IEC 61784-5-2

Edition 4.0 2018-08

# INTERNATIONAL STANDARD

colour inside

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



IEC 61784-5-2:2018-08(en)

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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 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.

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

| FDIS | Report on voting |
|---|---|
| 65C/924/FDIS | 65C/925/RVD |

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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 will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

# INTRODUCTION

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

IEC 61918:2018 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.



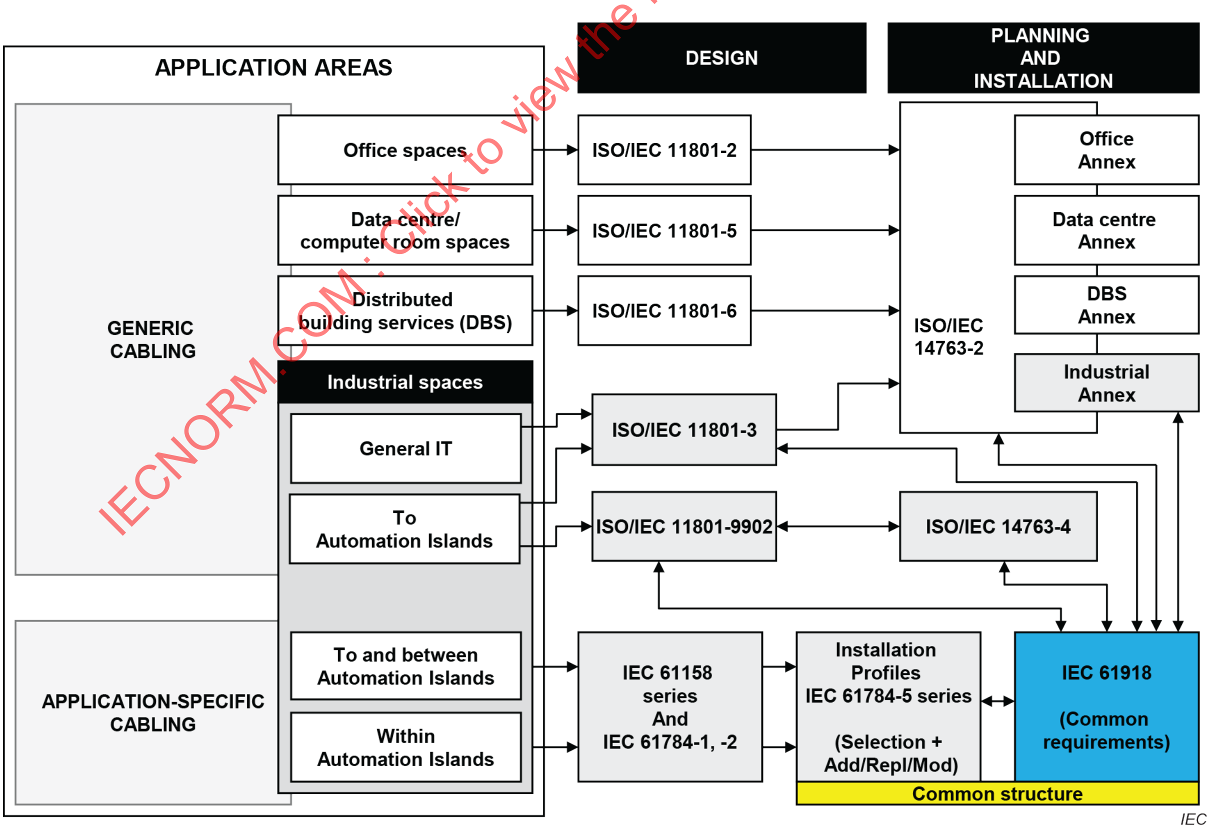


Figure 1 – Standards relationships

# 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™[1]).

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

## 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, *Industrial communication networks – Installation of communication networks in industrial premises*

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, 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.

## 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™[2]) are specified in Annex A.

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[1] 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.

The installation requirements for CP 2/2 (EtherNet/IP™[3]) are specified in Annex B.

The installation requirements for CP 2/3 (DeviceNet™[4]) 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.

If all (sub)clauses of a (sub)clause are omitted but in this (sub)clause it is written "*(Sub)clause × has "addition:*" (or "*replacement:*") or "(Sub)clause × is not applicable.", then



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2 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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(Sub)clause × 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[5] as either

Compliance to IEC 61784-5-2:—[6] for CP 2/m <name> or

Compliance to IEC 61784-5-2 (Ed.4.0) for CP 2/m <name>

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

NOTE The name may 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).



5 In accordance with ISO/IEC Directives.

6 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[7], *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.



[7] 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.

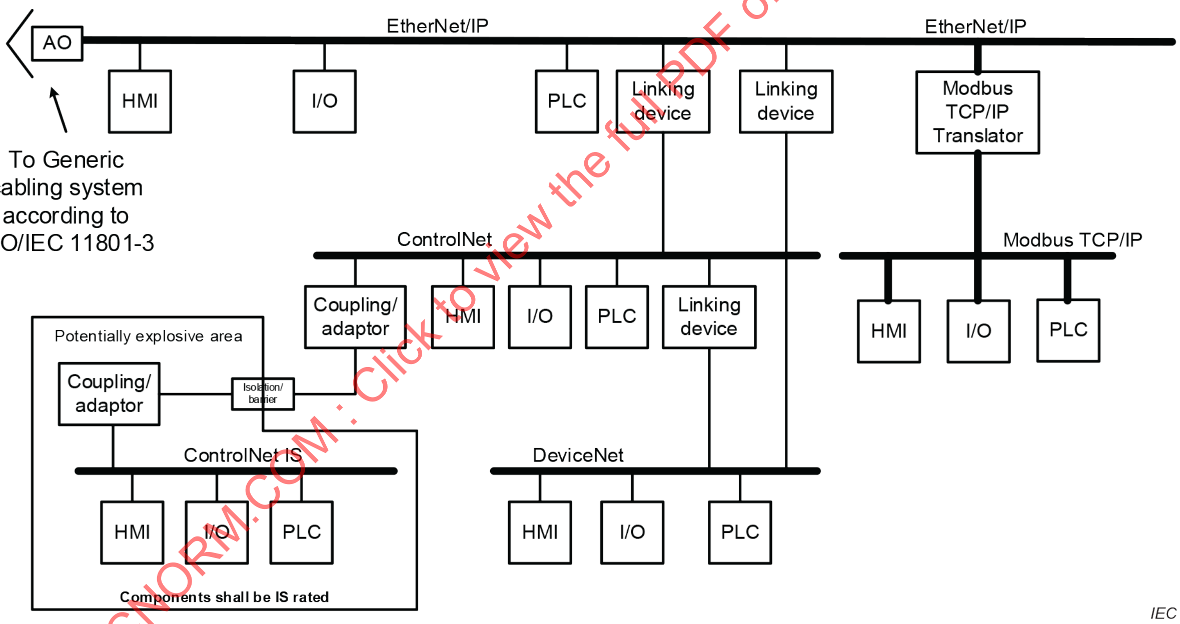



**Figure A.1 – Interconnection of CPF 2 networks**

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).

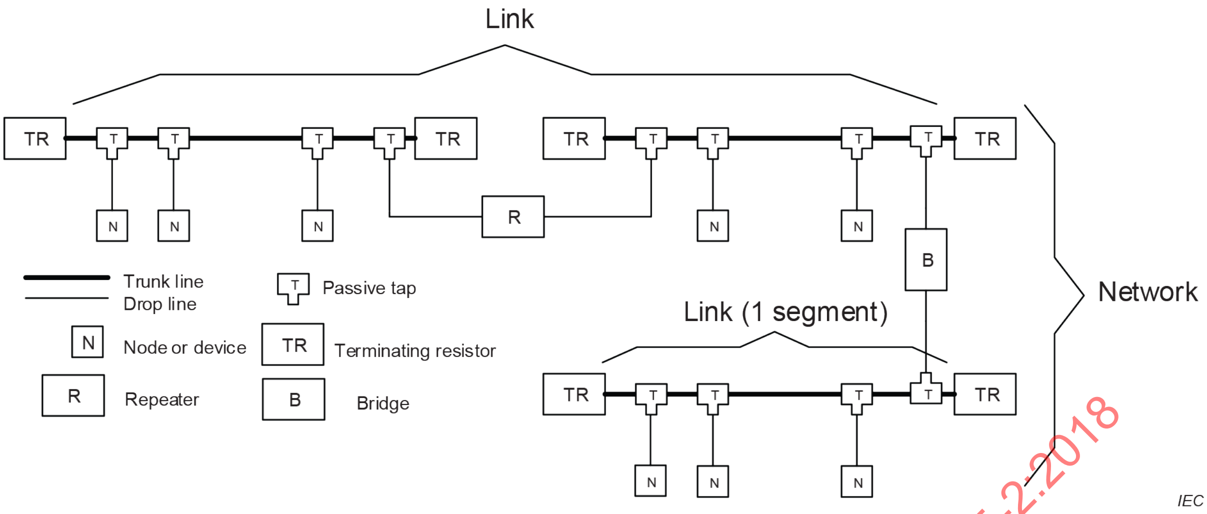



**Figure A.2 – Overview of CPF 2/1 networks**

### 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 µs round trip or 121 µs 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.

