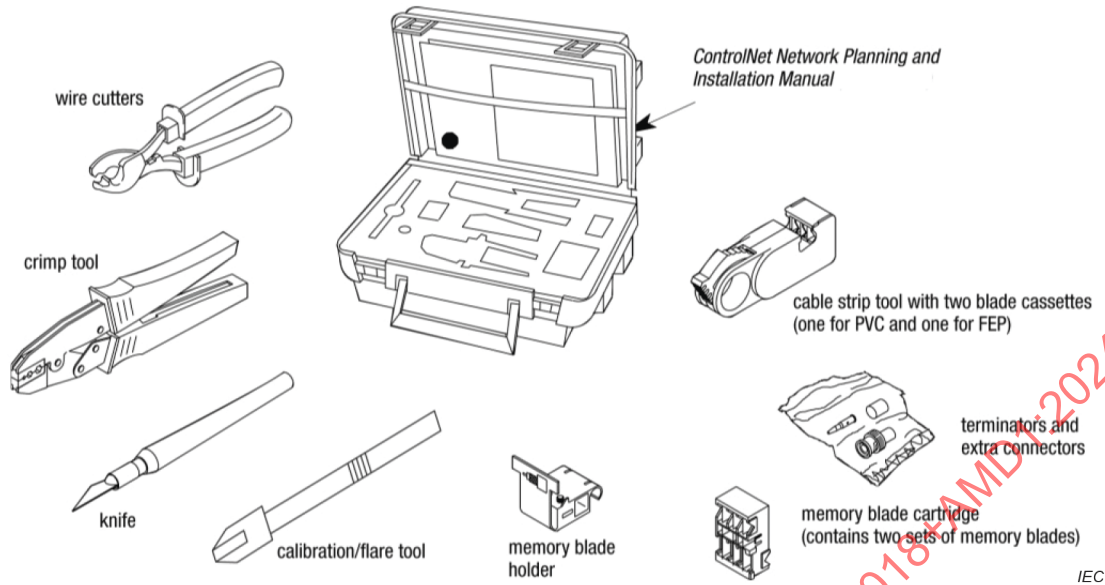
Not applicable.

**A.5.3.4 Specific requirements for CPs**

*Addition:*

**a) Tools**

To install the cable connector, it is recommended that the proper tools be used that match the cable and the connectors. An example toolkit is provided in Figure A.26.



**Figure A.26 – Example tool kit for installing BNC connectors**

Additional tools:

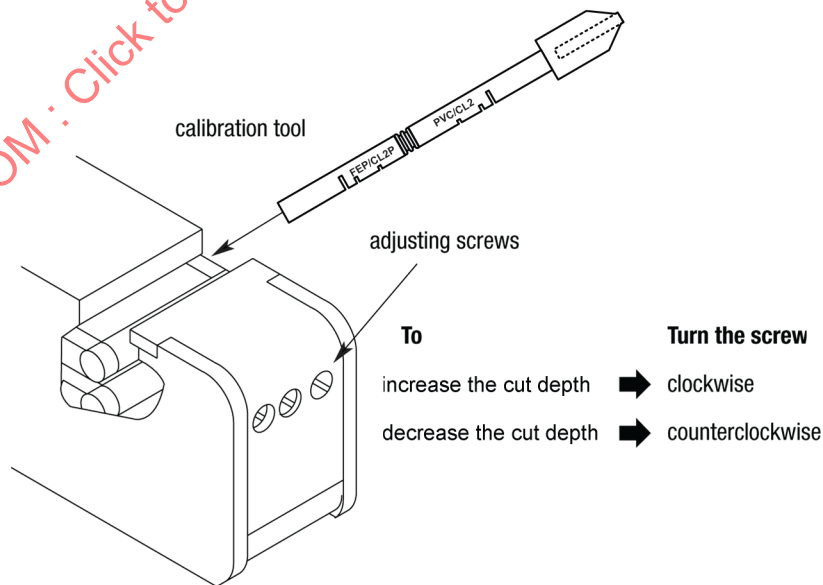
- Heat gun (for IP67 sealed connectors)

If using a coaxial stripping tool, calibration is required.

**b) Tool calibration**

The following procedure shall be used to calibrate the cable strip tool to cut FEP or PVC cable.

- 1) Turn the three screws outward to back the blades out. This prevents the calibration tool from bottoming out.
- 2) Place the calibration tool into the cable strip tool with the narrow end installed and facing forward for FEP cable (use the wider end for PVC) as shown in Figure A.27.



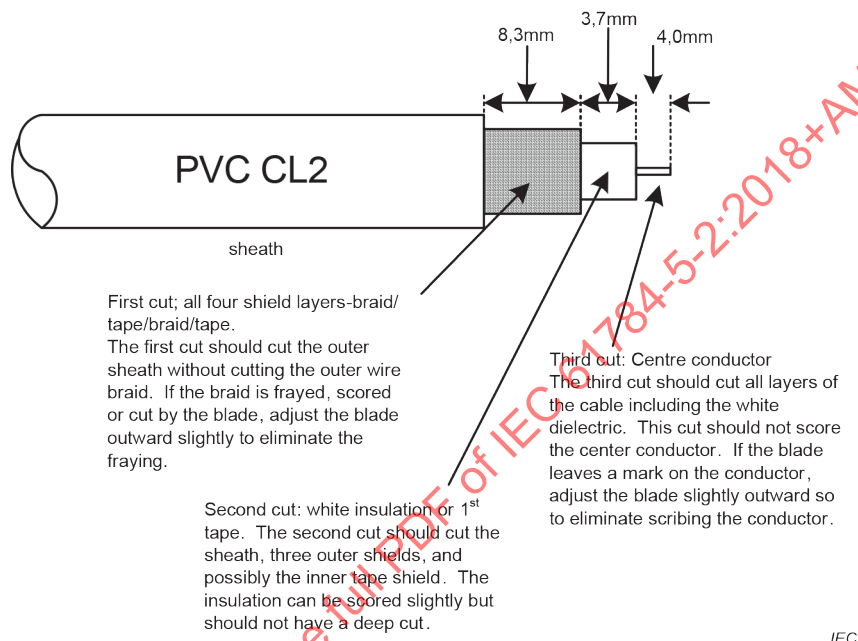
**Figure A.27 – Calibration of coaxial stripper**

- 3) Tighten the chamber gauge ring until the calibration tool is locked in place. Close all the way to the chamber gauge stop.

NOTE When aligned properly, the grooves of the calibration tool will be aligned with the blades.

- 4) Adjust the three screws clockwise until the blades just contact the bottom of the calibration grooves.
- 5) Retract the handle of the cable strip tool.
- 6) Remove the calibration tools from the cable strip tool.

When finished, the blade shall make a cut of the following dimensions in the cable as shown in Figure A.28.



**Figure A.28 – Coax PVC strip length detail (informative)**

### c) Stripping the cable

Important: The first and second cut adjustments need to be precise. Adjustments of 1/12 to 1/8 of a turn can make the difference between a correct and incorrect cut.

The calibration procedure shall be performed the first time the tool is used and every time the blade is changed. In addition, the calibration procedure shall be performed for each different coaxial cable that will be used.

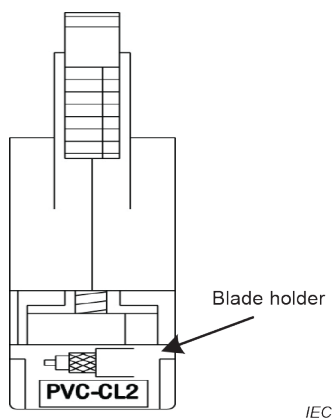
Check the outer braid of the cable for cut or scored braid wire after stripping the cable. If the braid is damaged, cut the damaged end off and strip the cable again. If needed, adjust the appropriate cutting blade by backing the set screw out 1/8 of a turn. Do not crimp the BNC to a damaged braid. This type of mistake accounts for the majority of the connectivity problems that occur. Precise, clean connections will reduce network errors.

When cutting cable sections, make them long enough to route from one tap to the next with sufficient length so that the bend radius is not less than:

- 77 mm for wiring external to enclosures;
- 38 mm for wiring inside enclosures.

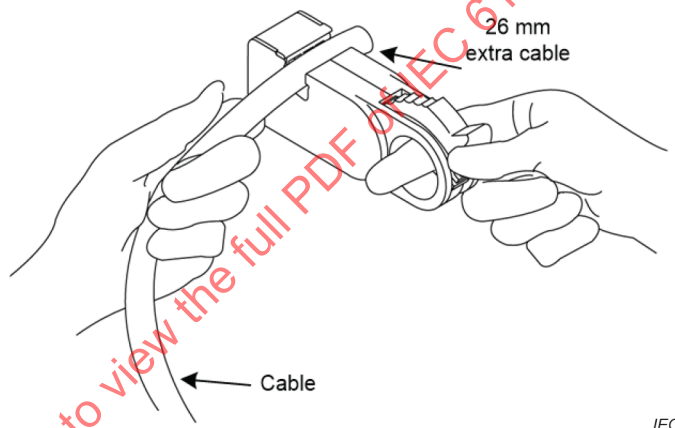
Proceed as follows.

- 1) Verify that the proper memory blade holder is installed for the type of cable to be stripped (PVC-CL2 or FEP-CL2P), see Figure A.29. The blades shall be recalibrated if the memory cartridge is replaced, see the calibration procedure above.



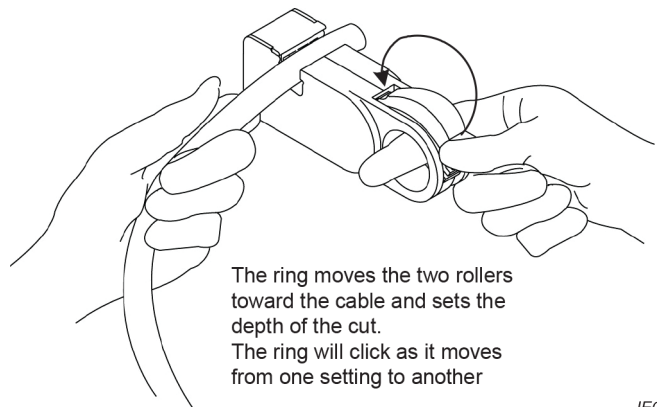
**Figure A.29 – Memory cartridge and blade**

- 2) Straighten out the end of the cable.
- 3) Insert the cable into the cable strip tool's cutting chamber so that approximately 26 mm (1 in) of extra cable extends beyond the edge of the tool as shown in Figure A.30.



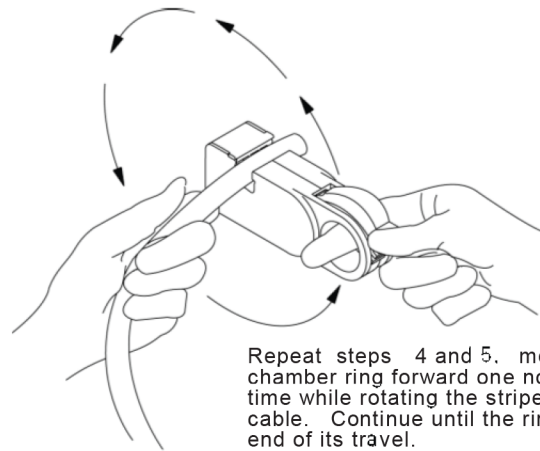
**Figure A.30 – Cable position**

- 4) Lock the cable into place by moving the chamber-gauge ring forward (see Figure A.31) until it meets the cable with slight resistance.



**Figure A.31 – Locking the cable**

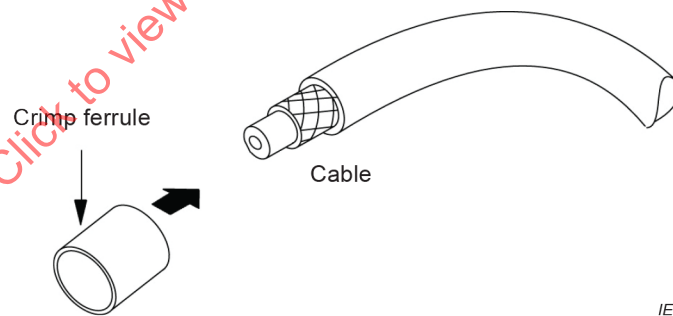
- 5) Holding the cable in one hand, place the index finger of the other hand inside the chamber-gauge ring and turn the strip tool 360° around the cable. Turn four or five full rotations until the strip tool glides easily around the cable as indicated in Figure A.32.



**Figure A.32 – Stripping the cable**

On the last repetition of steps 4) and 5), it is important to apply sufficient pressure on the chamber gauge ring to make sure the ring has reached the last stage. The chamber gauge should read "stop" for the last repetition.

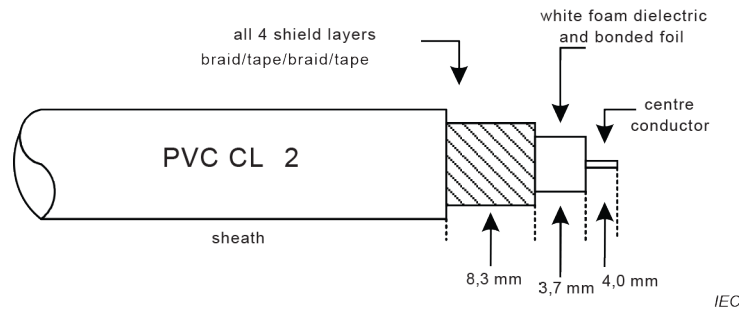
- 6) After the chamber ring has been moved to the last position and turned a final time around the cable:
- Move the chamber ring backward to release the strip tool and remove it from the cable.
  - If using IP65/67, corrosion-resistant connectors, slide the heat shrink tubing over the cable.
  - Slip the crimp ferrule onto the cable as shown in Figure A.33. Push it back to the sheath area of the cable to keep it out of the way for the moment.



**Figure A.33 – Install the crimp ferrule**

- Strip away the appropriate portion of the cable without using the strip tool.
- Clean the remaining cable parts from the strip chamber after each use.

This procedure should appropriately strip the cable, exposing these layers of the cable as detailed in Figure A.34.

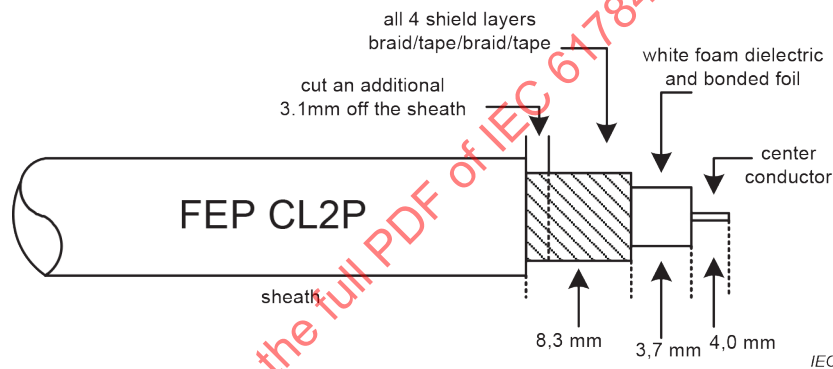


**Figure A.34 – Cable preparation for PVC type cables (informative)**

If there are not three distinct layers of cable or if the outer braid has been scored or cut, snip off the exposed end with the wire cutters and repeat the entire cable-stripping process. It is very important that the outer braid be intact before crimping the connector.