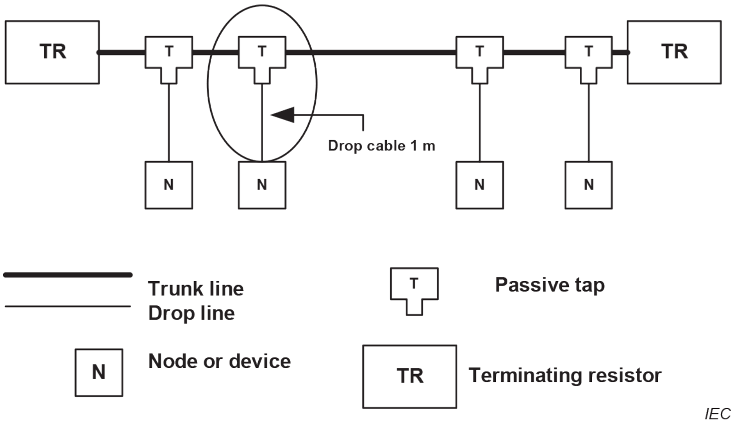



**Figure A.3 – Drop cable requirements**

### 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.

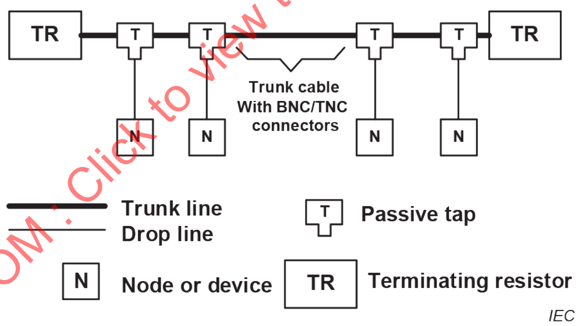



**Figure A.4 – Placement of BNC/TNC plugs**



### 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.

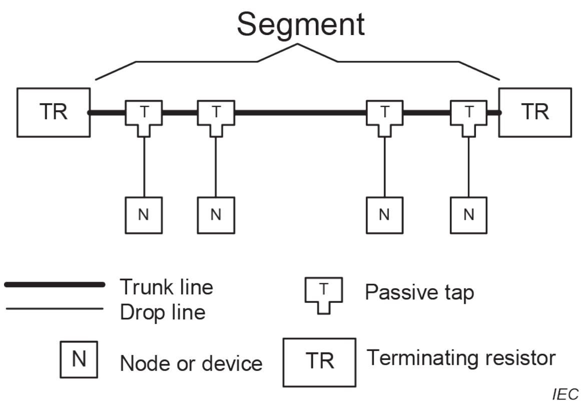



**Figure A.5 – Placement of terminators**

### 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.

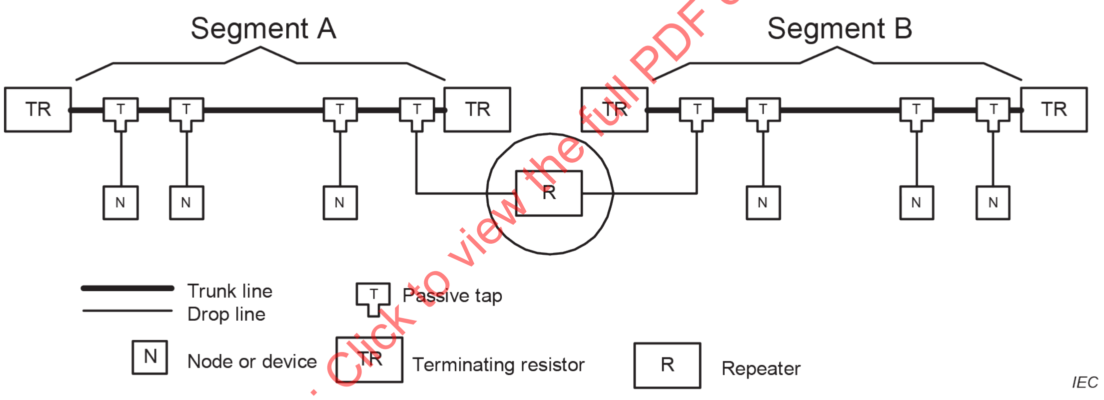



**Figure A.6 – Extending a network using repeaters**

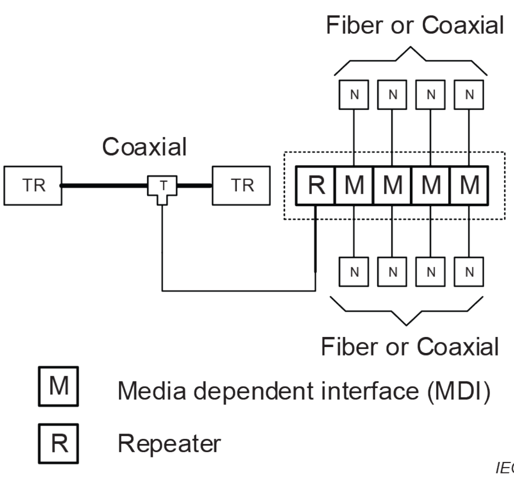



**Figure A.7 – Extending a network using active star topology**

#### 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.

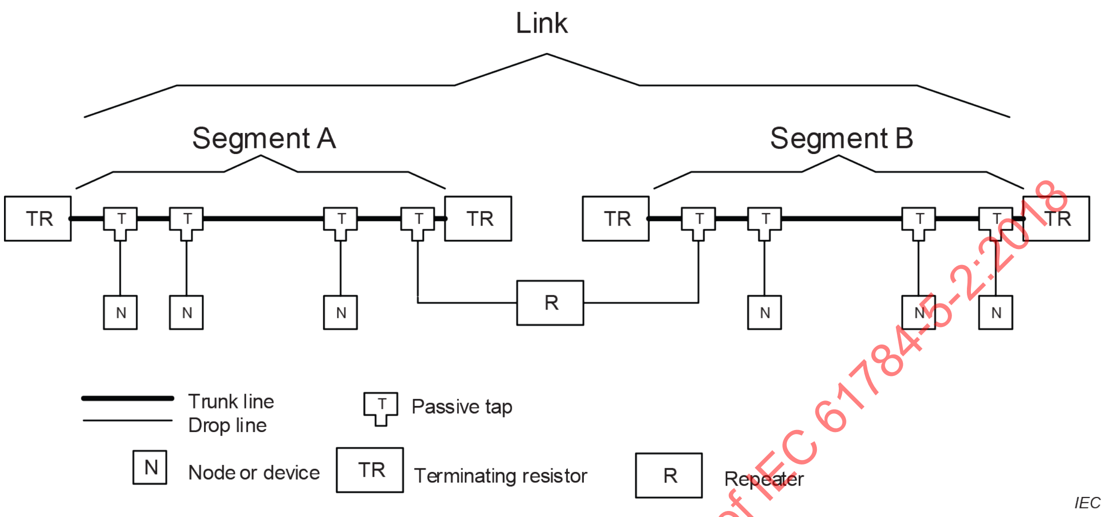



**Figure A.8 – Links**

#### 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.

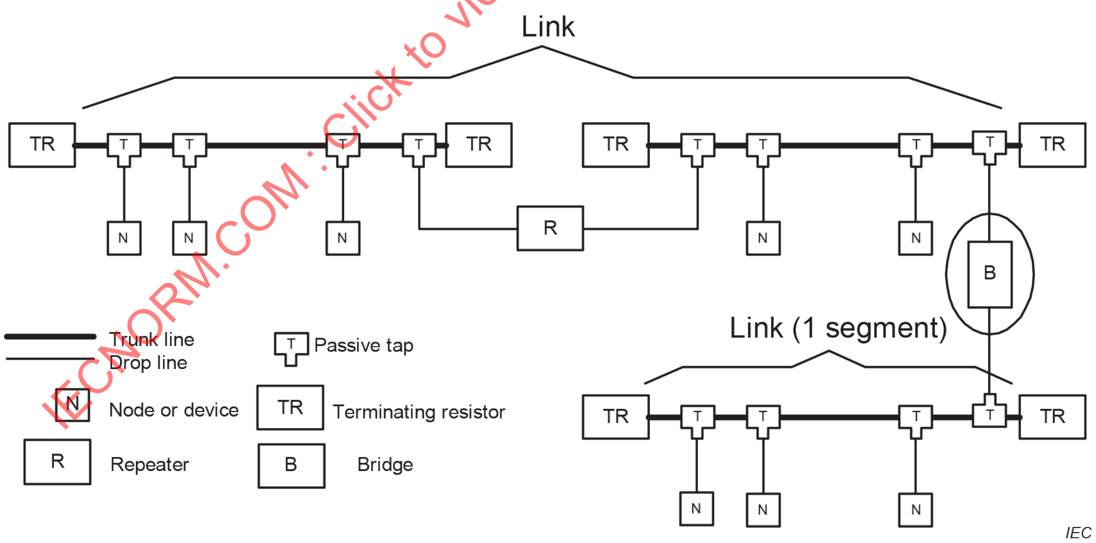



**Figure A.9 – Extending the network beyond 99 nodes**

#### 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 |
|---|---|
| **Basic transmission technology** | Linear bus |
| **Length / transmission speed** | |
| Transmission speed | Segment length<br>m |
| 5 Mbit/s | Segment: 1 000 m maximum (see Figure A.10)<br>Link: 20 km maximum [a] |
| **Maximum capacity** | **Max. no.** |
| Devices / segment | 48 |
| Devices / link | 99 |
| Devices / network | Unlimited |

[a] 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 *λ (nm)* | 20 MHz 1 310 nm |
| | Minimum length (m) | 0 |
| | Maximum length[a] (m) | 20 000[b] |
| | 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 *λ (nm)* | 20 MHz 1 300 nm |
| | Minimum length (m) | 0 |
| | Maximum length[a] (m) | M = 3 000[c]<br>L = 10 000[c]<br>XL = 10 000[c] |
| | Maximum channel Insertion loss/optical power budget (dB) | M = 13,3<br>L = 15<br>XL = 10,5 |
| | Connecting HW | See A.4.4.2.5 |
| POF | Modal bandwidth (MHz × km) at *λ (nm)* | – |
| | Minimum length (m) | – |
| | Maximum length[a] (m) | – |
| | Maximum channel Insertion loss/optical power budget (dB) | – |
| | Connecting HW | – |
| Hard clad silica | Modal bandwidth (MHz × km) at *λ (nm)* | 20 MHz 650 nm |
| | Minimum length (m) | 0 |
| | Maximum length[a] (m) | 300 |
| | Maximum channel Insertion loss/optical power budget (dB) | 4,2[d] |
| | Connecting HW | See A.4.4.2.5 |

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

[b] Extra Long Repeaters Only.

[c] M = Medium distance capable modules, L = Long distance capable modules and XL = Extra long distance capable modules.

[d] 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 Ω 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 ± 3) Ω |
| Delay | (4,1 ± 0,1) 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 Ω/km nominal |
| Shield DC resistance | 24 Ω/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<br>0,823 $mm^2$ ± 0,020 4 $mm^2$ |
| Dielectric material and diameter | 4,65 mm ± 0,13 mm |
| Shield construction 4 layers | Layer 1: foil<br>Layer 2: 60 % braid<br>Layer 3: foil<br>Layer 4: 40 % braid |
| Jacket diameter | 7,67 mm ± 0,13 mm |

*Addition:*

CP 2/1 uses 75 Ω 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[a] |
|---|---|
| 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<br>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 |
| [a] 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[a] | Yes[a] | Yes[a] | – | Yes[a] |
| NOTE Duplex and simplex cords/cables are supported. | | | | | |
| [a] 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<br>IEC 61169-8 | Others |
|---|---|---|
| Characteristics for CP 2/1 (ControlNet) | BNC | TNC<br>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** |
| **CP 2/1 (ControlNet)** | 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 µm single mode silica | 50/125 µm multimode silica | 62,5/125 µm multimode silica | 980/1 000 µm step index POF | 200/230 µm step index hard clad silica | Others |
| BFOC/2,5 | 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 µm. | | | | | | |

#### 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.

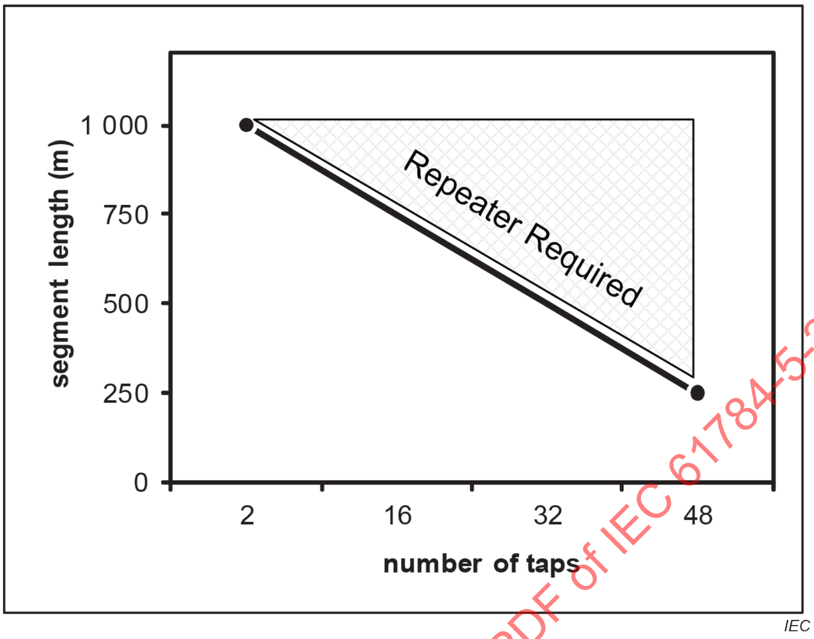



**Figure A.10 – Maximum allowable taps per segment**



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 m – 16,3 m × [10 – 2]

1 000 m – 130,4 m = 869,6 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:

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

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:

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

or

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

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).



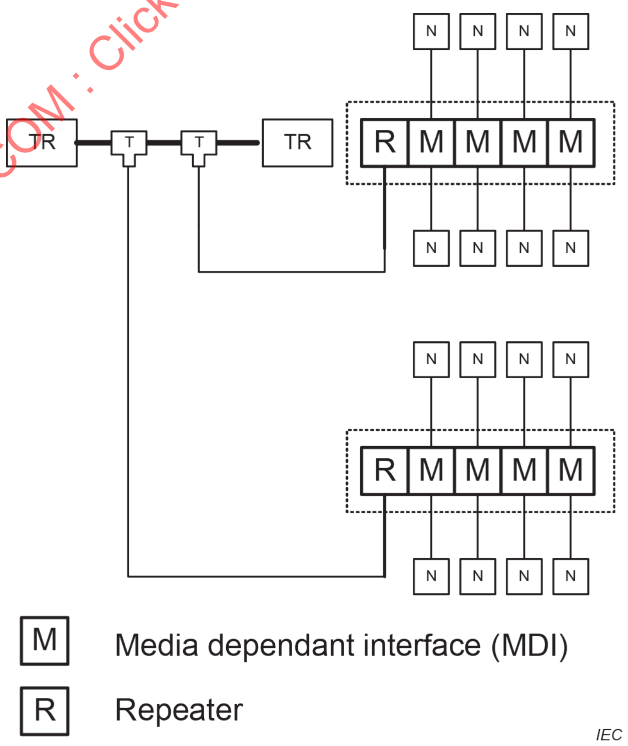



**Figure A.11 – Example of repeaters in star configuration**

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 µs end-to-end or 242 µs 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.

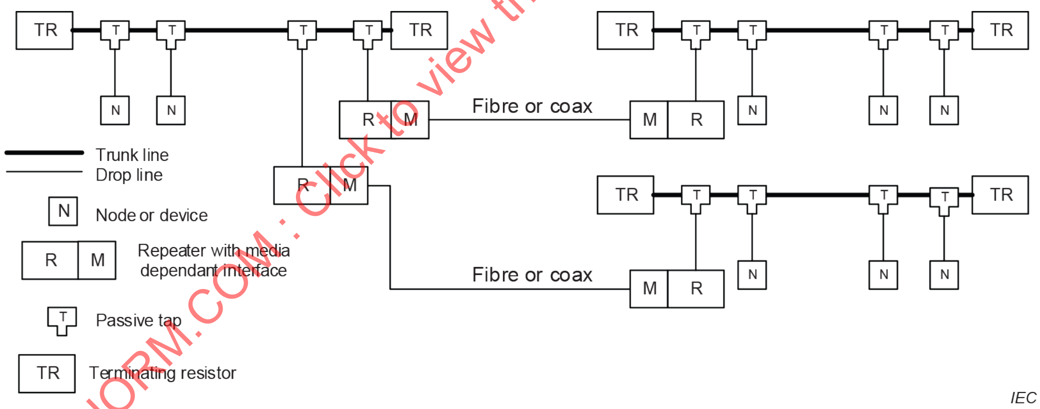



**Figure A.12 – Repeaters in parallel**



**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.

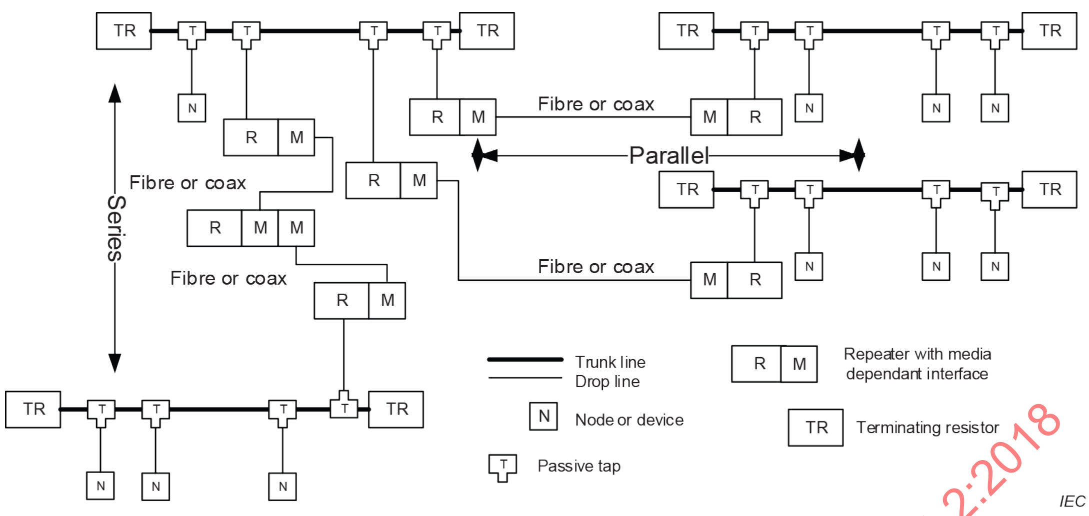



**Figure A.13 – Repeaters in combination series and parallel**

**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.

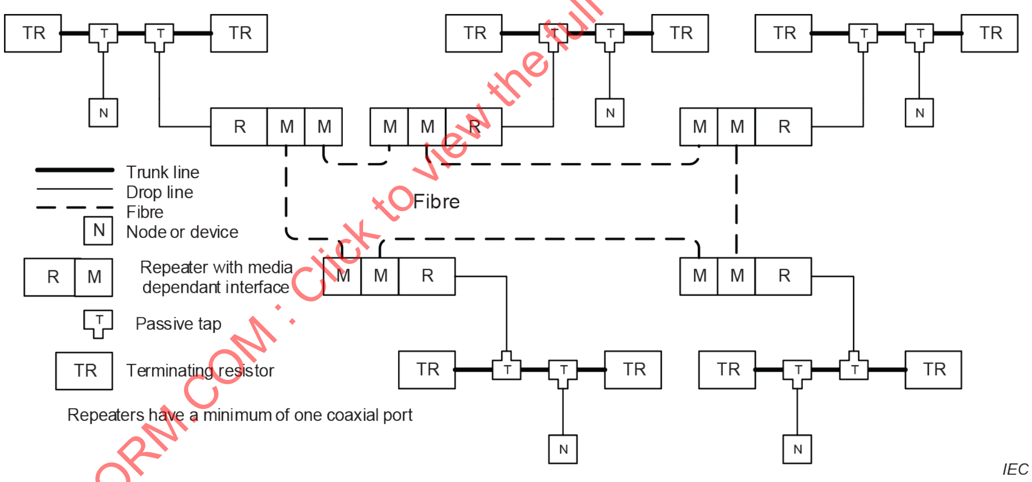



**Figure A.14 – Ring repeater**

### 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 Ω, 45 Ω minimum and 80 Ω 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.

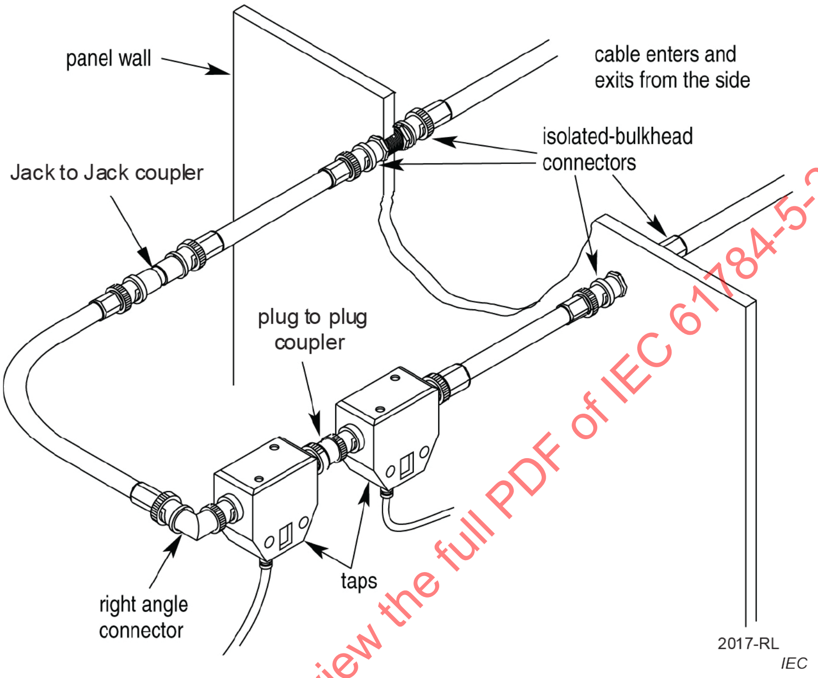



**Figure A.15 – Installing bulkheads**



#### 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 Ω, 45 Ω minimum and 80 Ω 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).

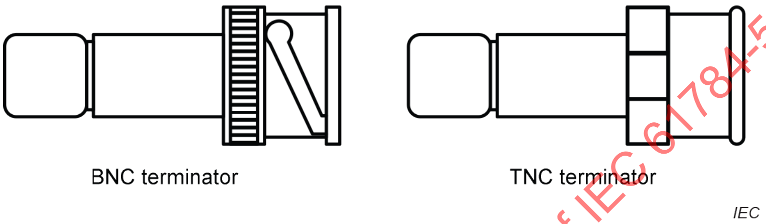



**Figure A.16 – Coaxial BNC and TNC terminators**

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.

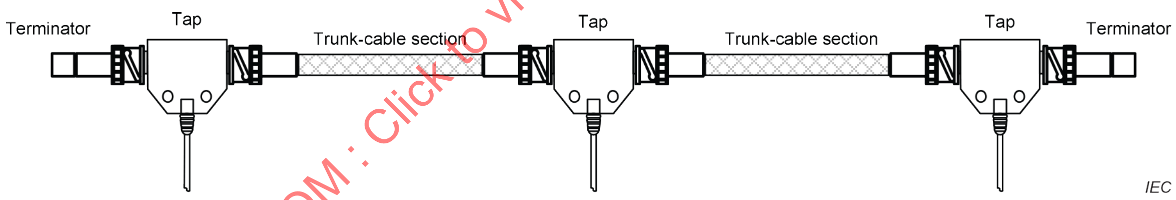



**Figure A.17 – Terminator placement in a segment**

#### 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:*

ContolNet 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.