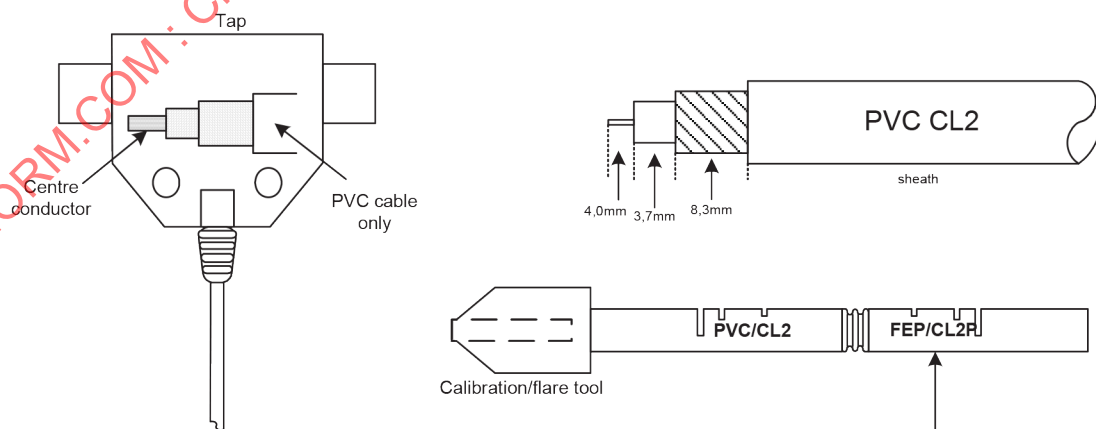
If stripping problems persist, the strip tool may need adjustment. See the calibration section for instructions on calibration.

- 7) For FEP cable, cut off an additional 3,1 mm of the outer sheath with a knife as shown in Figure A.35.



**Figure A.35 – Cable preparation for FEP type cables (informative)**

- 8) Confirm that the centre conductor is 4,0 mm long by using the strip guides on the tap body or an appropriate tool. Figure A.36 provides two examples of guides available.



The centre conductor should be 4,0 mm exactly. If the centre conductor is too long, cut off the excess with the wire cutter provided in the cable kit. If it is too short, repeat the entire cable stripping process.

Use this end of the calibration/strip tool to verify proper measurements for FEP cables.

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**Figure A.36 – Strip guides**

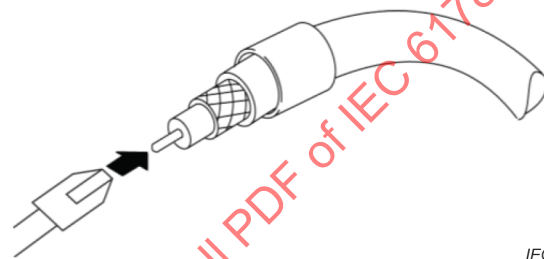
Check for any braid stranding that may not have been cut to the proper length. If any strand comes into contact with the centre conductor, it will short out the cable. Cut any shield strands to the proper length.

Important: Check the outer braid of the cable for cut or scored braid wire after stripping the cable. If the braid is damaged, cut off the end and strip the cable again. Adjustment of the appropriate stripper blade by backing the set screw out 1/8 of a turn may be necessary. Do not crimp the connector to a damaged braid. This type of mistake accounts for most of the connectivity problems that can occur. Precise, clean connections will reduce network errors.

#### d) Installing the connectors

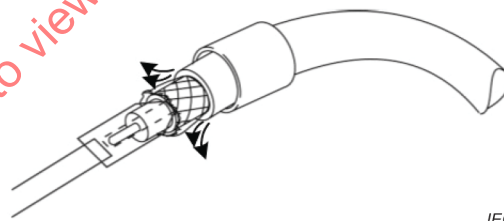
Proceed as follows.

- 1) Place the crimp ring over the cable if not already on the cable.
- 2) If installing an IP65/67, corrosion-resistant connector, slip the heat shrink tubing (provided by the connector manufacturer) onto the cable.
- 3) Push the flare tool onto the cable with a slight twisting motion (with sufficient inward pressure) to expand the braid as shown in Figure A.37 and Figure A.38.
- 4) Push the flare/calibration tool gently in, working the tool in a circular motion onto the cable while applying forward pressure. This will work the tool underneath the wire braid.



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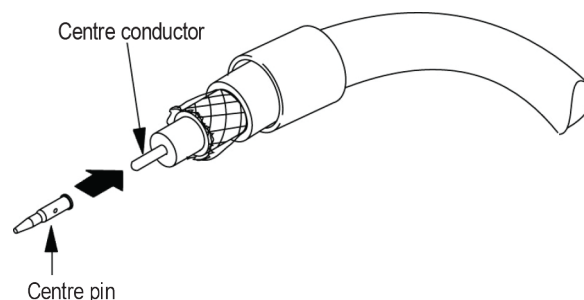
Figure A.37 – Using the flare tool



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Figure A.38 – Expanding the shields

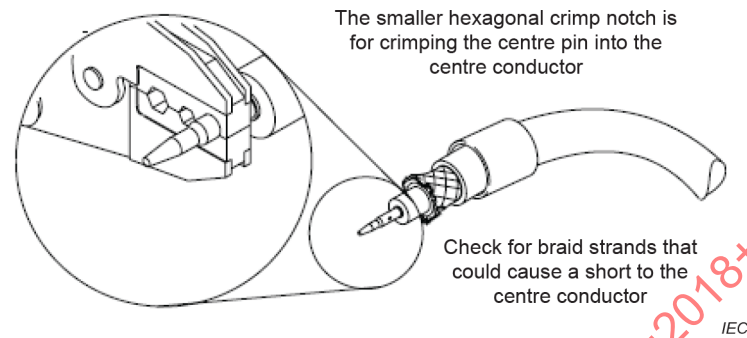
Figure A.39 shows the placement of the centre pin over the centre conductor.



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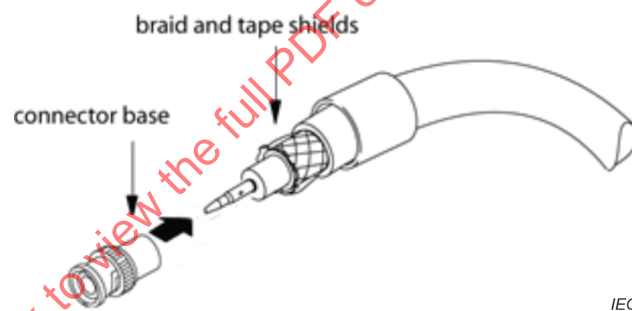
Figure A.39 – Install the centre pin

- 5) Check for strands of insulation or braid that are not cut properly. Remove any debris from the centre conductor before installing the centre pin.
- 6) Confirm that the centre pin slips onto the centre conductor completely. The back shoulder of the centre pin shall be up against the white dielectric. If it is not, recheck the centre wire length, trim if necessary.
- 7) With the centre pin in place, use the crimp tool to crimp the pin in place as shown in Figure A.40.



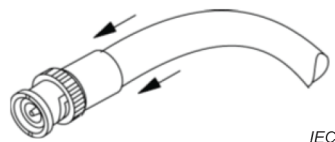
**Figure A.40 – Crimping the centre pin**

- 8) If the innermost shield is not bonded to the dielectric, then all four (foil, braid, foil, braid) shall remain on the outside of the connector body. If the innermost shield is bonded to the dielectric, it shall go inside the connector base. The outer three shields shall remain on the outside of the connector body. Slide the connector body onto the cable (see Figure A.41).



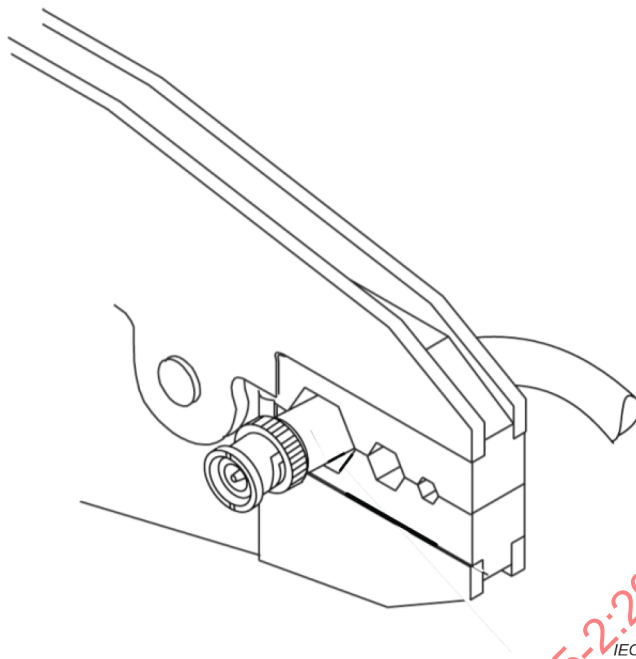
**Figure A.41 – Installing the connector body**

- 9) Slide the crimp ferrule over the three outer shields and connector base until it meets the shoulder of the connector as shown in Figure A.42.



**Figure A.42 – Installing the ferrule**

- 10) Using the crimp tool in Figure A.43, crimp the ferrule. Position the crimp tool on the ferrule as close as possible to the connector base and ferrule meeting line. The larger hexagonal crimping notch is for crimping the ferrule which holds the connector to the cable. Squeeze the crimp tool handles until the crimp tool crimps the ferrule to the connector body and releases.



**Figure A.43 – Crimp tool**

Important: Many network problems are caused by improperly installed connectors. The connectors shall be tight-fitting on the end of all the cables. Pull the connector to verify that it is properly attached. If it is loose or comes off, cut off the end of the cable and install a new connector. The connector retention should be a minimum of 270 N if properly installed.

11) If installing IP65/67, corrosion-resistant connectors:

Use only the ACUM heat-shrink tubing provided in the IP65/67 Tap and Cable Kit. Do not substitute other types of heat-shrink tubing. Substitutions may cause a loss of the IP65/67 rating.

**Warning:** Be careful when using heat guns. High temperatures can lead to burns, risk of fire, or other property damage.

12) Follow these guidelines when heating the tubing (see Figure A.44):

- i) Place the tubing against the shoulder of the TNC connector.
- ii) Allow the heat gun to come to a temperature of between 110 °C and 160 °C.
- iii) Hold the cable assembly approximately 50 mm away from the heat exhaust area of the heat gun while shrinking the tubing.
- iv) Continuously rotate the cable assembly around the heat exhaust area of the heat gun. The entire process should take about 4 min.
- v) Inspect the heat-shrink tubing to ensure that there are no voids where the glue has incompletely melted. Voids could cause a loss of the IP65/67 rating.
- vi) Test the connection.
- vii) Test the final cable.

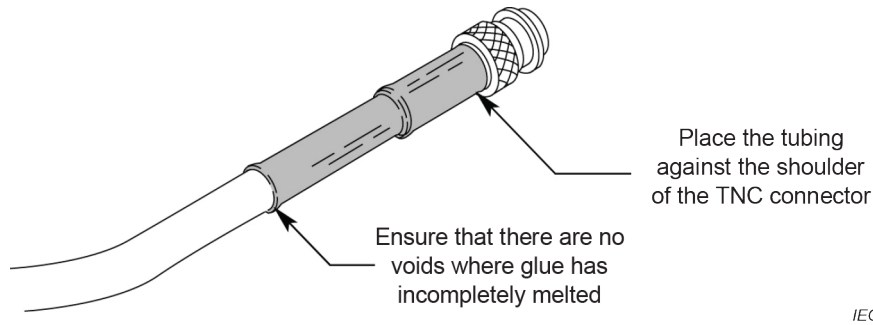


Figure A.44 – Sealed IP65/67 cable

#### A.5.3.5 Specific requirements for wireless installation

Not applicable.

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

#### A.5.4 Terminator installation

##### A.5.4.1 Common description

##### A.5.4.2 Specific requirements for CPs

*Addition:*

Each end or each cable segment shall be terminated with a coaxial BNC or TNC terminator. The location of the terminator shall be at the outermost port of the passive tap as shown in Figure A.45. For more details, see the planner's documentation and Clause A.4.

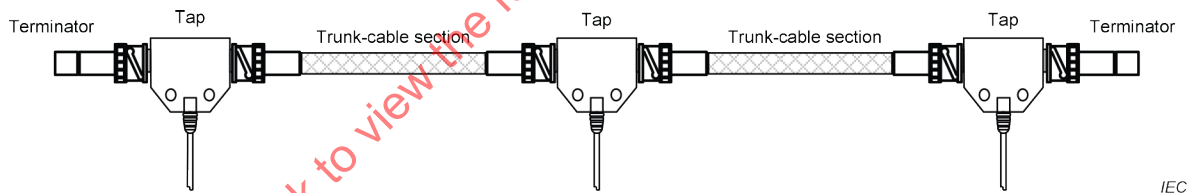


Figure A.45 – Terminator placement

#### A.5.5 Device installation

##### A.5.5.1 Common description

##### A.5.5.2 Specific requirements for CPs

*Addition:*

The drop cable on the tap shall not be extended or shortened under any circumstances.

Selecting where to mount the taps:

- there is no spacing requirement between taps; install two adjacent taps by using a barrel connector;
- be certain that the location where the tap is to be mounted is convenient for the cable route;
- be certain that the location where the tap is to be mounted does not cause any cable bend radii to exceed the limits listed in this Clause A.5;

- do not mount the tap in a position that routes the drop cable over any AC power terminals on nearby modules.

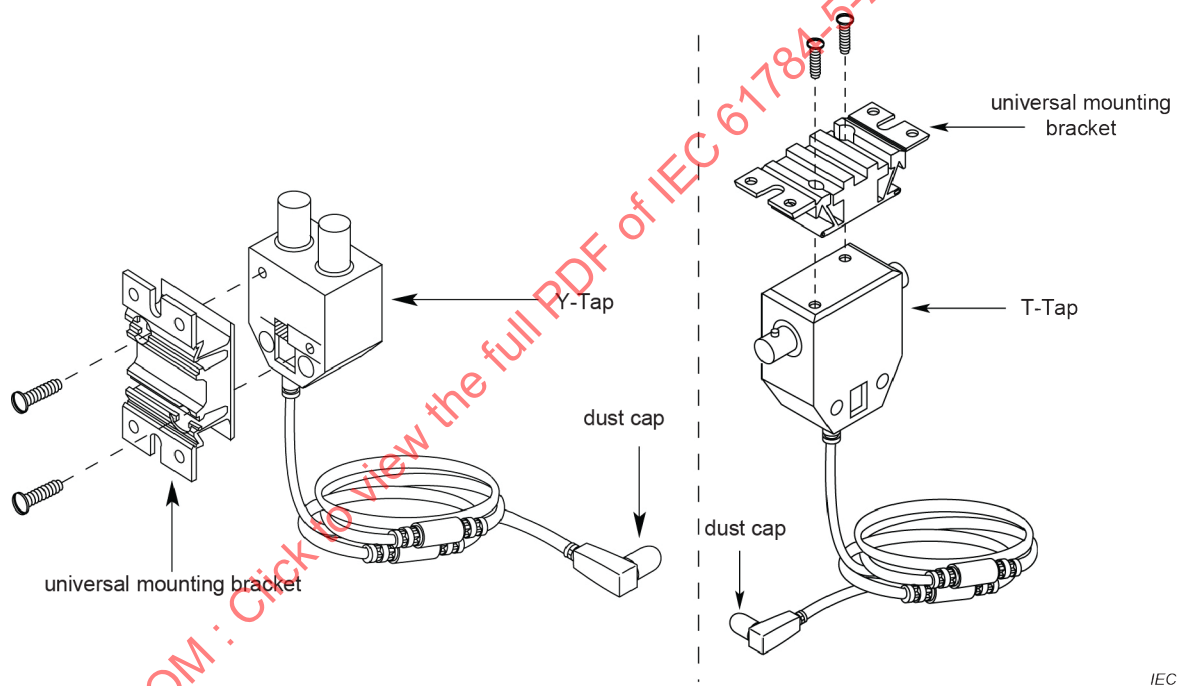
Do not allow any metal portions of the tap, such as the universal mounting bracket screws or connectors, to contact any conductive material. This contact could introduce noise on the network.

Mount the ControlNet taps (Y-tap and T-tap) options:

- to a universal mounting bracket, and then mount the tap and bracket as an assembly;
- through the body holes in the tap using:
  - screws and flat washers,
  - a tie wrap.

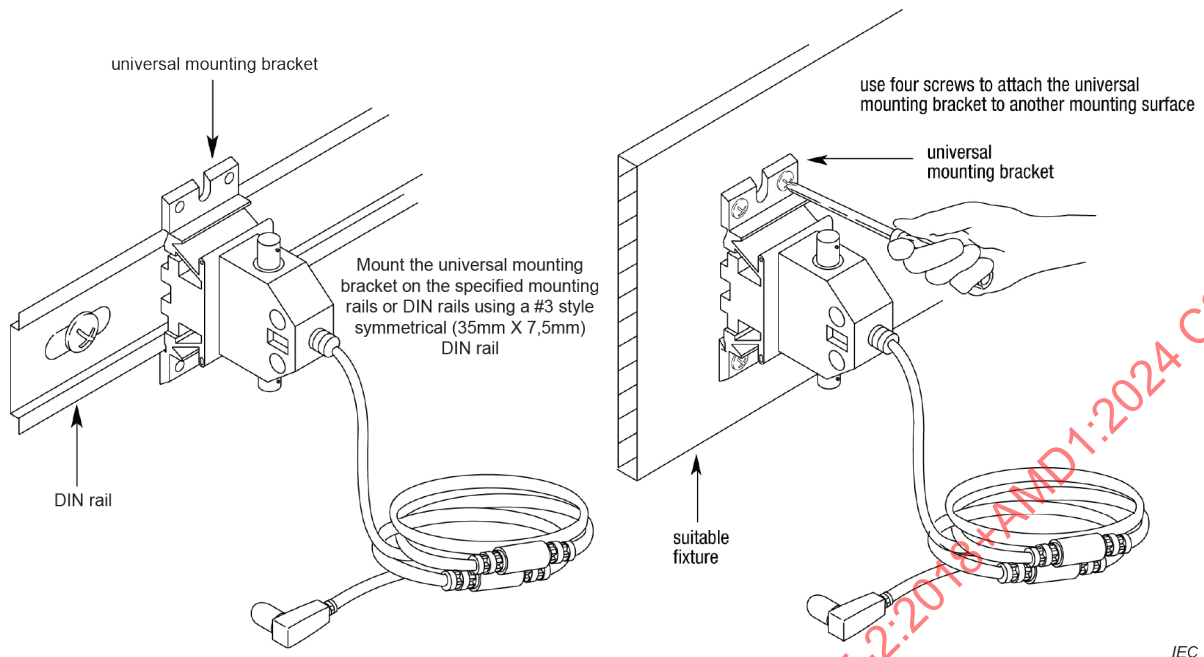
If mounting the ControlNet taps to the universal mounting bracket as shown in Figure A.46, follow the steps below:

- 1) Align the universal mounting bracket with the mounting holes on the tap.
- 2) Using the screws provided with the tap, attach the tap to the universal mounting bracket.



**Figure A.46 – Mounting the taps**

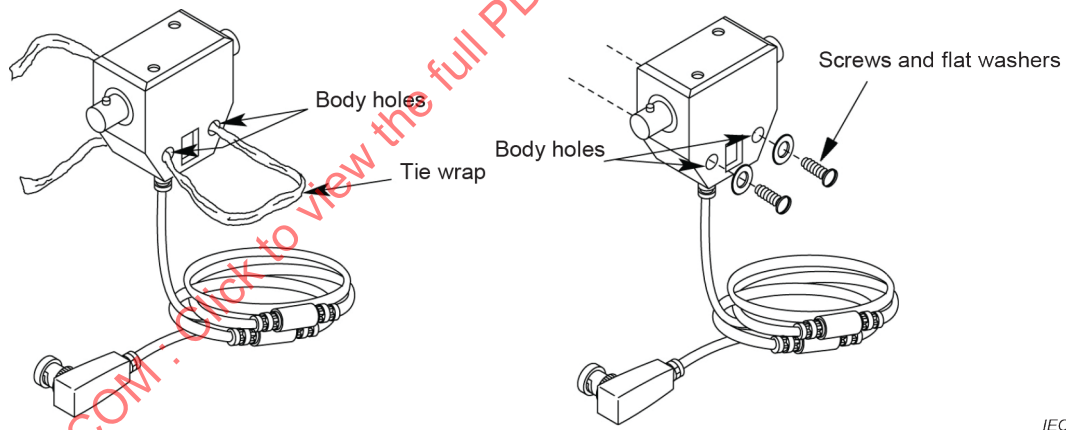
- 3) Figure A.47 shows how to mount the tap and bracket assembly to a DIN rail or flat surface.



**Figure A.47 – Mounting the tap assembly using the universal mounting bracket**

Figure A.48 shows two alternate mounting methods using the mounting holes provided in the ControlNet tap body.

Mount the taps to a suitable fixture using tie wraps or screws as shown in Figure A.48.



**Figure A.48 – Mounting the tap using tie wraps or screws**

Do not over-tighten the screws. Over-tightening the screws can damage the tap.

## A.5.6 Coding and labelling

### A.5.6.1 Common description

### A.5.6.2 Specific requirements for CPs

*Addition:*

ControlNet products are labelled in accordance with the icons in Figure A.49 with the dark icon representing redundant media.

**Figure A.49 – Redundant network icons****A.5.7 Earthing and bonding of equipment and devices and shield cabling****A.5.7.1 Common description****A.5.7.2 Bonding and earthing of enclosures and pathways****A.5.7.3 Earthing methods****A.5.7.3.1 Equipotential**

*Addition:*

The earthing method shall be in accordance with the planner's documentation. If there is an earth potential offset in the communication coverage area, equalization conductors shall be installed to mitigate the offset. The cross-sectional area of these conductors shall be in accordance with IEC 61918:2018, 4.4.7.2.1, Table 14.

**A.5.7.3.2 Star**

*Addition:*

In addition to the requirements of A.4.4.7.3.2, the following shall be observed.

Cable shields for the communications equipment shall be referenced only to the signal earth (functional earth). Other equipment such as motors or motor controllers shall not be referenced to the functional earth. The star earth of the two systems (functional earth and protective earth) shall converge at one point within the building as shown in IEC 61918:2018, Figure 17. Earthing connections for the cabinets shall not be daisy chained.

**A.5.7.3.3 Earthing of equipment (devices)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions and the planner's documentation.

**A.5.7.4 Shield earthing methods****A.5.7.4.1 General****A.5.7.4.2 Parallel RC**

*Addition:*

The cable shield ends are terminated to earth via parallel RC circuits that are integral to the active interfaces. The coaxial cables are not connected directly to earth at any point in the system; doing so may cause noise loops in the network causing communications faults. The installer shall verify the completed installation in such a way that the shield resistance to earth is greater than 2 M $\Omega$  when the active devices are disconnected. A suitable DVM may be used for this verification. For each active device connected the shield resistance to earth shall follow the following formula.

$$\text{Shield to earth} = \frac{1 \text{ M}\Omega}{\text{number of nodes}}$$

Since the repeaters are also required to have a 1 M $\Omega$  resistor from the cable shield to earth, they are also included in the number of counted nodes.

**A.5.7.4.3 Direct**

Not applicable.

**A.5.7.4.4 Derivatives of direct and parallel RC**

Not applicable.

**A.5.7.5 Specific requirements for CPs**

Not applicable.

**A.5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

**A.5.8 As-implemented cabling documentation**

**A.6 Installation verification and installation acceptance test**

**A.6.1 General**

**A.6.2 Installation verification**

**A.6.2.1 General**

**A.6.2.2 Verification according to cabling planning documentation**

**A.6.2.3 Verification of earthing and bonding**

**A.6.2.4 Verification of shield earthing**

*Addition:*

The ControlNet cabling system uses a parallel RC between earth and the shield. The installer shall verify that the shield resistance to earth is greater than 2 M $\Omega$  when the active devices are disconnected using a suitable DVM. For each active device connected, the shield resistance to earth shall follow the following formula:

$$\text{Shield to earth} = \frac{1 \text{ M}\Omega}{\text{number of nodes}}$$

Since the repeaters are also required to have a 1 M $\Omega$  resistor from the cable shield to earth, they are also included in the number of counted nodes.

**A.6.2.5 Verification of cabling system****A.6.2.5.1 Verification of cable routing****A.6.2.5.2 Verification of cable protection and proper strain relief****A.6.2.6 Cable selection verification****A.6.2.6.1 Common description****A.6.2.6.2 Specific requirements for CPs**

*Addition:*

The installer shall use cables defined in the installation documentation.

**A.6.2.6.3 Specific requirements for wireless installation**

Not applicable.

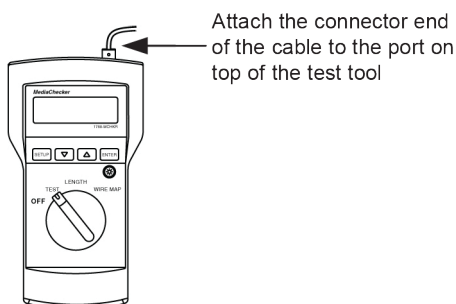
**A.6.2.7 Connector verification****A.6.2.7.1 Common description****A.6.2.7.2 Specific requirements for CPs**

*Addition:*

The coaxial cabling test tool shall be fitted with a BNC/TNC interface and capable of determining:

- cabling faults (open and shorts);
- distance to cable fault;
- presence of proper terminator;
- segment and or section length.

After installing the BNC or TNC connector use a suitable coaxial cable tester or a DVM or suitable network test tool as shown in Figure A.50 to confirm proper continuity.

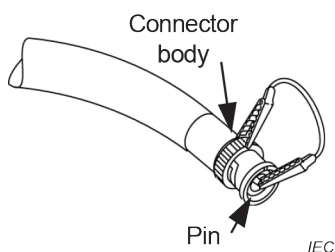


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**Figure A.50 – Network test tool**

An alternate method is to use an ohmmeter or continuity tester to test for a short between the connector body and centre pin.

Use a shorting clip as shown in Figure A.51 to connect a temporary short between the centre pin and connector body at one end of the cable.



**Figure A.51 – Shorting the cable to test for continuity**

At the other end of the cable, use a continuity tester or ohmmeter to test for electrical continuity. Use Table A.14 to determine the course of action to be taken depending on test results.

**Table A.14 – Test matrix for BNC/TNC connectors**

If resistance reading indicates:		Then:
Far end shorted with jumper	that a short exists	Remove jumper and test open
	there is no short	Use a set of wire cutters to cut off the connector, install a new connector and begin testing again
Far end open	that a short exists	Use a set of wire cutters to cut off the connector, install a new connector and begin testing again
	there is no short	Continue to next section

Replace the trunk cable section if the problem persists with the cable after completing the tests.

Each cable section shall be fitted with a BNC or TNC plug. Inline cable jacks are not supported. Sections may be extended using a back-to-back jack (bulkhead or inline bullet).

Properly installed BNC/TNC connectors (crimp style) shall have a retention force of no less than 270 N. If the connector pulls off at less than 270 N, it is either improperly installed or an incorrect match between the cable, connector and crimp tool.

The following may help in determining the problem:

- confirm that the cable and connector are mechanically compatible;
- confirm that the strip lengths meet the connector manufacturer's data sheet;
- check the connector manufacturer's data sheet for crimp tool recommendations;
- verify the crimp dies are within specification (not worn out); if the crimp force is too high, the braid will be damaged. A crimp force that is too high or too low will reduce the retention of the connector.

**A.6.2.7.3 Specific requirements for wireless installation**

Not applicable.

**A.6.2.8 Connection verification**

**A.6.2.8.1 Common description**

**A.6.2.8.2 Number of connections and connectors**

**A.6.2.8.3 Wire mapping**

Not applicable.

**A.6.2.9 Terminator verification****A.6.2.9.1 Common description****A.6.2.9.2 Specific requirements for CPs**

*Addition:*

With a DVM or suitable coaxial cable tester, verify that the terminator is properly installed. If a DVM is used, the DCR of the cable will need to be taken into account. If both terminators are installed in a segment, the DCR measurement shall be no less than 37,5  $\Omega$  and increase as a function of screen DCR/unit length X cable length.

**A.6.2.10 Coding and labelling verification****A.6.2.11 Verification report****A.6.3 Installation acceptance test****A.6.3.1 General**

*Addition:*

The following are other tools that may be useful in the verification and certification of the network:

- suitable coaxial cable test tool or time domain reflectometer (TDR);
- suitable fibre optic optical time domain reflectometer (OTDR).

**A.6.3.2 Acceptance test of Ethernet-based cabling**

Not applicable.

**A.6.3.3 Acceptance test of non-Ethernet-based cabling****A.6.3.3.1 Copper cabling for non-Ethernet-based CPs****A.6.3.3.1.1 Common description****A.6.3.3.1.2 Specific requirements for copper cabling for non-Ethernet-based CPs**

*Addition:*

The segment length shall be measured and confirmed to be within the length limit specified in Figure A.10 and the planner's documentation.

The cable attenuation shall be verified to meet the requirements in Clause A.4.

**A.6.3.3.2 Optical fibre cabling for non-Ethernet-based CPs****A.6.3.3.2.1 Common description****A.6.3.3.2.2 Specific requirements for non-Ethernet-based CPs**

*Addition:*

The segment length shall be measured and confirmed to be within the design guidelines in Clause A.4.

The fibre path loss shall be verified to be within the allowable power budget as defined in Clause A.4. If the path loss is greater than allowed and the fibre length is within the path length limit, then the connector attenuation may be too great and may necessitate re-termination or additional polishing.