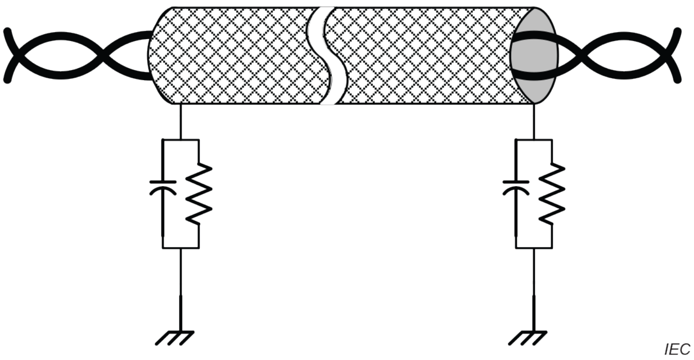



**Figure A.18 – RC Shield Termination in Active Devices**

#### 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 coaxial 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

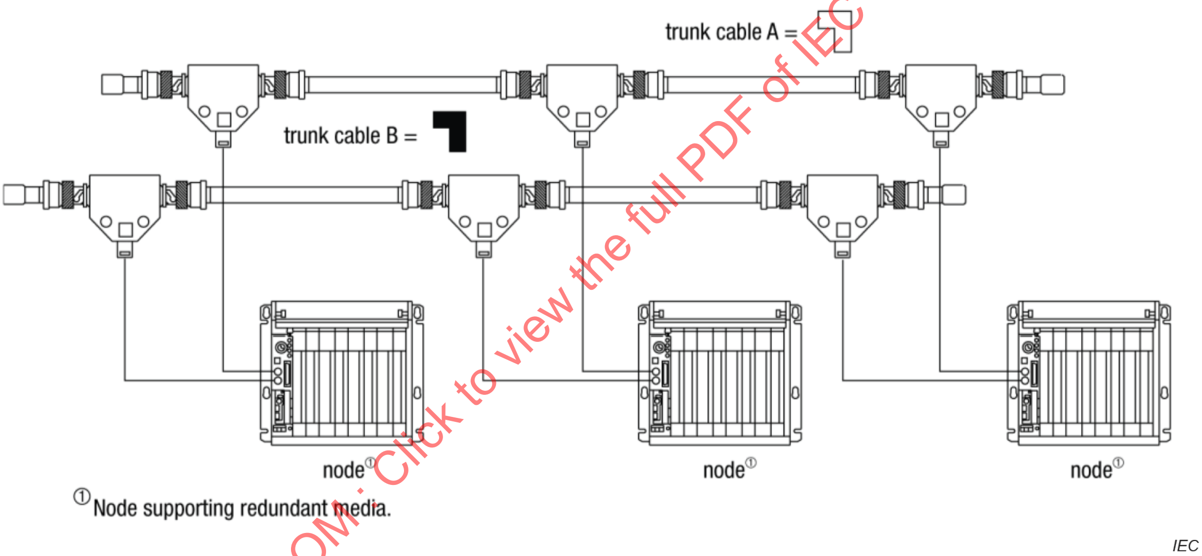



**Figure A.20 – Redundant coax media**

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

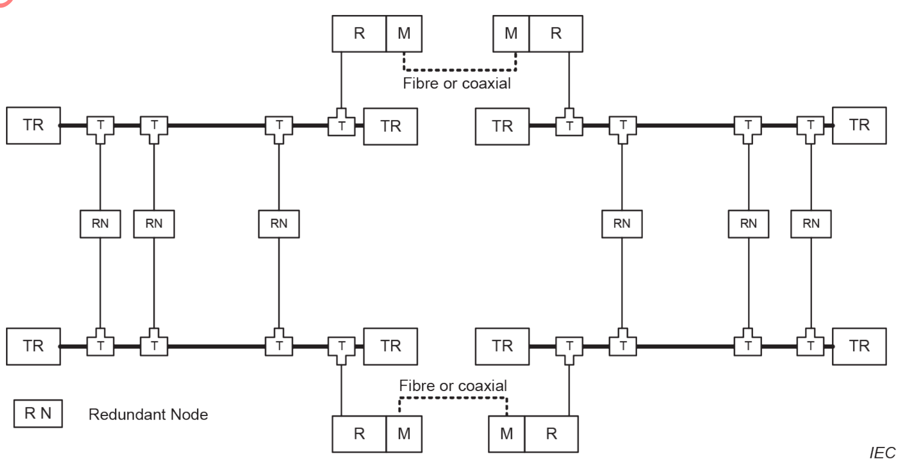



**Figure A.21 – Redundant fibre media**

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.

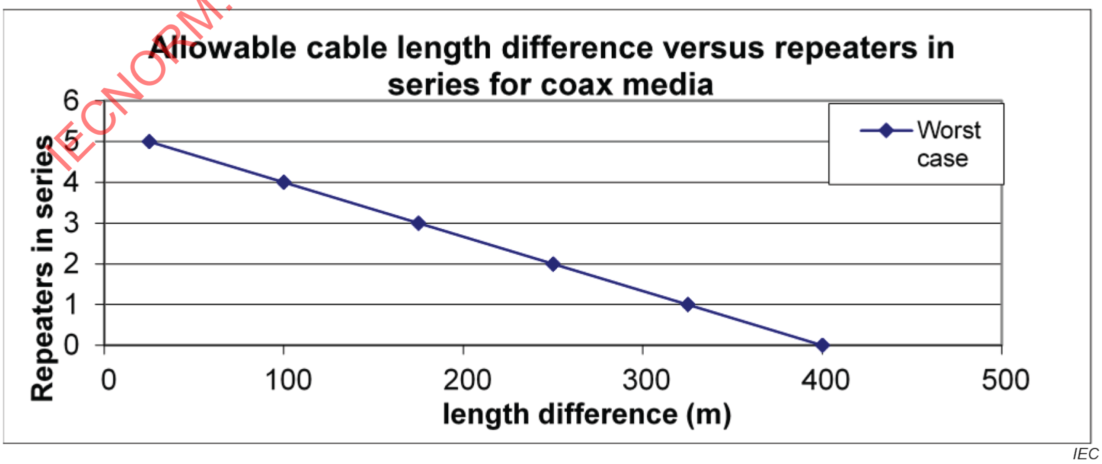



**Figure A.22 – Repeaters in series versus length difference for coax media**

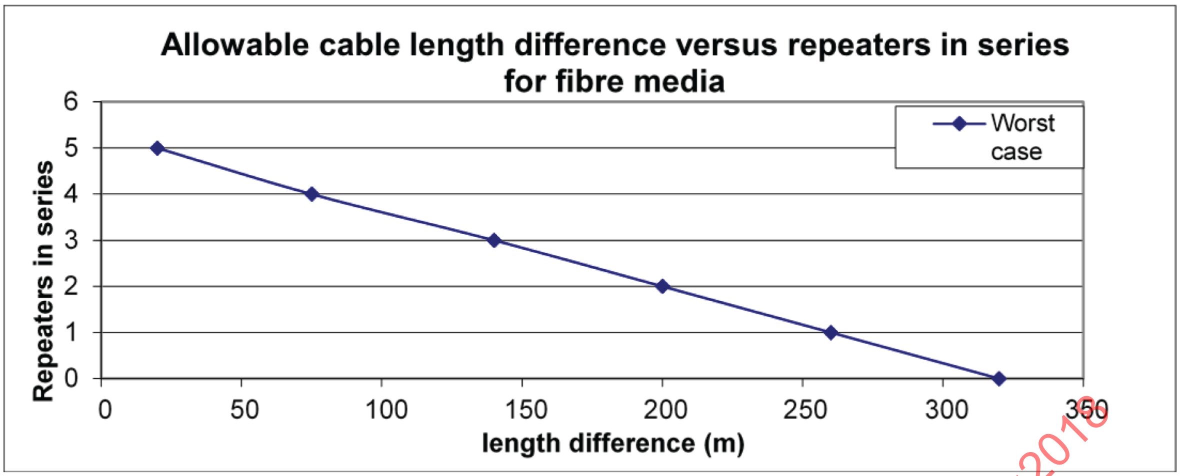



**Figure A.23 – Repeaters in series versus length difference for fibre media**

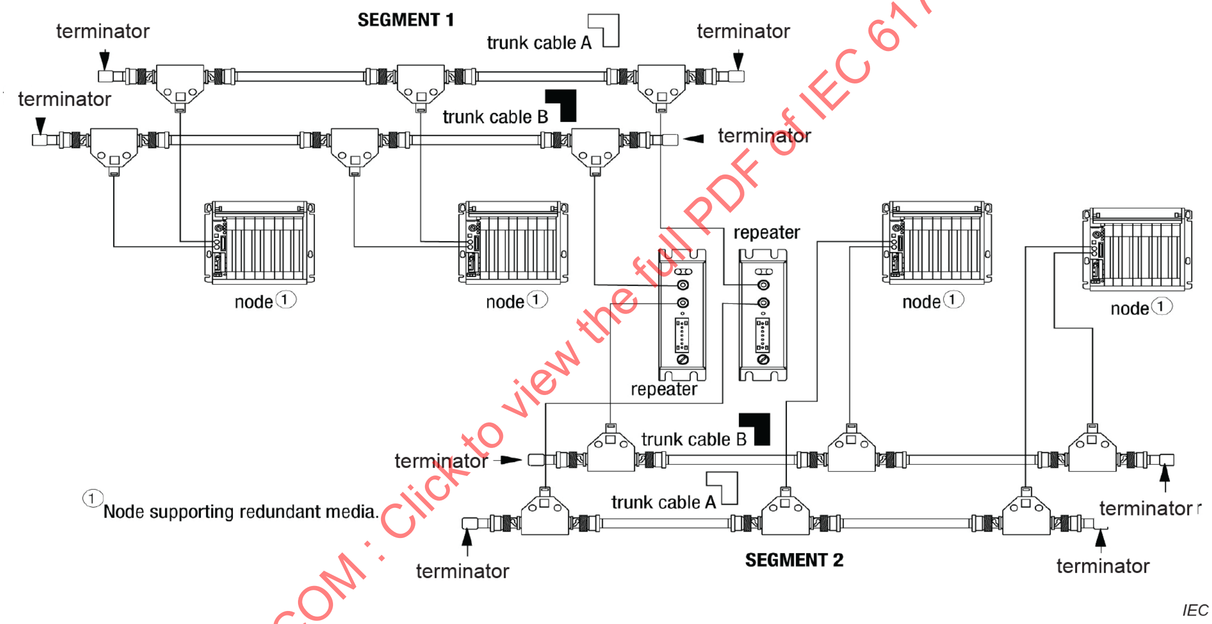



**Figure A.24 – Example of redundant coax network with repeaters**

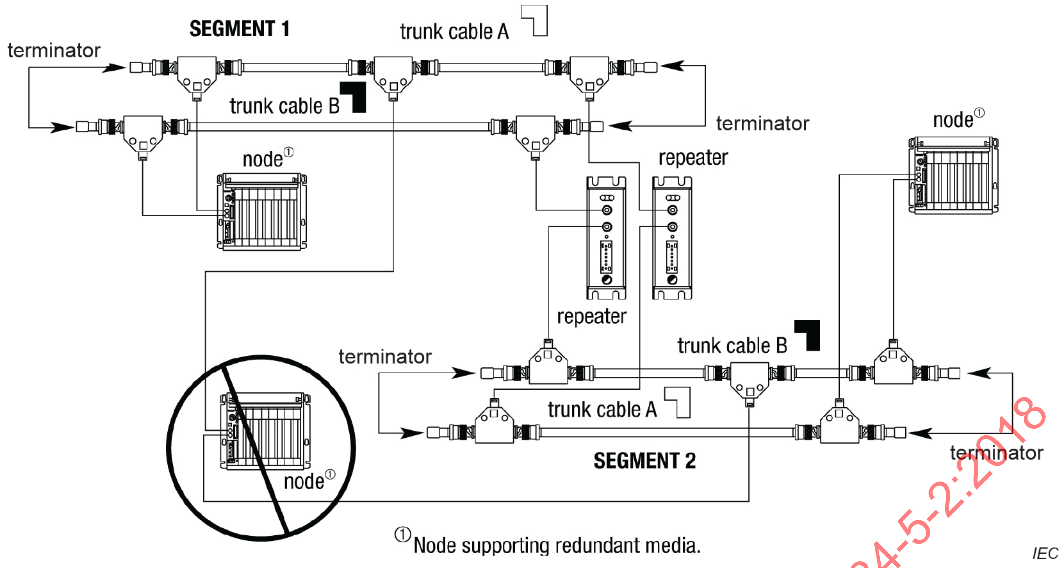



**Figure A.25 – Example of improper redundant node connection**

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 |
| Mechanical force | 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.