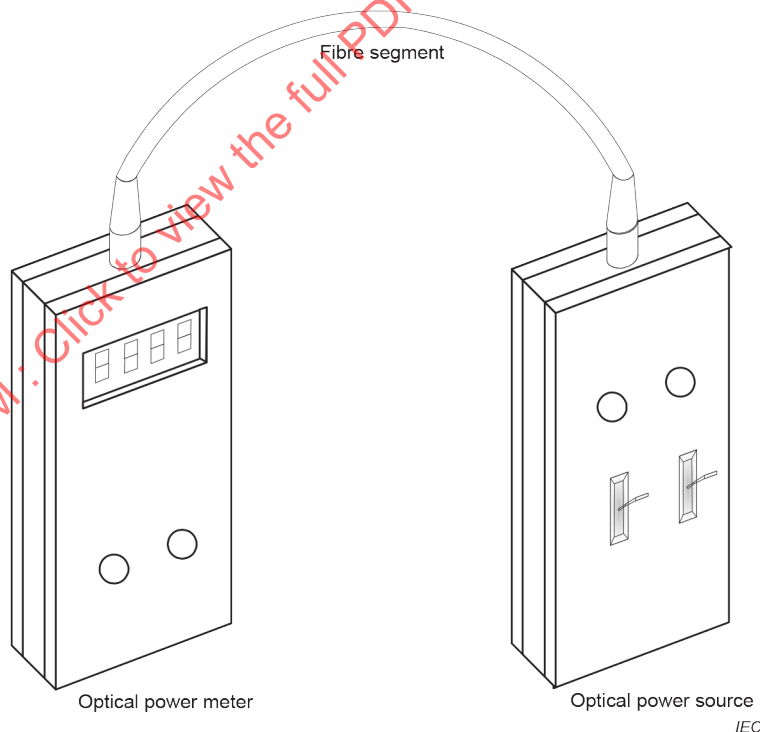
After the initial installation of fibre cable, the sections shall be checked using an optical power meter or OTDR to verify that the attenuation is less than the limits specified in Table A.2. The power source used to test the fibre shall match the power source rating of the cable being tested.

The power loss measurement shall be within the limits described in Table A.2 and Table A.6 for the types of fibres used as shown in Table A.15. The cable shall not be tested with the wrong light source; inaccurate readings will result. The power budgets are specified at the wavelengths of the light source.

Using a reference light source at the specific wavelength and an optical power meter, as shown in Figure A.52, the insertion loss of the fibre optic segment can be determined.

A ControlNet software configuration tool should be used to determine whether or not the system meets the network parameter requirements. Based on the system parameters entered, such as NUT, SMAX, UMAX, and worst case network delay, the ControlNet software configuration tool will calculate scheduled messaging for the network.

Once the values have been entered into the ControlNet software configuration tool and scheduled messaging is calculated, the software will indicate whether the configured network is acceptable as planned. If the network is not valid, adjustments shall be made to meet the planned requirements.



**Figure A.52 – Testing fibre segments**

**Table A.15 – Wavelength and fibre types**

Wavelength nm	Fibre type
640	200/230 $\mu\text{m}$ Graded Index MM
1 300	62,5/125 $\mu\text{m}$ MM
1 300	62,5/125 $\mu\text{m}$ MM
1 300	62,5/125 $\mu\text{m}$ and 9/125 $\mu\text{m}$ SM

#### **A.6.3.3.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **A.6.3.4 Specific requirements for wireless installation**

Not applicable.

#### **A.6.3.5 Acceptance test report**

### **A.7 Installation administration**

Subclause 7.8 is not applicable.

### **A.8 Installation maintenance and installation troubleshooting**

#### **A.8.1 General**

#### **A.8.2 Maintenance**

#### **A.8.3 Troubleshooting**

*Subclause 8.3.2 has addition:*

If testing a single-mode or multimode cable with a 640 nm light source, an incorrect loss measurement will result. The correct wavelength light source shall be used to test the fibre. For medium, long and extra-long fibre modules, a 1 300 nm light source that matches the cable rating shall be used. Records should always be maintained for attenuation levels for each cable section, strand. The attenuation records are valuable tools for troubleshooting and maintaining the network. Considerable power loss in the cable could be a result of:

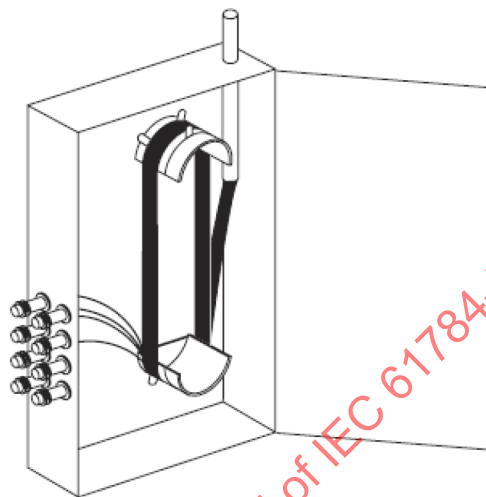
- poor splices;
- improper bend radius;
- bending losses;
- broken fibres;
- poor connections;
- contaminated or damaged connectors;
- poorly polished connector.

#### **a) OTDR measurement**

In addition to power loss measurement, the total fibre network should be examined using an OTDR. The OTDR emits light into a strand of fibre optic cable and displays the reflected light. OTDR tests provide the following measurements that will help to troubleshoot and maintain the network:

- total distance along the cable to a fibre break;
- distance to an event (splice, bend, connector) that attenuates the light;
- distance between two attenuating events;
- light attenuation between two points of the cable;
- total reflected light or light reflected from a single event.

Records should be kept of the traces for each cable strand on either hard copy or computer backup. Figure A.53 shows an example of a connector panel with incoming multi-fibre backbone cable and connectors for interconnect cables.



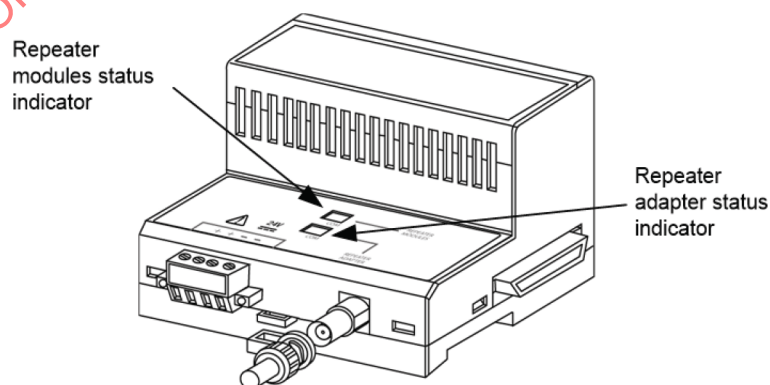
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**Figure A.53 – Multi-fibre backbone cable housing**

There are many choices of fibre optic cables designed for use in different environments. The applications' designer or an installation professional should be consulted to determine the best type of cable to use for the environmental conditions.

#### **b) Troubleshooting fibre repeaters**

See Figure A.54 for the following discussion. The fibre repeater has one LED for the coax connection and one for the accumulate indications of the fibre channels.



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**Figure A.54 – Repeater adapter module**

The status indicator LEDs in the repeater adapter module can be interpreted singly or together. Table A.16 to Table A.19 list different combinations of LEDs and their interpretations.

**Table A.16 – LED status table**

These status indicator LEDs and their interpretation	Are shown in
Repeater adapter and repeater modules	Table A.17
Repeater adapter only	Table A.18
Repeater modules only	Table A.19

The following are the only valid indicator combinations. Other combinations are not valid. For example, the combination of the repeater adapter indicator being solid green and the repeater modules indicator being solid red is not valid and probably indicates a defective module.

**Table A.17 – Repeater adapter and module diagnostic**

If both indicators are	This means	Resolution
Alternating red/green	The repeater adapter is being powered up or reset	Do nothing. The repeater adapter is operating properly
Solid red	A jabber condition has occurred. Another node or repeater on the network is transmitting constantly	Check the network and component for proper operation
Off	The repeater adapter is not powered or has failed	Check the power input to the repeater adapter for correct voltage and polarity

**Table A.18 – Repeater adapter indicator diagnostic**

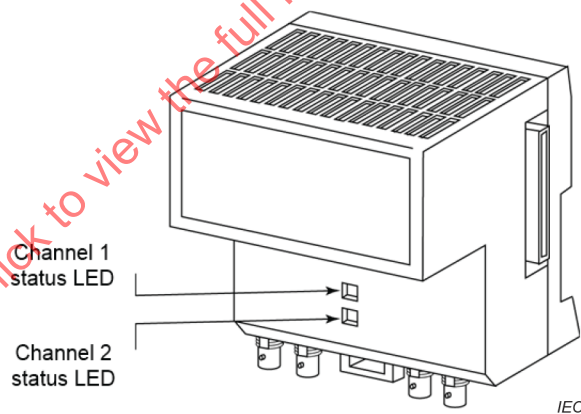
If the repeater adapter indicator is	This means	Resolution
Solid green	Error-free data is being recovered at the coax port of the repeater adapter	Do nothing. This is the normal operating mode
Flashing green/off	Data with errors is occasionally being recovered at the coax port of the repeater adapter	This situation will normally correct itself. If the situation persists check that: <ul style="list-style-type: none"> <li>– all BNC connector pins are seated properly</li> <li>– all taps are ControlNet taps</li> <li>– all terminators are 75 <math>\Omega</math> and are installed at both ends of all segments</li> <li>– the coax cable has not been earthed</li> </ul>
Flashing red/off	Either no data is being received at the coax port of the repeater adapter, or data with a large number of errors is being received at the coax port of the repeater adapter	Check for: <ul style="list-style-type: none"> <li>– broken cables</li> <li>– broken taps</li> <li>– missing segment terminators</li> </ul>

**Table A.19 – Repeater module indicator**

If the repeater adapter indicator is	This means	Resolution
Solid green	Error-free data is being recovered at all of the attached repeater modules	Do nothing. This is the normal operating mode
Flashing green/off	Data with errors is occasionally being recovered at some or all of the repeater modules	This situation will normally correct itself. If the situation persists check that: <ul style="list-style-type: none"> <li>– all BNC connector pins are seated properly</li> <li>– all taps are ControlNet Taps</li> <li>– all terminators are 75 Ω and are installed at both ends of all segments</li> <li>– the coax cable has not been earthed</li> <li>– fibre optic connectors are of the correct type and are correctly attached to the fibre optic cable</li> <li>– fibre optic cable is of the correct type</li> </ul>
Flashing red/off	Either no data is being received at any repeater modules, or the received data at some or all of the repeater modules has a high number of errors	Check for: <ul style="list-style-type: none"> <li>– broken cables</li> <li>– broken taps</li> <li>– missing segment terminators</li> </ul>

**c) Short distance and medium distance diagnostic LEDs**

See Figure A.55 and Table A.20 for the diagnostic LED description.



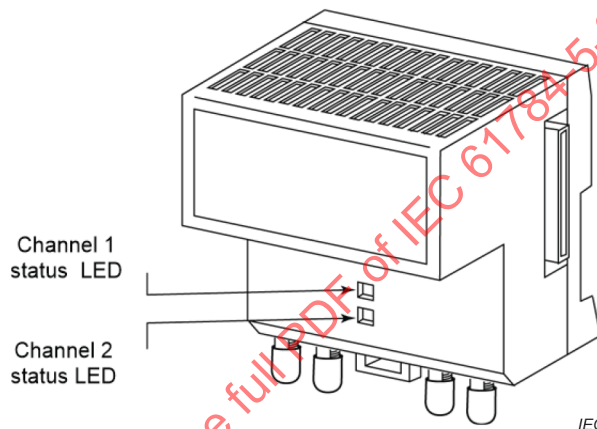
**Figure A.55 – Short and medium distance fibre module LEDs**

**Table A.20 – Short and medium distance troubleshooting chart**

If the repeater module indicator is	This means	Resolution
Off	Repeater not connected to the power supply or adapter module is faulted	Check power supply connections and status. Reset adapter by cycling power
Solid green	Repeater is running without network errors	Do nothing
Flashing green/off	No data activity on network	If the cable is attached: <ul style="list-style-type: none"> <li data-bbox="943 510 1353 584">– confirm that the receive channel is connected to the transmit channel on both modules</li> <li data-bbox="943 595 1225 627">– check for broken fibres</li> </ul>

**d) Long and extra long distance diagnostic LEDs**

See Figure A.56 and Table A.21 for the diagnostic LED description.



**Figure A.56 – Long and extra long repeater module LEDs**

**Table A.21 – Long and extra long troubleshooting chart**

If the repeater module indicator is	This means	Resolution
Off	Repeater not connected to the power supply or adapter module is faulted	Reset module
Solid green	Repeater is running without network errors	No action required
Flashing green/off	No data activity on network. If the cable is attached	<ul style="list-style-type: none"> <li>– confirm that the receive channel is connected to the transmit channel on both modules</li> <li>– check for broken fibres</li> </ul>
Flashing red/off	Module is powered, but not ready for operation	This state should also occur during module reset and last for approximately 5 s
Intermittent red	As more data errors are detected the frequency of the flashing red increases until a solid red displays	Verify network parameters. Verify the network cabling
Red	Excessive receive signal distortion	<ul style="list-style-type: none"> <li>– confirm that the correct fibre type matches the module</li> <li>– check fibre length and attenuation to ensure that it is within specification</li> <li>– replace the downstream fibre repeater module on the channel having the intermittently flashing red LED</li> <li>– confirm that the total network length is not out of specification (see Clause A.4)</li> <li>– confirm that SMAX is correctly defined in the ControlNet software configuration tool</li> </ul>

**A.8.4 Specific requirements for maintenance and troubleshooting**

Not applicable.

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## Annex B (normative)

### CP 2/2 (EtherNet/IP™) specific installation profile

#### B.1 Installation profile scope

*Addition:*

This Annex specifies the installation profile for Communication Profile CP 2/2 (EtherNet/IP). The CP 2/2 is specified in IEC 61784-1 and IEC 61784-2. This profile is based on standard implementations of ISO/IEC 8802-3 TP-PMDs and FO-PMD such as 100BASE-FX and 1000BASE-T.

#### B.2 Normative references

*Addition:*

IEC 60603-7-2, *Connectors for electronic equipment – Part 7-2: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 100 MHz*

IEC 60603-7-3, *Connectors for electronic equipment – Part 7-3: Detail specification for 8-way, shielded, free and fixed connectors, for data transmission with frequencies up to 250 MHz*

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

IEC 60603-7-5, *Connectors for electronic equipment – Part 7-5: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz*

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

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

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 61156-5, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Horizontal floor wiring – Sectional specification*

ANSI/TIA-568.2-D, *Commercial building telecommunications cabling standards – Part 1: General requirements*

ANSI/TIA-1005-A, *Telecommunications Infrastructure Standard for Industrial Premises*

IEEE Std 802.1Q-2018, *IEEE Standard for Local and Metropolitan Area Networks – Bridges and Bridged Networks*

### **B.3 Installation profile terms, definitions, and abbreviated terms**

#### **B.3.1 Terms and definitions**

#### **B.3.2 Abbreviated terms**

*Addition:*

FO-PMD	Fibre optic – Physical layer medium dependent
LLCR	Low level contact resistance
RF	Radio frequency
ST	Optical fibre connector in accordance with IEC 61754-2
T568A / T568B	Wiring conventions (see ANSI/TIA/EIA 568-C.1)
TN-S	Terminal node – Separate earth
TP-PMD	Twisted pair – Physical layer medium dependent

#### **B.3.3 Conventions for installation profiles**

Not applicable.

### **B.4 Installation planning**

#### **B.4.1 General**

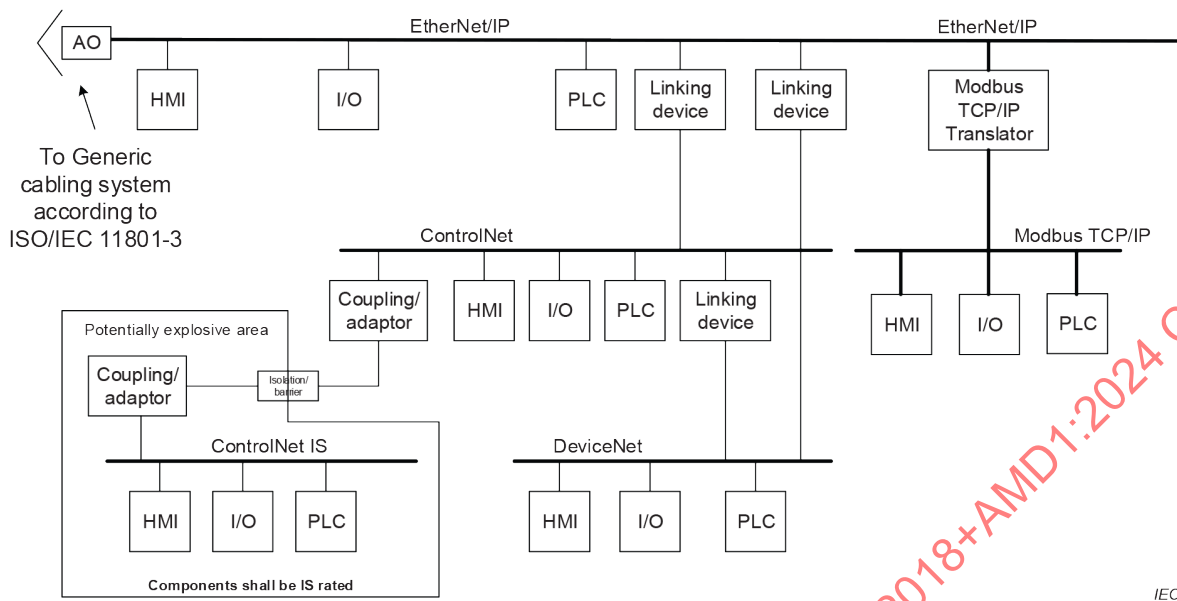
##### **B.4.1.1 Objective**

##### **B.4.1.2 Cabling in industrial premises**

*Addition:*

CP 2/2 is designed to be deployed within the automation island and between automation islands as detailed in IEC 61918:2018, 4.1.2, Figure 5. CP 2/2 may be directly connected to a generic cabling system with the appropriate firewall protection and the AO as shown in Figure B.1. In this case, the AO is the demarcation point between the generic cabling and EtherNet/IP. The AO shall be the AO defined in this profile. For further requirements, see B.4.4.2.2.

The interconnection of CP 2/2 with CP 2/1 and CP 2/3 can be accomplished through a converter/adaptor (linking device) as shown in Figure B.1. Direct physical connection from the TO to the AO is possible, this CP 2/2 supports Variant 1 of IEC 61076-3-106 and the M12-8 X-coding connector. The two connector types provide a sealed connection that meets most industrial environments.



**Figure B.1 – Interconnection of CPF 2 networks**

**B.4.2 Planning requirements**

**B.4.2.1 Safety**

**B.4.2.1.1 General**

**B.4.2.1.2 Electrical safety**

**B.4.2.1.3 Functional safety**

**B.4.2.1.4 Intrinsic safety**

Not applicable.

**B.4.2.1.5 Safety of optical fibre communication systems**

**B.4.2.2 Security**

*Addition:*

Control applications may require access to the control network 100 % of the time. Intrusions by other users into the control network could cause processing delays and loss of control. For this reason, the control network shall be isolated from the office environment and the Internet. The planner is strongly encouraged to provide appropriate security through the use of filtering devices, gateways, firewalls, routers, and/or appropriate security software. The planner and maintenance personnel are cautioned about installing devices on the control network that could bypass network security, such as telephone modems.

Network maintenance personnel in particular shall be made aware that inadvertent intrusions resulting from system maintenance and housekeeping, network upgrades, or broadcast storms may disrupt the control system. Details of network security are beyond the scope of this manual and the planner is advised to consult appropriate standards.

CP 2/2 has provisions for supporting secure system designs aligned with IEC 62443. For each security level as defined by IEC 62443 there are different measures such as identification and authentication, data access control, tamper detection, data access restriction, data confidentiality, response time, and resource availability. Aspects of the system could need mitigations depending on the level of security risk identified.

NOTE See ODVA: PUB00148 [45] for more information on securing the installation of CP 2/2 systems. See ANSI/TIA 5017 [46] for more information for deterrence or restricted access measures that can be taken for securing the physical infrastructure of zones where it is deemed necessary or appropriate.

### B.4.2.3 Environmental considerations and EMC

#### B.4.2.3.1 Description methodology

#### B.4.2.3.2 Use of the described environment to produce a bill of material

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

### B.4.3 Network capabilities

#### B.4.3.1 Network topology

##### B.4.3.1.1 Common description

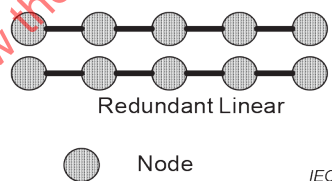
##### B.4.3.1.2 Basic physical topologies for passive networks

Not applicable.

##### B.4.3.1.3 Basic physical topologies for active networks

*Addition:*

EtherNet/IP supports redundant active linear bus topologies as shown in Figure B.2.

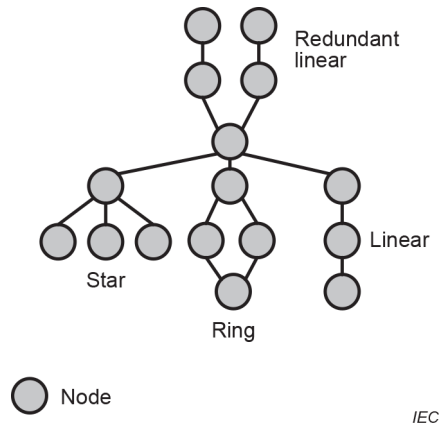


**Figure B.2 – Redundant linear bus**

##### B.4.3.1.4 Combination of basic topologies

*Replacement:*

Combination of topologies is achieved through bridging defined in IEEE Std 802.1Q-2018 and subsequent documents. CP 2/2 provides for routing of data through active topologies and allows interfacing of all equipment through a hierarchical star topology. This is typically facilitated through a network zone approach where an individual node on a network can be replaced with an entire subnetwork configured in an independent topology such as a ring, active linear bus, redundant active linear bus, or an additional active star. This concept is shown in Figure B.18.



**Figure B.18 – Example of combination of basic active topologies**

#### **B.4.3.1.5 Specific requirements for CPs**

*Addition:*

EtherNet/IP supports point-to-point connections as shown in Figure B.3 through a crossover cable. The crossover cable shall meet the wiring scheme detailed in IEC 61918:2018, Annex H.



**Figure B.3 – Peer-to-peer connections**

#### **B.4.3.2 Network characteristics**

##### **B.4.3.2.1 General**

##### **B.4.3.2.2 Network characteristics for balanced cabling not based on Ethernet**

Not applicable.

##### **B.4.3.2.3 Network characteristics for balanced cabling based on Ethernet**

*Modification:*

Table B.1 provides values based on the template given in IEC 61918:2018, Table 2.

Table B.1 describes the minimum basic network characteristics for EtherNet/IP networks.

**Table B.1 – Network characteristics for balanced cabling based on Ethernet**

Characteristic	CP 2/2
Supported data rates (Mbit/s)	10/100 and 1 000
Supported channel length (m) <sup>b</sup>	100 maximum (see channel and link length and limits below)
Number of connections in the channel (max.) <sup>a,b</sup>	6 <sup>a</sup>
Patch cord length (m) <sup>a</sup>	See IEC 61918:2018, Clause 4 and ISO/IEC 11801-3
Channel class per ISO/IEC 11801-3 (min.) <sup>b, d</sup>	Class D
Cable category ISO/IEC 11801-3 (min.)	5
Connecting HW category per ISO/IEC 11801-3 (min.) <sup>c</sup>	5
Cable types	As needed for application
<sup>a</sup> See B.4.4.3.2. <sup>b</sup> For the purpose of this table the channel definitions of ISO/IEC 11801-3 are applicable. <sup>c</sup> For additional information see IEC 61156 series. <sup>d</sup> The TCL, ELTCTL and CA of ISO/IEC 11801-3 apply and are dependent on location of installation.	

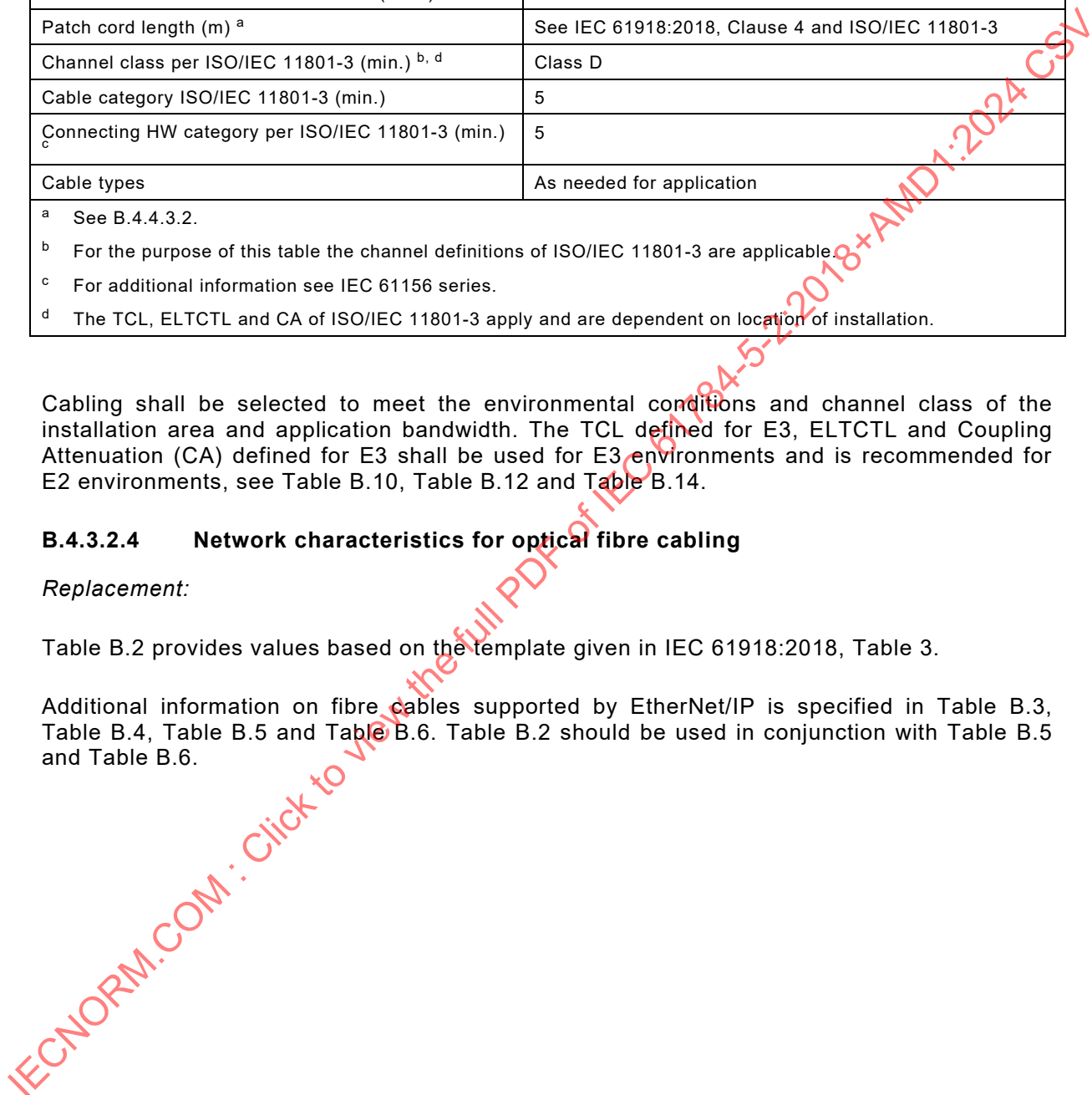
Cabling shall be selected to meet the environmental conditions and channel class of the installation area and application bandwidth. The TCL defined for E3, ELTCTL and Coupling Attenuation (CA) defined for E3 shall be used for E3 environments and is recommended for E2 environments, see Table B.10, Table B.12 and Table B.14.

**B.4.3.2.4 Network characteristics for optical fibre cabling**

*Replacement:*

Table B.2 provides values based on the template given in IEC 61918:2018, Table 3.

Additional information on fibre cables supported by EtherNet/IP is specified in Table B.3, Table B.4, Table B.5 and Table B.6. Table B.2 should be used in conjunction with Table B.5 and Table B.6.



**Table B.2 – Network characteristics for optical fibre cabling**

CP 2/2		
Optical fibre type	Description	
Single mode silica	Bandwidth (Mbit/s) or equivalent at $\lambda$ (nm)	1 000 Mbit/s, 1 310 nm and 1 550 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	10 000
	Maximum channel Insertion loss/optical power budget (dB)	In accordance with ISO/IEC 11801
	Connecting hardware	See B.4.4.2.5
Multimode silica	Bandwidth (Mbit/s) at $\lambda$ (nm)	1 000 Mbit/s, 850 nm and 1 300 nm
	Minimum length (m)	0
	Maximum length <sup>a</sup> (m)	2 000
	Maximum channel Insertion loss/optical power budget (dB)	In accordance with ISO/IEC 11801
	Connecting hardware	See B.4.4.2.5
POF	Bandwidth (Mbit/s) at $\lambda$ (nm)	100 Mbit/s, 650 nm
	Minimum length (m)	0,055
	Maximum length <sup>a</sup> (m)	See Table B.3 Table B.4
	Maximum channel Insertion loss/optical power budget (dB)	4,2 dB
	Connecting hardware	See B.4.4.2.5
Hard clad silica	Bandwidth (Mbit/s) at $\lambda$ (nm)	125 Mbit/s, 650 nm
	Minimum length (m)	0,055
	Maximum length <sup>a</sup> (m)	See Table B.3 Table B.4
	Maximum channel Insertion loss/optical power budget (dB)	4,2 dB
	Connecting hardware	See B.4.4.2.5

<sup>a</sup> This value is reduced by connections, splices and bends in accordance with Formula (1) in 4.4.3.4.1 of IEC 61918:2018.