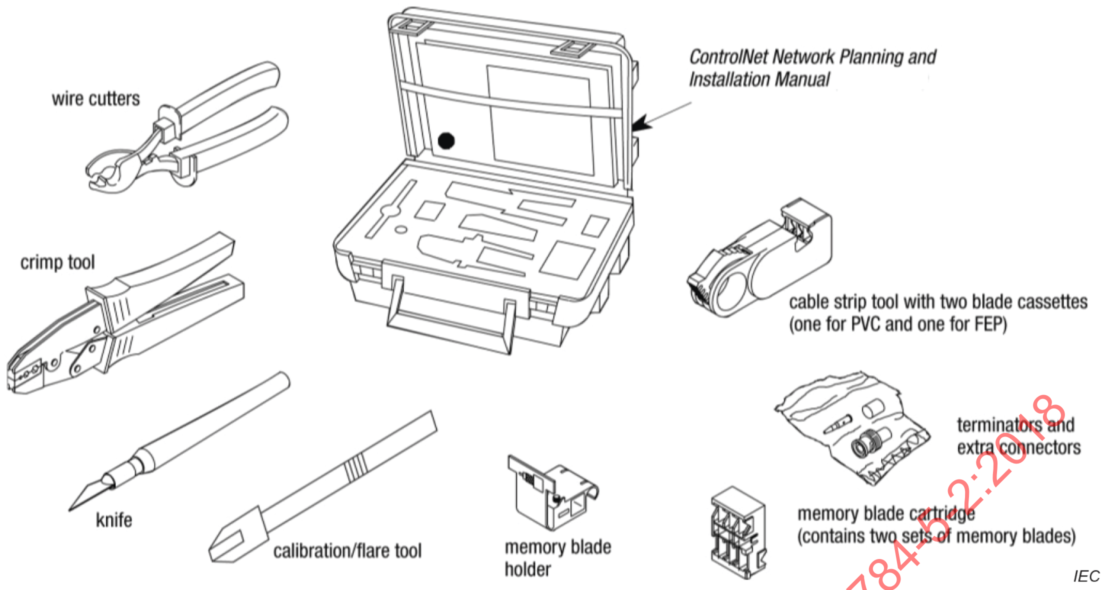



**Figure A.26 – Example tool kit for installing BNC connectors**

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.

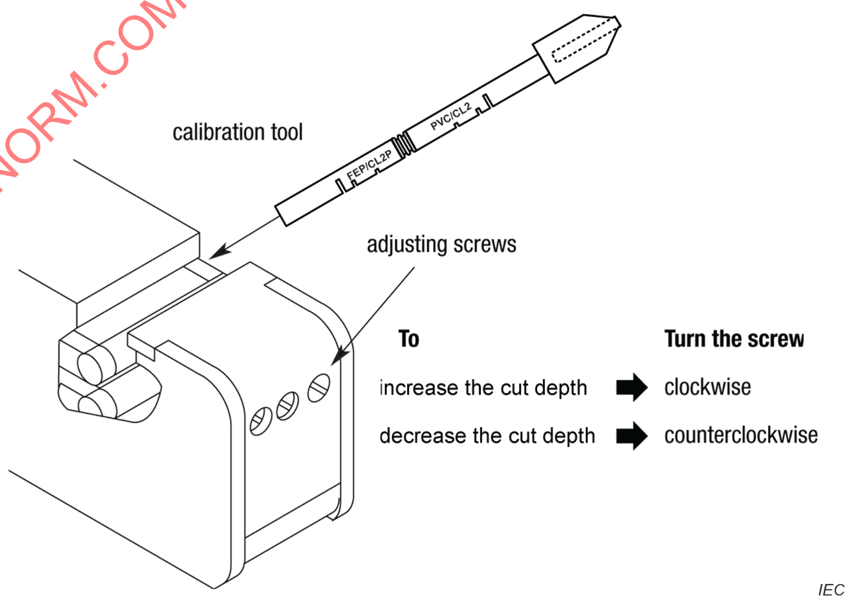



**Figure A.27 – Calibration of coaxial stripper**

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 groves.

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.

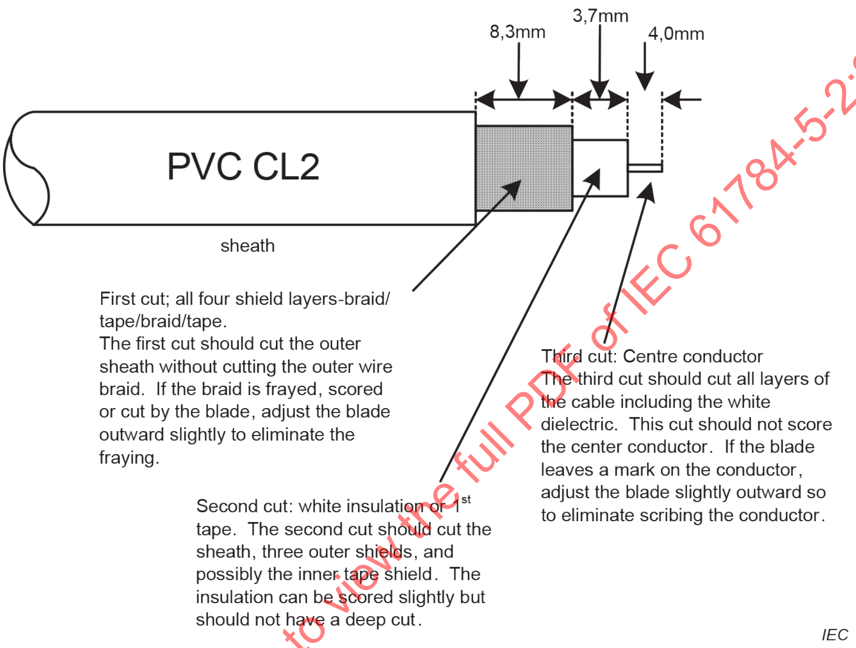



**Figure A.28 – Coax PVC strip length detail (informative)**



**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.

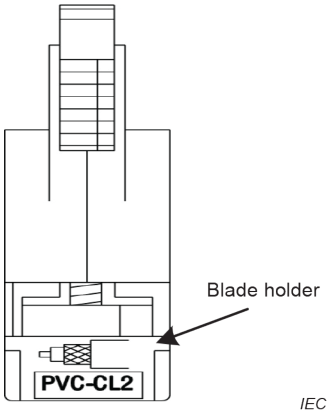



**Figure A.29 – Memory cartridge and blade**

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.

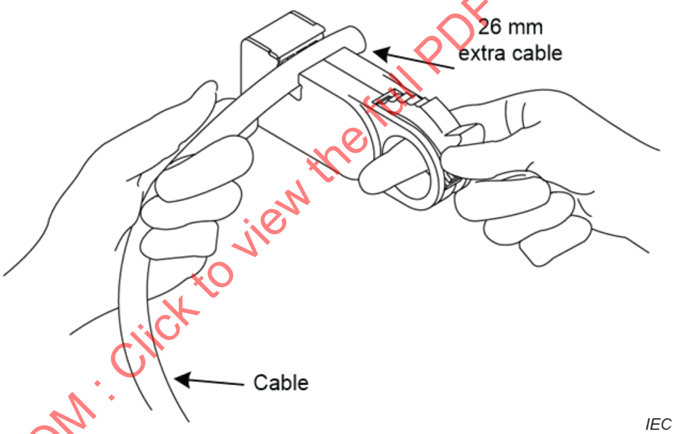



**Figure A.30 – Cable position**

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.

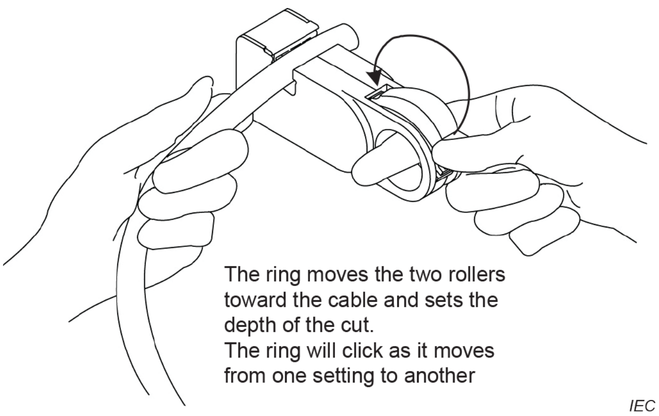



**Figure A.31 – Locking the cable**

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.

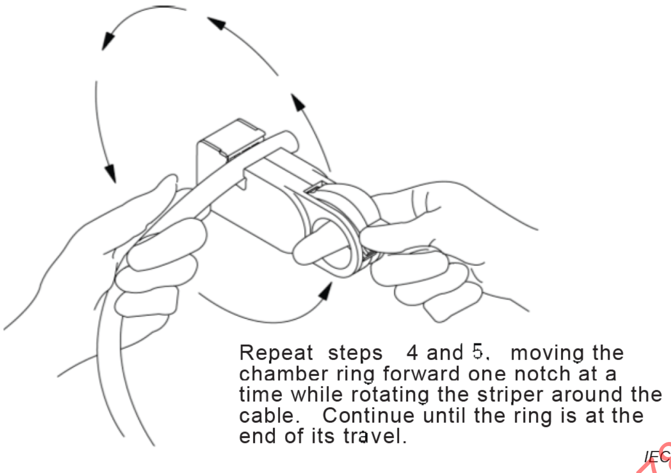



**Figure A.32 – Stripping the cable**

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.

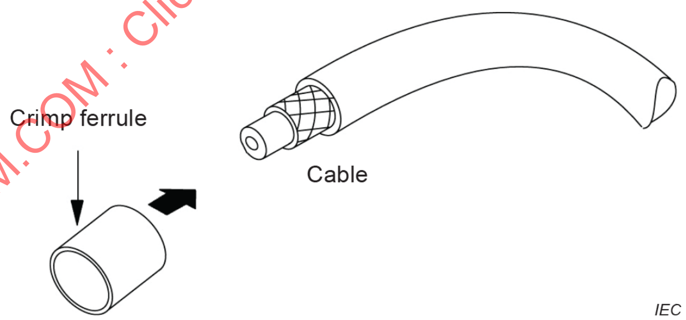



**Figure A.33 – Install the crimp ferrule**

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.

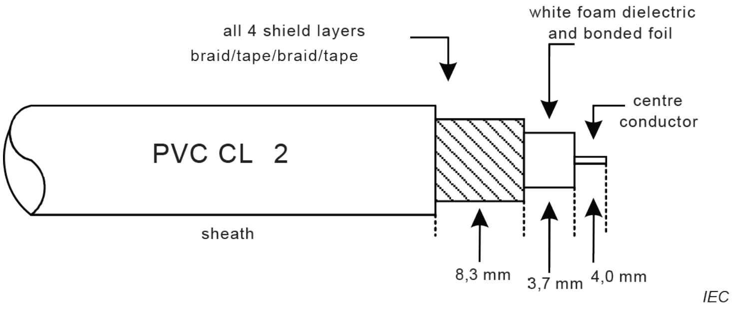



**Figure A.34 – Cable preparation for PVC type cables (informative)**

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.

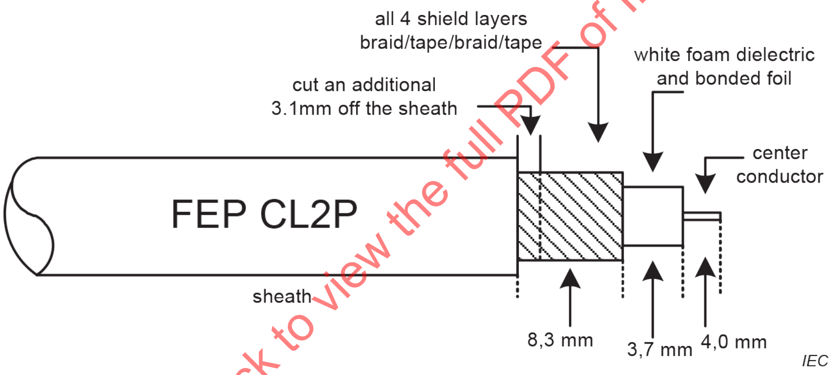



**Figure A.35 – Cable preparation for FEP type cables (informative)**

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.