**Table B.3 – Fibre lengths for 1 mm POF A4a.2 POF 0.5 NA**

Maximum link length with additional losses due to bend radius and number of connections			Number of connections <sup>b</sup>		
Number of bends / Loss	Worst case losses		0	1	2
	dB		0 dB	3 dB	6 dB
	Number of bends	Maximum losses due to bend radius <sup>c</sup>	Maximum length <sup>a</sup>		
		dB	m		
0		0,00	55	43	32
1		0,87	52	40	29
2		0,96	51	40	28
3		1,03	51	40	28
4		1,06	51	39	28
5		1,09	51	39	28

NOTE See footnotes a, b and c in Table B.4.

**Table B.4 – Fibre lengths for 1 mm POF A4d POF 0.3 NA**

Maximum link length with additional losses due to bend radius and number of connections			Number of connections <sup>b</sup>		
Number of bends / Loss	Worst case losses		0	1	2
	dB		0 dB	3 dB	6 dB
	Number of bends	Maximum losses due to bend radius <sup>c</sup>	Maximum length <sup>a</sup>		
		dB	m		
0		0,00	65	53	41
1		0,87	63	51	39
2		0,96	62	50	38
3		1,03	62	50	38
4		1,06	62	50	38
5		1,09	62	50	38

<sup>a</sup> Fibre loss

Fibre base loss includes environmental influences mainly from absorption of water, (which is reversible), and the launch NA of the source.

<sup>b</sup> Connections

Bulkhead coupling loss is included in minimum launch power of the transmitter and worst case receiver sensitivity. Worst-case fibre-to-fibre loss by a connector is assumed to be 3,0 dB. Two mated connectors coupled with an adapter make a connection, see Figure B.4.



**Figure B.4 – Mated connections**

<sup>c</sup> Bending loss

Bending loss is measured for the fibre with maximum link length. The bending losses at 25 mm radius given in Table B.3 and Table B.4 are used as typical value, 1 bend = 360°. If a bend radius is greater than 180 mm, it is considered straight with no loss. Other bend radii are allowable. Manufacturer's data sheet should be consulted for bending losses.

The fibres detailed in Table B.5 are recommended for use in EtherNet/IP networks. The recommended lengths are provided in this table.

**Table B.5 – Recognized fibre types**

Fibre type	Supported fibres	Designations	Bandwidth at 850 nm/1 310 nm	Standard
Multimode	62,5 µm/125 µm	OM1	200 MHz × km/500 MHz × km	IEC 60793-2-10, type A1-OM1
	62,5 µm/200 µm/230 µm	OM1	200 MHz × km/500 MHz × km	IEC 60793-2-30, type A3g
	50 µm/125 µm	OM2	500 MHz × km/500 MHz × km	IEC 60793-2-10, type A1-OM2
		OM3	2 000 MHz × km/500 MHz × km	IEC 60793-2-10, type A1-OM3
		OM4	4 700 MHz × km/500 MHz × km	IEC 60793-2-10, type A1-OM4
		OM5	4 700 MHz × km/500 MHz × km	IEC 60793-2-10, type A1-OM5
	50 µm/200 µm/230 µm	OM2	400 MHz × km/400 MHz × km	IEC 60793-2-30, type A3f
Single-mode	9 µm/125 µm	OS1	N/A	IEC 60793-2-50, type B-652.B
		OS2	N/A	IEC 60793-2-50, type B-652.D
Setp Index Multimode	980 µm/1 000 µm	N/A	4 MHz × km	IEC 60793-2-40, type A4a.2 and A4d

The PMDs of Table B.6 are acceptable to be used in Ethernet/IP networks. They provide coverage for the most popular data rates, 100 Mb/s and 1 000 Mb/s. Other PMDs may be used but are not supported.

**Table B.6 – Recognized fibre PMDs**

IEEE 803.3 fiber PMD	Supported fibres	MSA	Application standard	Cabling standard
100BASE-FX	OM1, OM2, OM3 and OM4, OM5	GBIC, SFP	IEEE 802.3u	ISO/IEC 11801
100BASE-FX	980 µm/1000 µm POF, OM5	N/A	IEEE 802.3u	IEC 60794-2-42
1000BASE-LX	OM1, OM2, OM3, OM4, OS1, OS2, OM5	GBIC, SFP	IEEE 802.3z	ISO/IEC 11801
1000BASE-SX	OM1, OM2, OM3, OM4, OM5	GBIC, SFP	IEEE 802.3z	ISO/IEC 11801
1000BASE-LX10 and 100BASE-LX10	OM1, OM2, OM3, OM4, OS1, OS2, OM5	GBIC, SFP	IEEE 802.3z	ISO/IEC 11801

#### B.4.3.2.5 Specific network characteristics

Not applicable.

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

**B.4.4 Selection and use of cabling components**

**B.4.4.1 Cable selection**

**B.4.4.1.1 Common description**

**B.4.4.1.2 Copper cables**

**B.4.4.1.2.1 Balanced cables for Ethernet-based CPs**

Replacement for Table 4 and Table 5:

Addition for Table 6:

Table B.7 to Table B.14 provide values based on the template given in IEC 61918:2018, Table 4 and Table 5.

**Table B.7 – Information relevant to copper cable: fixed cables 10/100 MHz**

Characteristic	CP 2/2
Nominal impedance of cable (tolerance)	95 Ω to 110 Ω from 1 MHz to 4 MHz 95 Ω to 107 Ω from 4 MHz to 100 MHz
Return loss (dB)	1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \log_{10}(f/20)$
NEXT	$NEXT(f) \geq 64 - 15 \times \log_{10}(f)$
Balanced or unbalanced	Balanced
DCR of conductors	Compliant with ISO/IEC 11801
DCR of shield	Compliant with ISO/IEC 11801
Number of conductors	4 <sup>a</sup> and 8 <sup>a</sup>
Shielding	User defined
Colour code for conductor	Compliant with Table D.2 of IEC 61918:2018
Jacket colour requirements	User defined
Jacket material	User and application defined
Resistance to harsh environment (e.g.: UV, oil resist, LS0H)	User and application defined
Agency ratings	According to local regulations
<sup>a</sup> In pairs, star quad cable designs are not allowed.	

**Table B.8 – Information relevant to copper cable: fixed cables 1 000 MHz**

Characteristic	Type	
	Shielded	Unshielded
<b>Electrical</b>		
Nominal Impedance of cable (tolerance)	95 Ω to 110 Ω, 1 MHz to 4 MHz 95 Ω to 107 Ω, 4 MHz to 100 MHz	95 Ω to 110 Ω, 1 MHz to 4 MHz 95 Ω to 107 Ω, 4 MHz to 100 MHz
RL (dB)	1 MHz to 10 MHz: $20 + 6\text{Log}_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 * \text{Log}_{10}(f/20)$	1 MHz to 10 MHz: $20 + 6\text{Log}_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 * \text{Log}_{10}(f/20)$
NEXT (dB)	ANSI/TIA-568.2-D Cat 5e	ANSI/TIA-568.2-D Cat 5e
Conductors Gauge	0,40 mm to 0,65 mm (26AWG to 22AWG)	
Configuration	2 or 4 pairs + Shield	2 or 4 pairs
Attenuation Solid Conductors	ANSI/TIA-568.2-D Cat 5e Horizontal	ANSI/TIA568.2-D Cat 5e Horizontal
Attenuation Stranded Conductors	ANSI/TIA568.2-D Cat 5e Patch <sup>1</sup>	ANSI/TIA568.2-D Cat 5e Patch <sup>a</sup>
Capacitance unbalance	<= 150 pf/100 m	<= 150 pf/100 m
DCR 26 AWG	14 Ω/100 m	14 Ω/100 m
DCR 24 AWG	9,38 Ω/100 m	9,38 Ω/100 m
DCR 22 AWG	9 Ω/100 m	9 Ω/100 m
DCR Unbalance	3 %	3 %
<b>Mechanical</b>	<b>Shielded</b>	<b>Unshielded</b>
Pulling Tension	111 N	111 N
Breaking Strength	400 N	400 N
Bend Radius	5× cable OD at -20 °C	5× cable OD at -20 °C
<b>Dimensional</b> (Recommended for RJ 45 compatibility)	<b>Shielded</b>	<b>Unshielded</b>
Jacket OD	8 mm (0,315") Max	8 mm (0,315") Max
Insulated Conductor	1,22 mm (0,048") Max	1,22 mm (0,048") Max
<sup>a</sup> The insertion loss is based on Commercial cables. Other constructions, such as high flex, may have different performance. Consult the manufacturer for more information.		

**Table B.9 – Information relevant to copper cable: cords 10/100 MHz**

Characteristic	CP 2/2
Nominal impedance of cable (tolerance)	95 Ω to 110 Ω from 1 MHz to 4 MHz 95 Ω to 107 Ω from 4 MHz to 100 MHz
Return loss (dB)	1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \log_{10}(f/20)$
NEXT	$\text{NEXT}(f) \geq 64 - 15 \times \log_{10}(f)$
Balanced or unbalanced	Balanced
DCR of conductors	Compliant with ISO/IEC 11801
DCR of shield	Compliant with ISO/IEC 11801
Number of conductors	4 <sup>a</sup> and 8 <sup>a</sup>
Length	82 m maximum (see IEC 61918:2018, Clause 4)

Characteristic	CP 2/2
Shielding	User defined
Colour code for conductor	Compliant to Annexe D of IEC 61918:2018
Jacket colour requirements	User defined
Jacket material	User and application defined
Resistance to harsh environment (e.g.: UV, oil resist, LSOH)	User and application defined
Agency ratings	According to local regulations
<sup>a</sup> In pairs, star quad cable designs are not allowed.	

Where category 6 or 6a cables are used, the extended requirements of ANSI/TIA 568.2-D apply in addition to the requirements listed in this Subclause B.4.4.1.2.1.

*Addition:*

Cables shall be selected based on ability to support one of the four options of channel and link electromagnetic performance as defined below.

- a) The UTP cable supporting 10BASE-T or 100BASE-T applications shall be selected and installed based on the ability to meet the Transverse Conversion Loss (TCL) and Equal Level Transverse Conversion Transfer Loss (ELTCTL) requirements at both ends of the cabling in accordance with Table B.27 and the environment local to the cabling.

**Table B.27 – Unbalance attenuation limits for unshielded twisted-pair cabling serving 10BASE-T and 100BASE-T applications**

Parameter	Frequency MHz	Limit dB <sup>a</sup>
TCL	$1 \leq f < 100$	Compliant with ISO/IEC 11801 series
ELTCTL	$1 \leq f < 30$	Compliant with ISO/IEC 11801 series

<sup>a</sup> Limits are applicable to all environmental classifications aligned with delineation in ISO/IEC 11801-1.

- b) The UTP cable supporting 1000BASE-T applications shall be selected and installed based on the ability to meet the Transverse Conversion Loss (TCL) and Equal Level Transverse Conversion Transfer Loss (ELTCTL) requirements at both ends of the cabling in accordance with Table B.28 and the environment local to the cabling.

**Table B.28 – Unbalance attenuation limits for unshielded twisted-pair cabling serving 1000BASE-T applications with enhanced components**

Parameter	Frequency MHz	Limit dB		
		E1	E2	E3
TCL	$1 \leq f < 30$	Compliant with ISO/IEC 11801 series	$69,2 - 15 \times \log_{10}(f)$	$79,2 - 15 \times \log_{10}(f)$
	$1 \leq f \leq 100$		$76,6 - 20 \times \log_{10}(f)$ (max. 40 dB)	$86,6 - 20 \times \log_{10}(f)$ (max. 46 dB)
ELTCTL	$1 \leq f < 30$	Compliant with ISO/IEC 11801 series	$42 - 20 \times \log_{10}(f)$ (max. 40 dB)	$52 - 20 \times \log_{10}(f)$ (max. 40 dB)

- c) The UTP cable supporting 1000BASE-T applications shall be selected and installed based on the ability to meet the Transverse Conversion Loss (TCL) and Equal Level Transverse Conversion Transfer Loss (ELTCTL) requirements at both ends of the cabling while also

restricting the insertion loss and indirectly the associated cable length in accordance with Table B.29 and the environment local to the cabling. Under this condition the nominal maximum cable length is limited to 72 m instead of the expected 100 m.

**Table B.29 – Unbalance attenuation limits for unshielded twisted-pair cabling serving 100BASE-T applications with length derating**

Parameter	Frequency MHz	Limit dB <sup>a</sup>
Insertion Loss	$1 \leq f \leq 100$	$0,72 \times (1,967\sqrt{f} + 0,023 \times f + 0,1/\sqrt{f})$
TCL	$1 \leq f \leq 100$	Compliant with ISO/IEC 11801 series
ELTCTL	$1 \leq f \leq 30$	Compliant with ISO/IEC 11801 series

<sup>a</sup> Limits are applicable to all environmental classifications aligned with delineation in ISO/IEC 11801-1.

- d) The shielded cable shall be selected and installed based on the ability to meet the coupling attenuation requirements at both ends of the cabling in accordance with Table B.30 and the environment local to the cabling. Coupling attenuation (see Table B.30) shall be measured in accordance with IEC 61156-5.

**Table B.30 – Coupling attenuation limits for screened twisted-pair cabling**

Parameter	Frequency MHz	Limit dB <sup>a</sup>
Coupling Attenuation	$30 \leq f \leq 100$	Compliant with ISO/IEC 11801 series

<sup>a</sup> Limits are applicable to all environmental classifications aligned with delineation in ISO/IEC 11801-1

#### B.4.4.1.2.2 Copper cables for non-Ethernet-based CPs

Not applicable.

#### B.4.4.1.3 Cables for wireless installation

#### B.4.4.1.4 Optical fibre cables

*Replacement:*

Table B.15 provides values based on the template given in IEC 61918:2018, Table 6.

**Table B.15 – 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 µ m step index POF	200/230 µm step index hard clad silica
Standard	OS1 or OS2	OM2, OM3, OM4, OM5	OM1	--	--
Maximum attenuation per km (650 nm)	–	–	–	18 dB	12 dB
Maximum attenuation per km (820 nm)	–	2,5 dB	3,0 dB	–	–
Maximum attenuation per km (1 310 nm)	0,4 dB	0,8 dB	1,0 dB	–	–
Number of optical fibres	2 minimum	2 minimum	2 minimum	–	–

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 PO F	200/230 µm step index hard clad silica
Connector type (e.g. duplex or simplex)	Duplex, duplex-able, simplex	Duplex, duplex-able, simplex	Duplex, duplex-able, simplex	–	–
Jacket colour requirements	User defined	User defined	User defined	–	–
Jacket material	User defined	User defined	User defined	–	–
Resistance to harsh environment (e.g. UV, oil resist, LSOH)	As needed to support application and environment	As needed to support application and environment	As needed to support application and environment	–	–

**B.4.4.1.5 Special purpose balanced copper and optical fibre cables**

**B.4.4.1.6 Specific requirements for CPs**

Not applicable.

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

**B.4.4.2 Connecting hardware selection**

**B.4.4.2.1 Common description**

**B.4.4.2.2 Connecting hardware for balanced cabling CPs based on Ethernet**

*Replacement:*

Table B.16 and Table B.17 provide values based on the template given in IEC 61918:2018, Table 7.

**Table B.16 – Connectors for balanced cabling CPs based on Ethernet**

	IEC 60603-7 series <sup>a</sup>		IEC 61076-3-106 <sup>b</sup>		IEC 61076-3-117 <sup>b</sup>	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
<b>CP 2/2</b>	IEC 60603-7 or IEC 60603-7	IEC 60603-7 or IEC 60603-7	Yes	No	No	Yes	Yes
<sup>a</sup> For IEC 60603-7 series, the connector selection is based on the desired channel performance. <sup>b</sup> Housings to protect connectors.							

**Table B.17 – Unbalance Attenuation limits for connectors based on Ethernet serving 1000BASE-T applications**

Parameter	Frequency MHz	Limit dB		
		E1	E2	E3
TCL	$1 \leq f < 250$	Not defined	Not defined	$94 - 20 \times \log_{10}(f)$
TCTL	$1 \leq f < 30$	Not defined	Not defined	$71.5 - 20 \times \log_{10}(f)$

Addition:

#### a) EtherNet/IP sealed 8-way modular connector housings

Sealed 8-way modular connectors play an important role in providing a reliable connection in harsh environments. EtherNet/IP supports Variant 1 in IEC 61076-3-106. This connector is suitable for use in information and control applications. The planner shall consult the manufacturer's data sheet for environmental compatibility as defined by the MICE concept.

Table B.18 contains the connector parameters for the 8-way modular connectors for use in sealed and unsealed industrial EtherNet/IP systems.

**Table B.18 – Industrial EtherNet/IP 8-way modular connector parameters**

Parameter	Type	
	Shielded	Unshielded
Conductors	8 + 1 shielded	8
Contact LLCR over life	< 20 mΩ	< 20 mΩ
Initial	< 2,5 mΩ	< 2,5 mΩ
Contact life	750 insertions and extractions min.	750 insertions and extractions min.

Sealed 8-way modular connectors shall meet the EtherNet/IP specification and utilize the encapsulation method defined in IEC 61076-3-106, Variant 1. Figure B.5 and Figure B.6 provide examples of the Variant 1 connector housing.



IEC

**Figure B.5 – The 8-way modular sealed jack & plug (plastic housing)**



IEC

**Figure B.6 – The 8-way modular sealed jack & plug (metal housing)**

#### b) 4-Pole M12 D-coding connectors

4-Pole M12 D-coding connectors are sealed to meet the IP65/67 specification for EtherNet/IP and designed to operate in harsh environments in accordance with IEC 61076-2-101.

4-Pole M12 D-coding connectors shall be used only with 2-pair cables. If support for all generic applications such as voice, video and data (1 Gbit/s and 10 Gbit/s Ethernet) is required, 4-pair cables and 8-way modular connector and compatible components shall be used.

See IEC 61918:2018, 4.4.3 for rules on 2- and 4-pair cabling within a channel.

Table B.19 provides the contact requirements for the M12-4 D-coding connector to ensure network reliability and connector compatibility.

**Table B.19 – Industrial EtherNet/IP M12-4 D-coding connector parameters**

Parameter	Type	
	M12 shielded	M12 unshielded
Conductors	4+1 shield	4
Contact LLCR over Life	Maximum: 5 mΩ	Maximum: 5 mΩ
Initial Contact LLCR	Nominal: < 1 mΩ	Nominal: < 1 mΩ
Contact Plating	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum
Contact Life	750 insertions-extractions	750 insertion-extractions

Figure B.7 is an example of a metallic shell M12-4 D-coding connector.



**Figure B.7 – M12-4 connectors**

The manufacturer's assembly instructions shall be followed to minimize the chance of failure or degraded performance.

**c) 8-Pole M12 X-coding connectors**

8-Pole M12 X-coding connectors are sealed to meet the IP65/67 specification for EtherNet/IP and designed to operate in harsh environments in accordance with IEC 61076-2-109.

8-Pole M12 X-coding connectors shall be used only with 4-pair cables. If support for all generic applications such as voice, video and data (1 Gbit/s and 10 Gbit/s Ethernet) is required, 4-pair cables and 8-way modular connector and compatible components shall be used.

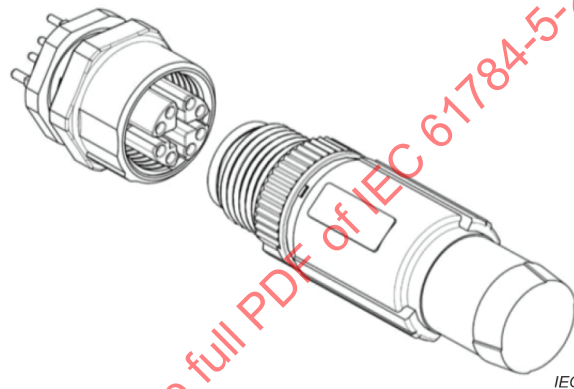
See IEC 61918:2018, 4.4.3 for rules on 2- and 4-pair cabling within a channel.

Table B.20 provides the contact requirements for the M12-8 X-coding connector to ensure network reliability and connector compatibility.

**Table B.20 – Industrial EtherNet/IP M12-8 X-coding connector parameters**

Parameter	Type	
	M12 shielded	M12 unshielded
Conductors	4+1 shield	4
Contact LLCR over Life	Maximum: 5 mΩ	Maximum: 5 mΩ
Initial Contact LLCR	Nominal: < 1 mΩ	Nominal: < 1 mΩ
Contact Plating	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum	0,762 μm gold over 1,27 μm nickel or 0,127 μm gold minimum over 0,508 μm palladium nickel over 1,27 μm nickel or equivalent plating. Gold shall be 24 karat minimum
Contact Life	750 insertions-extractions	750 insertion-extractions

Figure B.8 is an example of a metallic shell M12-8 X-coding connector.

**Figure B.8 – Example of a metallic shell M12-8 X-coding connectors**

Construction of conversion cables is permissible. Conversion cables constructed with M12 X-coding connector to 8-Way modular connectors shall be constructed from 4 pair cables containing the wire colour codes defined in Colour codes for 2-pair and 4-pair cabling shall conform to the colour code in IEC 61918:2018, Annex D. The connector pin mapping shall conform to IEC 61918:2018, Annex H. Construction of crossover cables between T568A and T568B is permissible.

#### **B.4.4.2.3 Connecting hardware for copper cabling CPs not based on Ethernet**

Not applicable.

#### **B.4.4.2.4 Connecting hardware for wireless installation**

#### **B.4.4.2.5 Connecting hardware for optical fibre cabling**

*Replacement:*

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 B.21 provides values based on the template given in IEC 61918:2018, Table 9.

**Table B.21 – 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	Circular M12
<b>CP 2/2</b>	Yes	Yes	Yes	Yes	No	Yes

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 IEC 61753 series.

*Addition:*

Most ferrules are ceramic, but some are metal or plastic. To minimize potential noise coupling, ceramic or plastic ferrules are recommended.

**LC style connector**

LC is a small form factor connector that uses a plastic or ceramic 1,25 mm diameter ferrule. It is available in a simplex or duplex configuration (see Figure B.9 and Figure B.10). The LC connector is available in sealed housing compliant with Variant 1 of IEC 61076-3-106 and the EtherNet/IP specification as shown in Figure B.11. The LC shall meet the requirements of IEC 61754-20.



IEC

**Figure B.9 – Simplex LC connector**



IEC

**Figure B.10 – Duplex LC connector**



IEC

**Figure B.11 – IP65/67 sealed duplex LC connector**

**SC-RJ style connector**

SC-RJ is a small form factor connector that uses a plastic or ceramic 2,5 mm diameter ferrule. It is available in a simplex or duplex configuration (see Figure B.12). The SC-RJ connector is

available in sealed housing compliant with Variant 1 of IEC 61076-3-106 and the EtherNet/IP specification as shown in Figure B.12.

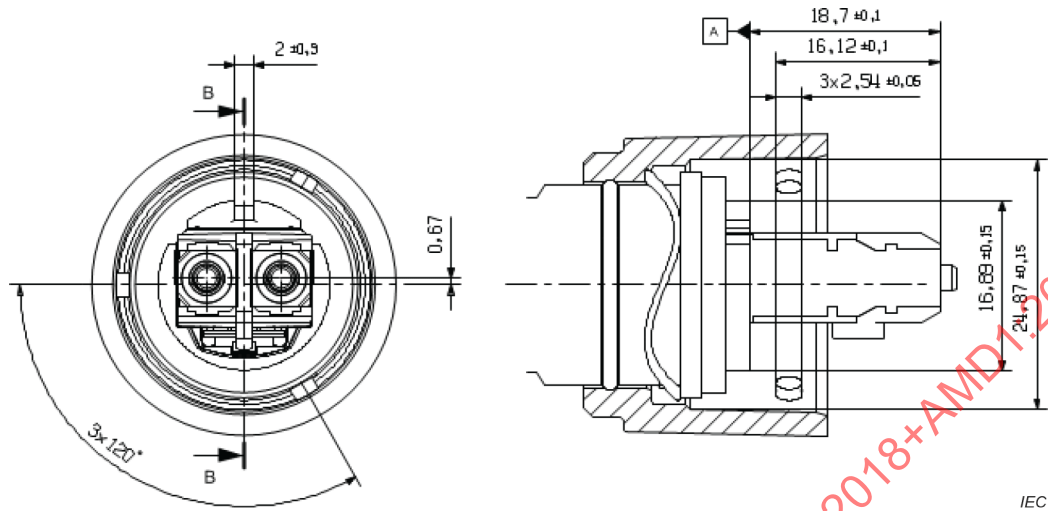


Figure B.12 – IP65/67 sealed duplex SC-RJ connector

Replacement:

Table B.22 provides values based on the template given in IEC 61918:2018, Table 10, modified as needed.

Table B.22 – Relationship between FOC and fibre types (CP2/2)

FOC	Fibre type					
	9/125 μm	50/125 μm	62,5/125 μm	POF 1 mm	200/230 μm Step index Hard cladde silica	Others
SC	Yes	Yes	Yes	Yes	Yes	–
ST	Yes	Yes	Yes	Yes	Yes	–
LC	Yes	Yes	Yes	No	No	–
SC-RJ	Yes	Yes	Yes	Yes	Yes	–
Circular M12	No	Yes	Yes	No	No	–

The connector insertion loss shall be met by the connectors as shown in Table B.23.

Table B.23 – Connector insertion loss

Connector type	Insertion loss	Return loss
SC, ST, SC-RJ and LC, Circular M12	0,75 dB maximum	Single-mode 26 dB minimum Multimode 20 dB minimum
SC-RJ	2,0 dB maximum (POF)	SI Multimode 20 dB minimum

The installation of fibre connectors is manufacturer specific and requires the manufacturer's specific tools for installation. Please consult the specific manufacturer for installation tools and methods for installing the connector.

**B.4.4.2.6 Specific requirements for CPs**

Not applicable.

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

**B.4.4.3 Connections within a channel/permanent link**

**B.4.4.3.1 Common description**

**B.4.4.3.2 Balanced cabling connections and splices for CPs based on Ethernet**

**B.4.4.3.2.1 Common description**

*Addition:*

The number of mated connections allowed in a channel is determined by the desired channel performance (category) and the performance level of the components selected as detailed in IEC 61918:2018, Annex J.

Alternate configurations shall be field tested to ensure adequate performance.

**B.4.4.3.2.2 Connections minimum distance**

*Addition:*

There is no minimum distance between back-to-back jacks or connections.

**B.4.4.3.2.3 Balanced cabling splices**

**B.4.4.3.2.4 Balanced cabling bulkhead connections**

*Replacement:*

See IEC 61918:2018, Annex J, for the performance requirements of the bulkhead connector.

The designer shall be aware of metallic bulkhead feedthroughs that connect the cabling shield at the enclosure wall. This may form an earth loop that could disrupt communications. Where an earth loop is formed, a separate equalization conductor shall be installed to create an equal potential between the two points. An alternative method would be to isolate the bulkhead feedthrough using an insulator between the bulkhead feedthrough and the enclosure wall.

Bulkhead feedthroughs connectors allow systems to be designed and built in modular configurations. This method should be considered based on user design and service preferences. Modularity provides quick deployment and ease of serviceability.

When bulkhead connectors or adaptors are used, they need to be counted in the number of connections within a channel. See IEC 61918:2018, Annex J, to determine how many connections are allowed in a channel.

Figure B.13 is an example of M12-4 D-coding EtherNet/IP bulkhead feedthrough connectors.



**Figure B.13 – M12-4 to 8-way modular bulkhead**

See the manufacturer's data sheet for mounting hole cut-out dimensions. Consider the panel minimum and maximum wall thickness of the enclosure when selecting a bulkhead connector. In addition, consider the earthing aspects when using shielded cabling with bulkhead connectors that provide earthing connections local to the bulkhead. Noise loops may be formed in the cabling system as a result of shield being earthed in the system.

**B.4.4.3.2.5 Balanced cabling J-J coupler (J-J adaptor)**

*Addition:*

See IEC 61918:2018, Annex J, for the performance requirements of the J-J couplers.

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

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

**B.4.4.3.4.1 Common description**

**B.4.4.3.4.2 Optical fibre splices**

**B.4.4.3.4.3 Optical fibre bulkhead connections**

**B.4.4.3.4.4 Optical fibre J-J couplers (or adaptors)**

*Addition:*

The fibre cable should be long enough for the intended installation. Splices should be avoided.

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

Not applicable.

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

**B.4.4.4 Terminators**

Not applicable.

**B.4.4.5 Device location and connection**

**B.4.4.5.1 Common description**

**B.4.4.5.2 Specific requirements for CPs**

*Addition:*

Devices shall be installed in accordance with the following:

- manufacturer's documentation;
- planner's documentation;
- cable routing.

#### **B.4.4.5.3 Specific requirements for wireless installation**

Not applicable.

#### **B.4.4.5.4 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.4.4.6 Coding and labelling**

#### **B.4.4.7 Earthing and bonding of equipment and devices and shielded cabling**

##### **B.4.4.7.1 Common description**

##### **B.4.4.7.2 Bonding and earthing of enclosures and pathways**

##### **B.4.4.7.2.1 Equalisation and earthing conductor sizing and length**

*Addition:*

If the building does not have an adequate equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets in the communications coverage area.

##### **B.4.4.7.2.2 Bonding straps and sizing**

*Modification:*

Equipotential bonding conductors should preferably be constructed of copper. Aluminium and steel constructions are not recommended for communications bonding straps.

Bonding plates and busbars should preferably be of copper construction. Tin or zinc coating may be used to reduce corrosion. The plating minimum thickness shall be as detailed in IEC 61918:2018, Table 15 and Table 16.

##### **B.4.4.7.2.3 Surface preparation and methods**

##### **B.4.4.7.2.4 Bonding and earthing**

#### **B.4.4.7.3 Earthing methods**

##### **B.4.4.7.3.1 Equipotential**

##### **B.4.4.7.3.2 Star**

##### **B.4.4.7.3.3 Earthing of equipment (devices)**

*Addition:*

Equipment shall be earthed in accordance with the manufacturer's installation instructions.