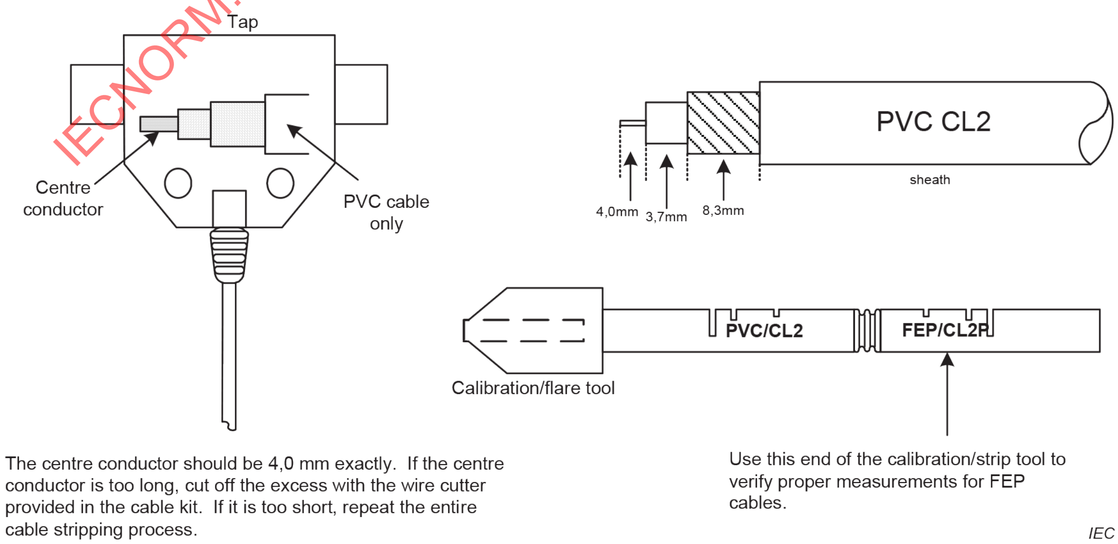



**Figure A.36 – Strip guides**

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.

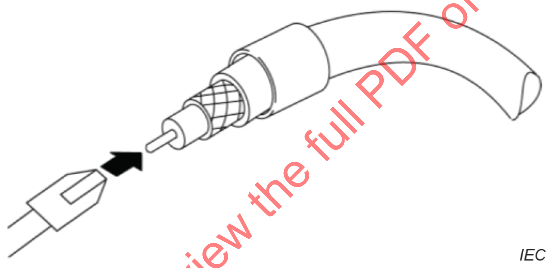



**Figure A.37 – Using the flare tool**

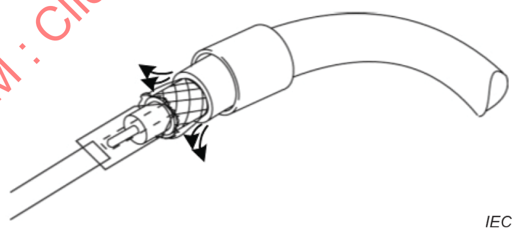



**Figure A.38 – Expanding the shields**



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

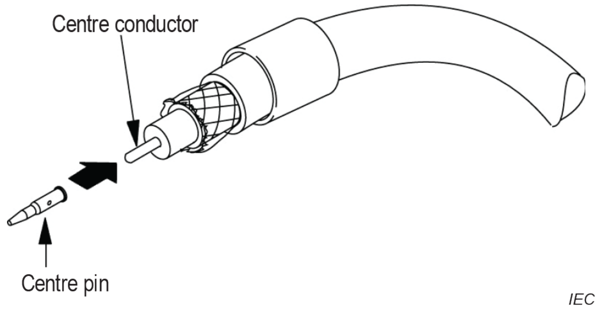



**Figure A.39 – Install the centre pin**

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.

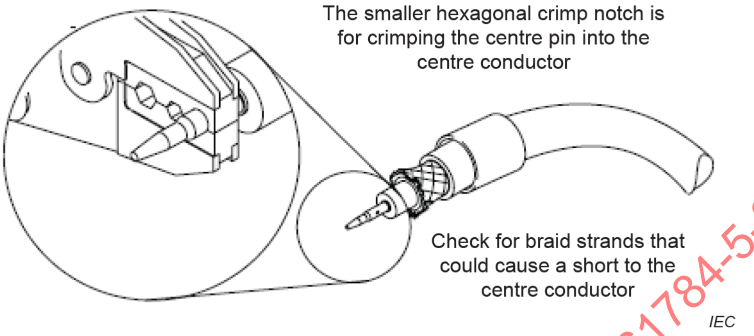



**Figure A.40 – Crimping the centre pin**

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).

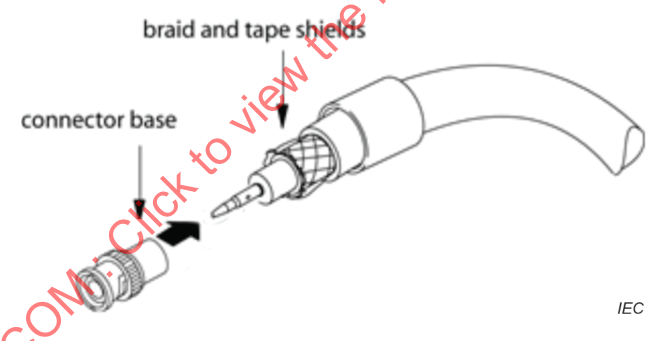



**Figure A.41 – Installing the connector body**

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.

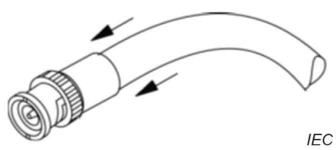



**Figure A.42 – Installing the ferrule**

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.

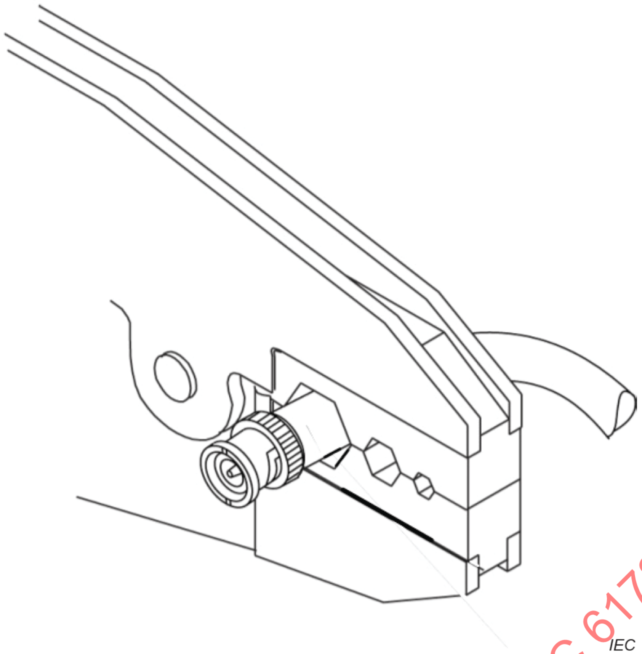



**Figure A.43 – Crimp tool**



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.