**B.4.4.7.3.4 Copper bus bars****B.4.4.7.4 Shield earthing****B.4.4.7.4.1 Non-earthing or parallel RC****B.4.4.7.4.2 Direct****B.4.4.7.4.3 Derivatives of direct and parallel RC**

*Addition:*

EtherNet/IP recommends that the communications shield be parallel RC earthed at one end of the channel and directly to earth at the other end (see IEC 61918:2018, Figure.37). The communications shield is normally directly earthed at the switch. If the device does not provide a parallel RC between the connector shell and earth, then the communications shield shall be left unterminated at the connector plug. If this is not possible, then appropriate steps shall be taken to equalize any earth potential offset.

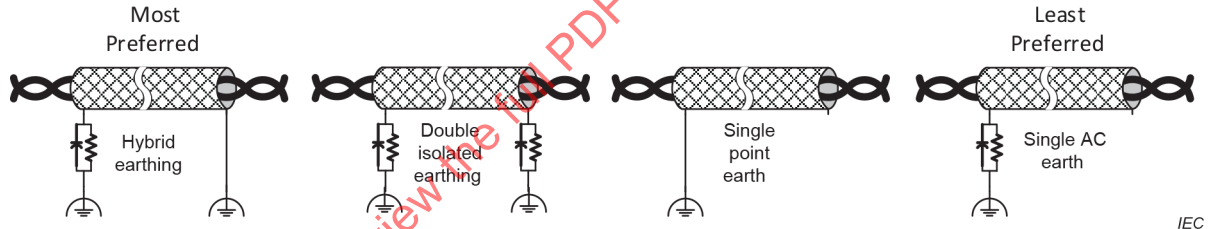
**B.4.4.7.5 Specific requirements for CPs**

*Addition:*

CP 2/2 ranks the shield application according to the applied earthing and bonding system.

## a) Star earthing

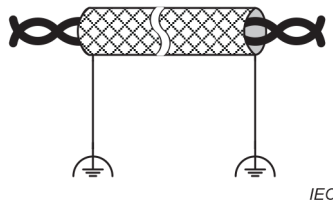
Ranking of preferred shield termination application in a star earthing arrangement is shown in Figure B.19 in order from left to right.



**Figure B.19 – Shield termination in star earthing arrangements**

## b) Equipotential/mesh earthing

In equipotential/mesh earthing arrangements, application of direct grounding at multiple points of the cable is preferred (see Figure B.20).



**Figure B.20 – Shield termination in mesh earthing arrangements**

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

**B.4.4.8 Storage and transportation of cables**

**B.4.4.9 Routing of cables**

**B.4.4.9.1 Common description**

**B.4.4.9.2 Cable routing of assemblies**

**B.4.4.9.3 Requirements for cable routing inside enclosures**

*Addition:*

To guard against coupling noise from one conductor to another, the general guidelines in IEC 61918:2018, Table 17, shall be followed when routing wires and cables (both inside and outside of an enclosure). The spacing given in these general guidelines shall be used, with the following exceptions:

- where connection points (for conductors of different EMC categories) on a device are closer together than the specified spacing;
- application-specific configurations for which the spacing is described in a publication for that specific application.

These guidelines are for noise immunity only. All local regulations for safety requirements shall be followed.

**B.4.4.9.4 Cable routing inside buildings**

*Addition:*

**B.4.4.9.4.1 Outside enclosures**

Cables that run outside protective enclosures can run along other conductors and circuits. To minimize cross-talk from nearby cables, it is good practice to maintain maximum separation between the Ethernet/IP cables and other potential noise carrying conductors. The magnitude of the coupled noise voltage increases as a function of the length that the two cables run in close proximity. Most of the noise coupling will occur within the first 3 m.

With respect to low voltages, the EtherNet/IP cables shall be routed following the guidelines in IEC 61918:2018, Table 17.

**B.4.4.9.4.2 Pathways**

Consult the local and national regulations regarding the grouping of cables. Ethernet cables shall be installed in accordance with the minimum limits defined in IEC 61918:2018, 4.4.9.3 and 4.4.9.4.

**B.4.4.9.5 Cable routing outside and between buildings**

**B.4.4.9.6 Installing redundant communication cables**

**B.4.4.10 Separation of circuits**

**B.4.4.11 Mechanical protection of cabling components**

**B.4.4.11.1 Common description**

*Addition:*

Communication enclosures may sometimes be placed close to the work area and in harsh conditions. Entry into and exit out of these enclosures either through openings in the side, back, bottom, top, or door, may require an adapter to transition from the dry, clean interior of the enclosure to the possible wet or dirty exterior, i.e. one MICE environment to another MICE environment. The connector shall be located in such a way to minimize exposure to liquids, dusts, mechanical damage and vibration. Bulkhead connectors or bulkhead cable glands shall be used where cables enter or exit the enclosures to maintain enclosure seal integrity. The sealed IP65/67 connectors specified in this installation profile shall be used in the bulkhead assemblies.

#### **B.4.4.11.2 Specific requirements for CPs**

Not applicable.

#### **B.4.4.11.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.4.4.12 Installation in special areas**

##### **B.4.4.12.1 Common description**

##### **B.4.4.12.2 Specific requirements for CPs**

*Addition:*

The cabling components shall be selected based on the environmental and application requirements. Highflex applications shall use cables designed to meet high flex. Cables expected to be subjected to weld splatter shall have the appropriate protection or jacket designs. Cables used in outdoor applications shall have the appropriate UV protection or jacketing design.

##### **B.4.4.12.3 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.4.5 Cabling planning documentation**

#### **B.4.6 Verification of cabling planning specification**

### **B.5 Installation implementation**

#### **B.5.1 General requirements**

*Addition:*

The installer should be trained and certified in installation practices for generic cabling.

##### **B.5.1.1 Common description**

##### **B.5.1.2 Installation of CPs**

##### **B.5.1.3 Installation of generic cabling in industrial premises**

#### **B.5.2 Cable installation**

##### **B.5.2.1 General requirements for all cabling types**

###### **B.5.2.1.1 Storage and installation**

###### **B.5.2.1.2 Protecting communication cables against potential mechanical damage**

*Replacement:*

Table B.24, Table B.25 and Table B.26 provide values based on the template given in IEC 61918:2018, Table 18, Table 19 and Table 20.

**Table B.24 – Parameters for balanced cables**

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	25 at –20 °C
	Bending radius, multiple bending (mm)	Vendor specified
	Pull forces (N)	110
	Permanent tensile forces (N)	–
	Maximum lateral forces (N)	400
	Temperature range during installation (°C)	Vendor specified

**Table B.25 – Parameters for silica optical fibre cables**

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

**Table B.26 – Parameters for POF optical fibre cables**

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

**B.5.2.2 Installation and routing**

**B.5.2.3 Specific requirements for CPs**

Not applicable.

**B.5.2.4 Specific requirements for wireless installation**

Not applicable.

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

**B.5.3 Connector installation**

**B.5.3.1 Common description**

*Addition:*

Not all 8-way modular connectors are suitable for harsh environments as classified by the MICE concept. The 8-way modular connector shall be carefully selected for the intended environment. The planner shall specify connectors that meet the requirements of Clause B.4 and IEC 61918:2018, Clause 4, and the environment as classified by MICE.

The connector housings in Figure B.14 and Figure B.15 are examples of the EtherNet/IP compliant housings in accordance with B.4.4.2.2. The planner shall specify in the design documentation the correct shell material (plastic or metal) for the application.



**Figure B.14 – The 8-way modular sealed jack & plug (plastic housing)**



**Figure B.15 – The 8-way modular sealed jack & plug (metal housing)**

The EtherNet/IP specification provides for the use of small sealed connectors such as the M12-4 D-coding connector found in Figure B.16.



**Figure B.16 – M12-4 connectors**

The connector wiring standard to use shall be determined.

There are two 8-way modular wiring methods in use today. Pairs 2 and 3 are swapped depending on which wiring standard, T568A or T568B is used (see Figure H.2 of IEC 61918:2018).

T568A shall be used in generic applications where support of 2-pair phone systems is needed. If 2-pair phone system support is not needed, then either wiring system (T568A or T568B) is acceptable. See IEC 61918:2018, Annex H and IEC 61918:2018/AMD1:2022, Annex H. The wiring scheme selected shall be used throughout the entire link and/or channel.

#### **B.5.3.2 Shielded connectors**

#### **B.5.3.3 Unshielded connectors**

#### **B.5.3.4 Specific requirements for CPs**

*Addition:*

See the manufacturer's data sheet for the assembly instructions of the sealed RJ-45 connector housing.

#### **B.5.3.5 Specific requirements for wireless installation**

Not applicable.

#### **B.5.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

#### **B.5.4 Terminator installation**

Not applicable.

#### **B.5.5 Device installation**

#### **B.5.6 Coding and labelling**

#### **B.5.7 Earthing and bonding of equipment and devices and shield cabling**

##### **B.5.7.1 Common description**

##### **B.5.7.2 Bonding and earthing of enclosures, and pathways**

##### **B.5.7.3 Earthing methods**

##### **B.5.7.3.1 Equipotential**

*Addition:*

The earthing method shall be in accordance with the planner's documentation. If there is an earth potential offset in the communication coverage area, equalization conductors shall be installed to mitigate the offset. The cross sectional area of these conductors shall be in accordance with IEC 61918:2018, 4.4.7.2.1, Table 14. EtherNet/IP supports both an Equipotential earthing system, and the Star earthing system. Due to its simplicity and effectiveness, it is recommended that the Star earthing system be employed.

##### **B.5.7.3.2 Star**

*Addition:*

In addition to the requirements of B.4.4.7.3.2, the following shall be observed.

Cable shields for the communications equipment shall be referenced only to the signal earth (functional earth). Other equipment such as motors or motor controllers shall not be referenced to the functional earth. The star earth of the two systems (functional earth and protective earth) shall converge at one point within the building as shown in IEC 61918:2018, Figure 17. Earthing connections for the cabinets shall not be daisy chained.

##### **B.5.7.3.3 Earthing of equipment (devices)**

*Addition:*

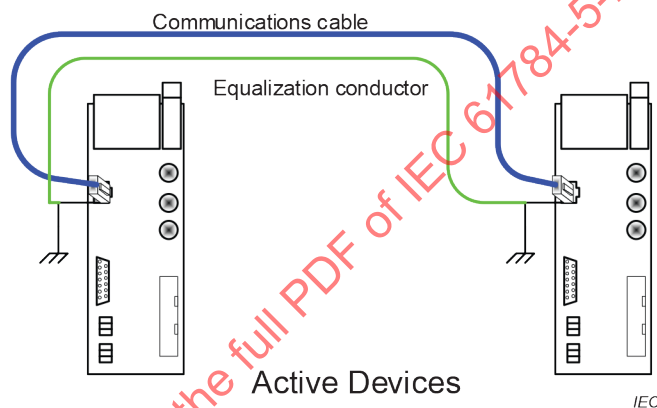
Equipment shall be earthed in accordance with the manufacturer's installation instructions and the planner's documentation.

**B.5.7.4 Shield earthing methods****B.5.7.4.1 General****B.5.7.4.2 Parallel RC****B.5.7.4.3 Direct****B.5.7.4.4 Derivatives of direct and parallel RC**

*Modification:*

Figure B.17 only applies if both the switch and the device are directly earthed. In this case, an equalization conductor shall be installed to assure that noise currents are not carried by the communications cable shields. The sizing of the conductor shall be in accordance with Table 14 of IEC 61918:2018. EtherNet/IP recommends that the active devices provide a parallel RC termination for the communications shield integral to the device. Therefore IEC 61918:2018, Figure 37 applies.

The switch provides direct connection to functional or protective earth.



**Figure B.17 – Earthing of cable shield**

*Addition:*

If the active device provides a low DC resistance (less than 500 k $\Omega$ ) to earth at the jack and connects to a link partner device that also provides a low DC resistance to earth at its jack, an equalizing shunt conductor shall be used to mitigate earth voltage offsets between the two end points, see IEC 61918:2018, Figure 35. The sizing of the conductor shall be in accordance with IEC 61918:2018, Table 14.

**B.5.7.5 Specific requirements for CPs**

Not applicable.

**B.5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 11801-3**

**B.5.8 As-implemented cabling documentation**

**B.6 Installation verification and installation acceptance test**

**B.6.1 General**

**B.6.2 Installation verification**

**B.6.2.1 General**

*Addition:*

The following additional parameters shall be verified:

- jacketed length;
- kinks in cable;
- breaks in the jacket, abraded or burned;
- bend radius;
- presence of dust caps for unused connectorized cabling and equipment;
- labelling per design documentation (outlets and cables);
- routing of cables with respect to other circuits according to IEC 61918:2018, Table 17.

**B.6.2.2 Verification according to cabling planning documentation**

**B.6.2.3 Verification of earthing and bonding**

**B.6.2.4 Verification of shield earthing**

**B.6.2.5 Verification of cabling system**

**B.6.2.5.1 Verification of cable routing**

*Addition:*

- a) The length of the end-to-end link or a channel is the sum of the lengths of the fixed horizontal cables and cords between the two end points. The length of a permanent link is the sum of the fixed horizontal cable and any intermediary cords not including those cords connecting directly to the end equipment. Length of the link/channel can be determined by physically measuring the length(s) of the cable(s), determined from the length markings on the cable(s), when present.
- b) The length of the permanent link shall not be greater than 90 m (295 ft). The length of the end-to-end link or channel shall not be greater than 100 m (328 ft), including equipment cords and patch cords. If the channel or permanent link has been de-rated because of temperature or cable attenuation, then the total channel length is less than 100 m (328 ft) and the permanent link will be less than 90 m (295 ft). See the derating tables in IEC 61918:2018 (Table 11 and Table 12).

**B.6.2.5.2 Verification of cable protection and proper strain relief**

**B.6.2.6 Cable selection verification**

**B.6.2.6.1 Common description**

**B.6.2.6.2 Specific requirements for CPs**

Not applicable.

**B.6.2.6.3 Specific requirements for wireless installation**

Not applicable.

**B.6.2.7 Connector verification****B.6.2.7.1 Common description****B.6.2.7.2 Specific requirements for CPs**

Not applicable.

**B.6.2.7.3 Specific requirements for wireless installation**

Not applicable.

**B.6.2.8 Connection verification****B.6.2.9 Terminator verification**

Not applicable.

**B.6.2.10 Coding and labelling verification****B.6.2.10.1 Common description****B.6.2.10.2 Specific coding and labelling verification requirements**

Not applicable.

**B.6.2.11 Verification report****B.6.3 Installation acceptance test****B.6.3.1 General****B.6.3.2 Acceptance test of Ethernet-based cabling****B.6.3.2.1 Validation of balanced cabling for CPs based on Ethernet****B.6.3.2.1.1 Common description**

*Addition:*

Acceptance testing shall include the following aspects of the network:

- Physical installation attributes that may affect the life of the installation, such as;
  - location of cabling with respect to electrical noise and environmental conditions,
  - earthing of devices and equipment where specified,
  - wire ways,
  - bend radii,
  - cable supports (hangers),
  - cable loading and crushing,
  - proper media commensurate with the environment.
- Electrical performance commensurate with the needs of the application, such as:
  - electrical and physical lengths of channels and permanent links,
  - swept frequency measurements as detailed later in this Clause B.6.