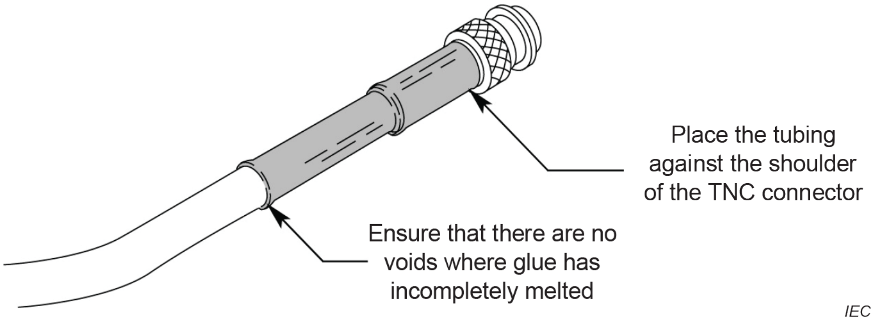



**Figure A.44 – Sealed IP65/67 cable**

#### 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.

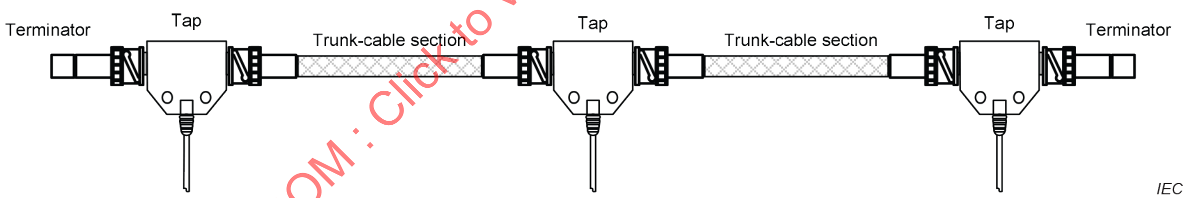



**Figure A.45 – Terminator placement**

### 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.

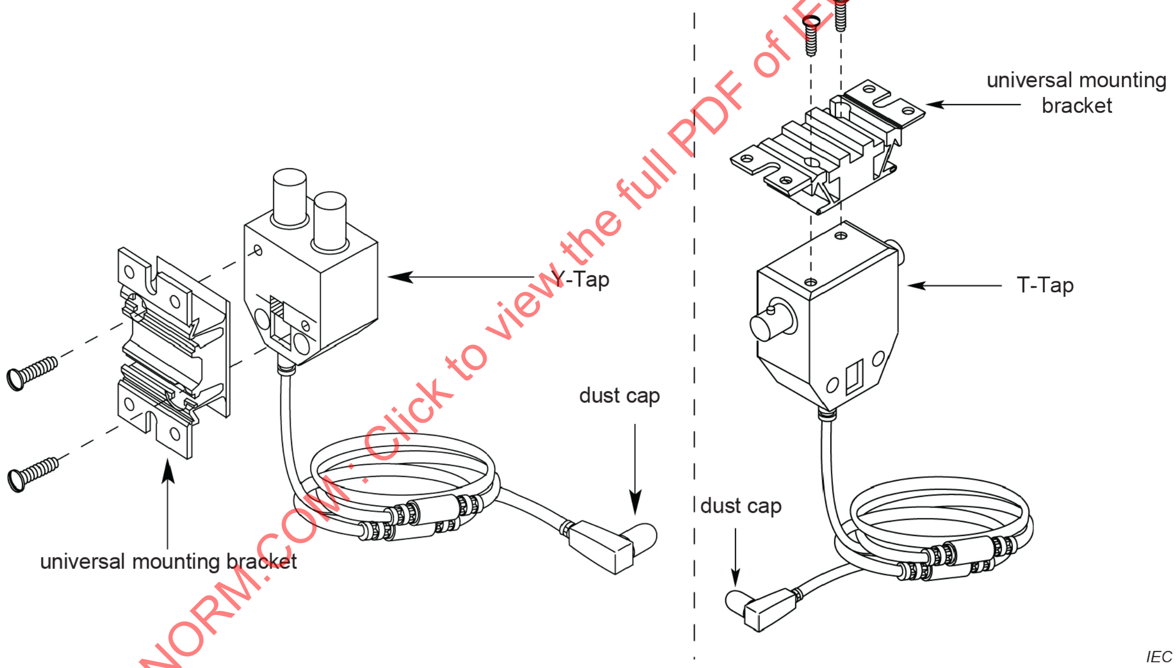



**Figure A.46 – Mounting the taps**

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

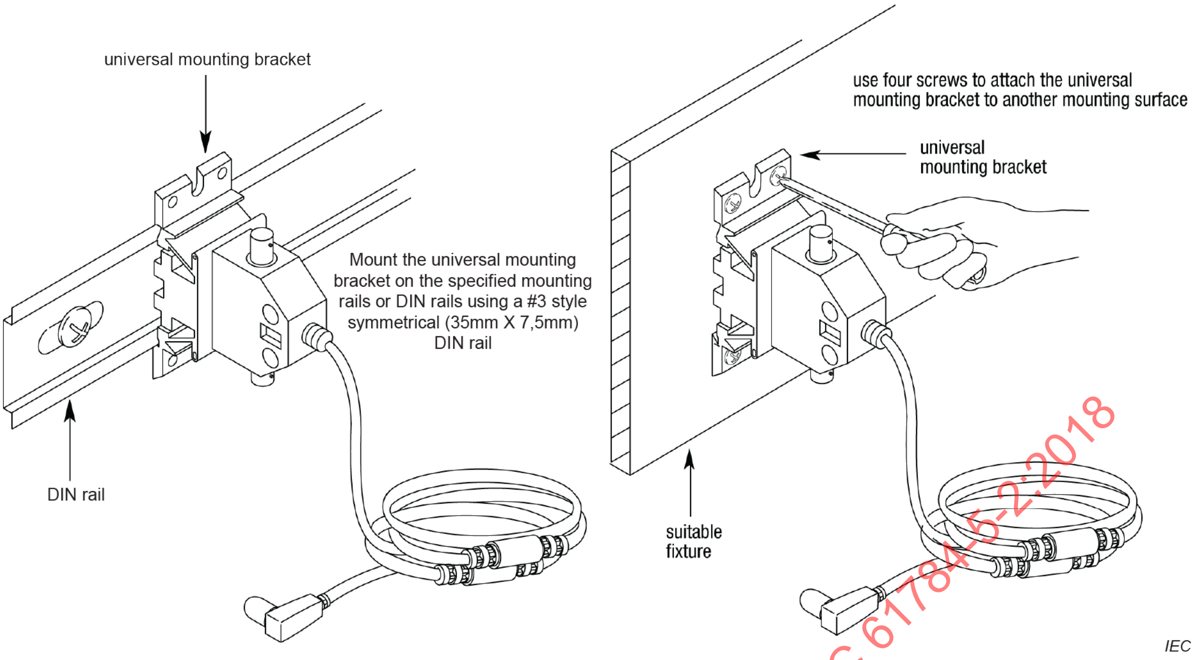



**Figure A.47 – Mounting the tap assembly using the universal mounting bracket**

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.

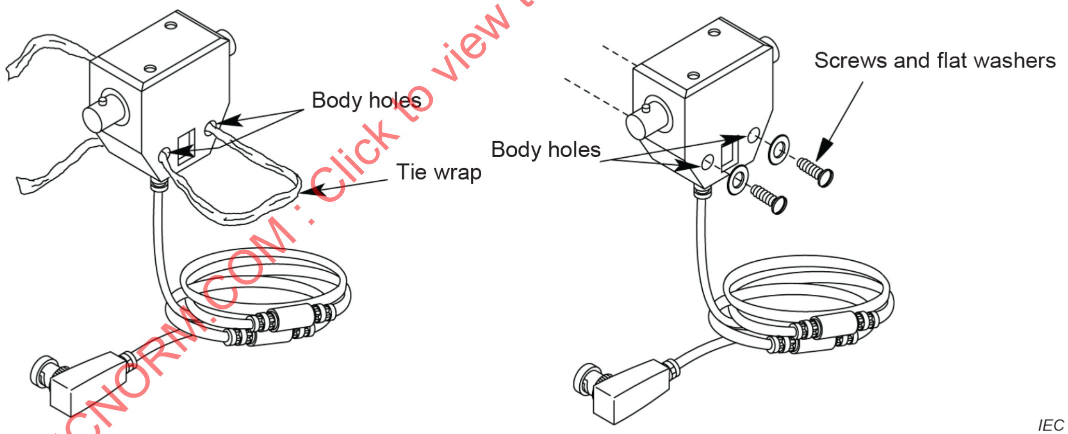



**Figure A.48 – Mounting the tap using tie wraps or screws**

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 MΩ 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 MΩ 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 MΩ 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:

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

Since the repeaters are also required to have a 1 MΩ 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.

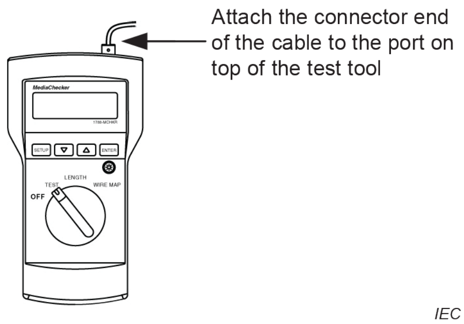



**Figure A.50 – Network test tool**

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.

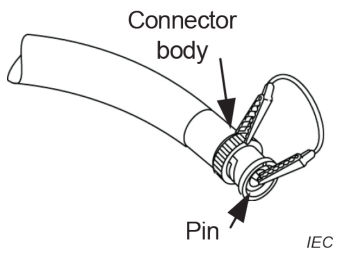



**Figure A.51 – Shorting the cable to test for continuity**

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 Ω 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.



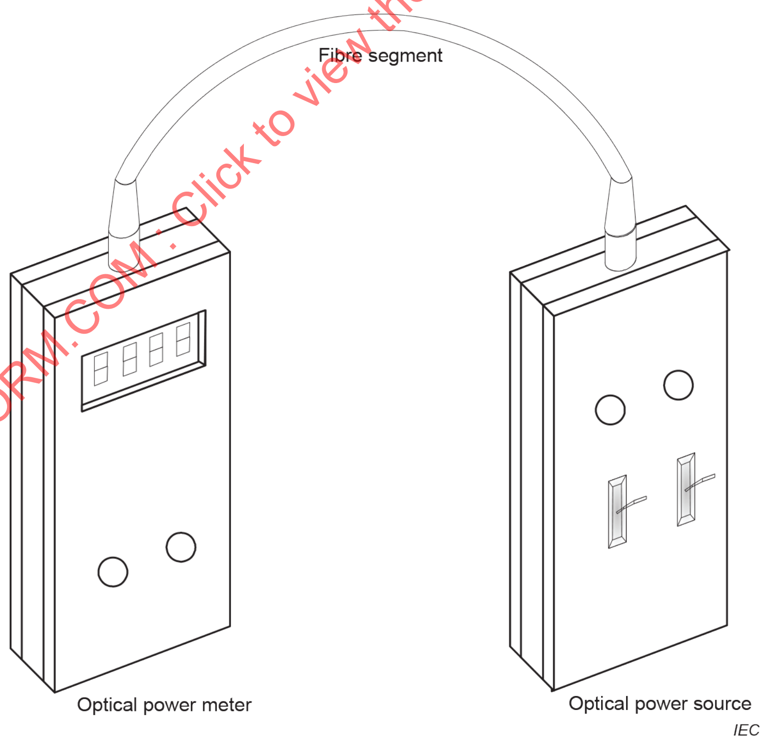



**Figure A.52 – Testing fibre segments**

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

| Wavelength<br>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.

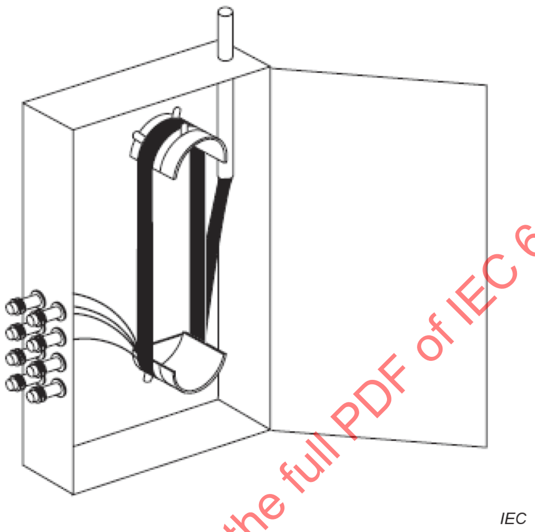



**Figure A.53 – Multi-fibre backbone cable housing**

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.

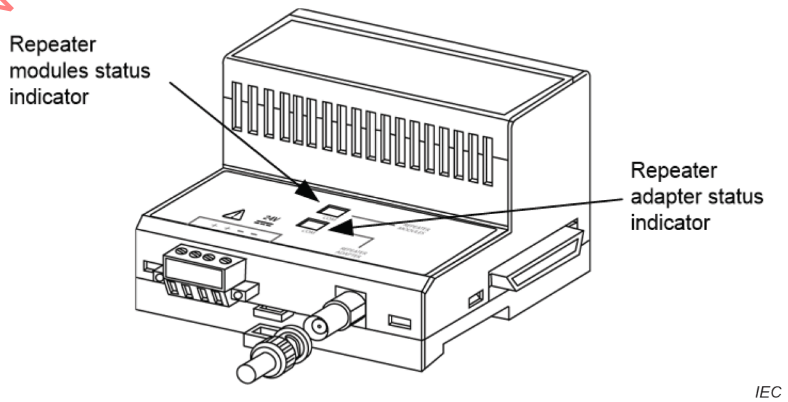



**Figure A.54 – Repeater adapter module**

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:<br>– all BNC connector pins are seated properly<br>– all taps are ControlNet taps<br>– all terminators are 75 Ω and are installed at both ends of all segments<br>– the coax cable has not been earthed |
| 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:<br>– broken cables<br>– broken taps<br>– missing segment terminators |

**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:<br>– all BNC connector pins are seated properly<br>– all taps are ControlNet Taps<br>– all terminators are 75 Ω and are installed at both ends of all segments<br>– the coax cable has not been earthed<br>– fibre optic connectors are of the correct type and are correctly attached to the fibre optic cable<br>– fibre optic cable is of the correct type |
| 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:<br>– broken cables<br>– broken taps<br>– missing segment terminators |



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

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

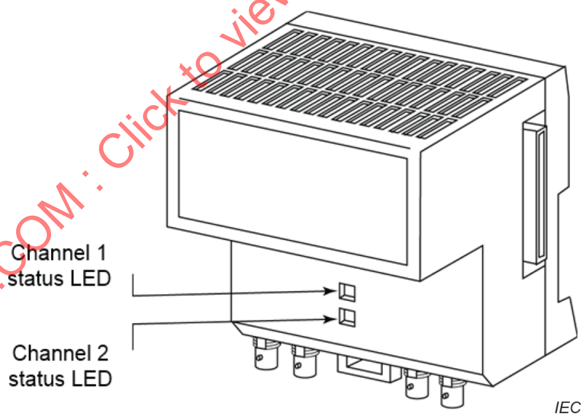



**Figure A.55 – Short and medium distance fibre module LEDs**

**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:<br>– confirm that the receive channel is connected to the transmit channel on both modules<br>– check for broken fibres |

## d) Long and extra long distance diagnostic LEDs

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

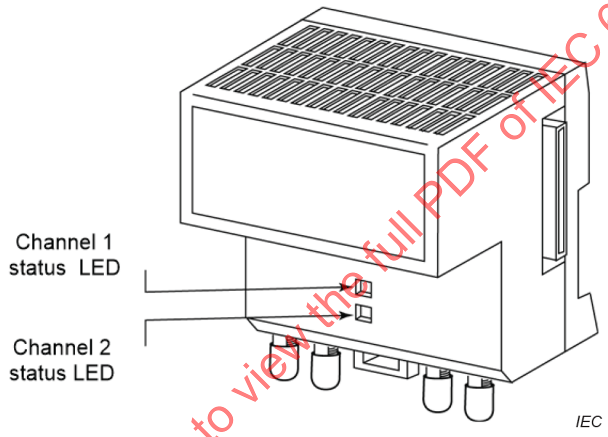



**Figure A.56 – Long and extra long repeater module LEDs**

**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 | – confirm that the receive channel is connected to the transmit channel on both modules<br>– check for broken fibres |
| 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 | – confirm that the correct fibre type matches the module<br>– check fibre length and attenuation to ensure that it is within specification<br>– replace the downstream fibre repeater module on the channel having the intermittently flashing red LED<br>– confirm that the total network length is not out of specification (see Clause A.4)<br>– confirm that SMAX is correctly defined in the ControlNet software configuration tool |

### 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 60793-2-50, *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.1, *Commercial building telecommunications cabling standards – Part 1: General requirements*

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



## 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.



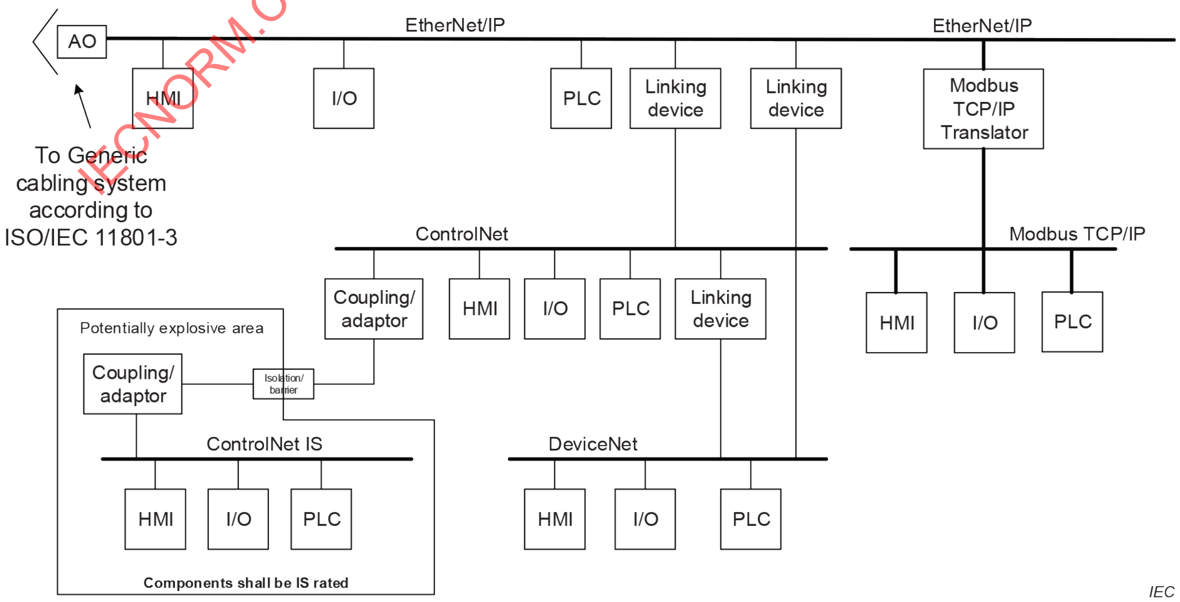



**Figure B.1 – Interconnection of CPF 2 networks**

### 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.

#### 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.

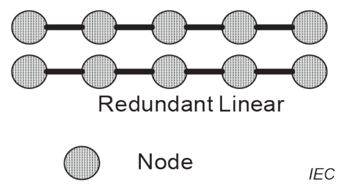



**Figure B.2 – Redundant linear bus**

#### B.4.3.1.4 Combination of basic topologies

Not applicable.

#### 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.

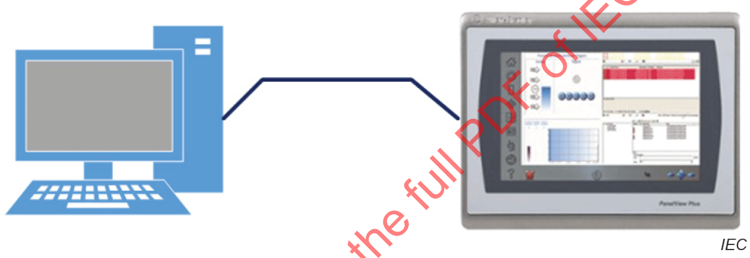



**Figure B.3 – Peer-to-peer connections**

### 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) [b] | 100 maximum (see channel and link length and limits below) |
| Number of connections in the channel (max.) [a,b] | 6[a] |
| Patch cord length (m) [a] | See IEC 61918:2018, Clause 4 and ISO/IEC 11801-3 |
| Channel class per ISO/IEC 11801-3 (min.) [b, d] | Class D |
| Cable category ISO/IEC 11801-3 (min.) | 5 |
| Connecting HW category per ISO/IEC 11801-3 (min.) [c] | 5 |
| Cable types | As needed for application |

[a] See B.4.4.3.2.

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

[c] For additional information see IEC 61156 series.

[d] 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) or equivalent at λ (nm) | 1 000 MHz, 1 310 nm and 1 550 nm |
| | Minimum length (m) | 0 |
| | Maximum length[a] (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) at λ (nm) | 1 000 MHz, 850 nm and 1 300 nm |
| | Minimum length (m) | 0 |
| | Maximum length[a] (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) at λ (nm) | 100 MHz, 650 nm |
| | Minimum length (m) | 0,055 |
| | Maximum length[a] (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) at λ (nm) | 125 MHz, 650 nm |
| | Minimum length (m) | 0,055 |
| | Maximum length[a] (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 |
| [a] 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[b]** | | |
|---|---|---|---|---|---|
| **Number of bends / Loss** | **Worst case losses**<br>dB | | **0** | **1** | **2** |
| | | | **0 dB** | **3 dB** | **6 dB** |
| | **Number of bends** | **Maximum losses due to bend radius[c]**<br>dB | **Maximum length[a]**<br>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[b] | | |
|---|---|---|---|---|---|
| Number of bends / Loss | Worst case losses<br>dB | | 0 | 1 | 2 |
| | | | 0 dB | 3 dB | 6 dB |
| | Number of bends | Maximum losses due to bend radius[c]<br>dB | Maximum length[a]<br>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 |

[a] Fibre loss

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

[b] 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**

[c] 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 @ 850 nm/1 310 nm | Standard |
|---|---|---|---|---|
| Multimode | 62,5 µm/125 µm | OM1 | 200 MHz × km/500 MHz × km | IEC 60793-2-10, type A1b |
| | 62,5 µm/ 200 µm/230 µm | OM1 | 200 MHz × km/500 MHz × km | IEC 60793-2-10, type A3f |
| | 50 µm/125 µm | OM2 | 500 MHz × km/500 MHz × km | IEC 60793-2-10, type A1a.1 |
| | | OM3 | 2 000 MHz × km/ 500 MHz × km | IEC 60793-2-10, type A1a.2 |
| | | OM4 | 4 700 MHz × km/ 500 MHz × km | IEC 60793-2-10, type A1a.3 |
| | 50 µm/200 µm/ 230 µm | OM2 | 500 MHz × km/ 500 MHz × km | IEC 60793-2-10, type A3g |
| Single-mode | 9 µm/125 µm | OS1 | N/A | IEC 60793-2-50, type B1.1 |
| | | OS2 | N/A | IEC 60793-2-50, type B1.3 |
| Setp Index Multimode | 980 µm/1 000 µm | N/A | 40 MHz × km | IEC 60793-2-40, type A4a.2 |

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 | GBIC, SFP | IEEE 802.3u | ISO/IEC 11801 |
| 100BASE-FX | 980 µm/1000 µm POF | N/A | IEEE 802.3u | IEC 60794-2-42 |
| 1000BASE-LX | OM1, OM2, OM3, OM4, OS1, OS2 | GBIC, SFP | IEEE 802.3z | ISO/IEC 11801 |
| 1000BASE-SX | OM1, OM2, OM3, OM4 | GBIC, SFP | IEEE 802.3z | ISO/IEC 11801 |
| 1000BASE-LX10 | OM1, OM2, OM3, OM4, OS1, OS2 | 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<br>95 Ω to 107 Ω from 4 MHz to 100 MHz |
| Return loss (dB) | 1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$<br>10 MHz to 20 MHz: 26<br>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[a] and 8[a] |
| 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 |
| [a] In pairs, star quad cable designs are not allowed. | |

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

| Characteristic | Type | |
|---|---|---|
| Electrical | Shielded | Unshielded |
| Nominal Impedance of cable (tolerance) | 95 Ω to 110 Ω, 1 MHz to 4 MHz<br>95 Ω to 107 Ω, 4 MHz to 100 MHz | 95 Ω to 110 Ω, 1 MHz to 4 MHz<br>95 Ω to 107 Ω, 4 MHz to 100 MHz |
| RL (dB) | 1 MHz to 10 MHz: $20 + 6\text{Log}_{10}(f)$<br>10 MHz to 20 MHz: 26<br>20 MHz to 100 MHz: $26-5*\text{Log}_{10}(f/20)$ | 1 MHz to 10 MHz: $20 + 6\text{Log}_{10}(f)$<br>10 MHz to 20 MHz: 26<br>20 MHz to 100 MHz: $26-5*\text{Log}_{10}(f/20)$ |
| NEXT (dB) | ANSI/TIA-568-C.2 Cat 5e | ANSI/TIA-568-C.2 Cat 5e |
| Conductors Gauge | 0,40 mm (26AWG), 0,51 mm (24AWG), 0,65 mm (22AWG) | |
| Configuration | 2 or 4 pairs + Shield | 2 or 4 pairs |
| Attenuation Solid Conductors | ANSI/TIA-568-C.2 Cat 5e Horizontal | ANSI/TIA568-C.2 Cat 5e Horizontal |
| Attenuation Stranded Conductors | ANSI/TIA568-C.2 Cat 5e Patch [1] | ANSI/TIA568-C.2 Cat 5e Patch [a] |
| 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 % |

| Characteristic | Type | |
|---|---|---|
| **Electrical** | **Shielded** | **Unshielded** |
| TCL | n/a | 89-15*log(f) for 0,7 < f ≤ 30 (MHz)<br>96,4-20log(f) for 30 < f < 250 (MHz) |
| ELTCTL | n/a | 54-20*log(f) 0,7 < f < 250 (MHz) |
| **Mechanical** | **Shielded** | **Unshielded** |
| 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 |
| **Dimensional**<br>(Recommended for RJ 45 compatibility) | **Shielded** | **Unshielded** |
| 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 |
| [a] 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<br>95 Ω to 107 Ω from 4 MHz to 100 MHz |
| Return loss (dB) | 1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$<br>10 MHz to 20 MHz: 26<br>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[a] and 8[a] |
| 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 |
| [a] In pairs, star quad cable designs are not allowed. | |

*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**<br>MHz | **Minimum TCL**<br>dB | | |
|---|---|---|---|---|---|
| | | | **E1** | **E2** | **E3** |
| 5e | D | $1 \leq f < 30$<br>$30 \leq f \leq 100$ | $60 - 20 \times \log_{10}(f)$ | $63 - 15 \times \log_{10}(f)$<br>$70{,}4 - 20 \times \log_{10}(f)$ | $73 - 15 \times \log_{10}(f)$<br>$80{,}4 - 20 \times \log_{10}(f)$ |
| 6 | E | $1 \leq f < 30$<br>$1 \leq f \leq 250$ | $60 - 20 \times \log_{10}(f)$ | $63 - 15 \times \log_{10}(f)$<br>$70{,}4 - 20 \times \log_{10}(f)$ | $73 - 15 \times \log_{10}(f)$<br>$80{,}4 - 20 \times \log_{10}(f)$ |

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

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

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

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

| **Frequency**<br>MHz | **Minimum ELTCTL**<br>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<br>MHz | Minimum<br>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.

#### 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 | OM1, OM2 or OM3 | OM1, OM2 or OM3 | -- | -- |
| Maximum attenuation per km (650 nm) | – | – | – | 18 dB | For further study |
| Maximum attenuation per km (820 nm) | – | – | – | – | – |
| Maximum attenuation per km (1 310 nm) | 1,0 dB | 2,0 dB | 3,0 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 | – | – |
| 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 [a] | | IEC 61076-3-106 [b] | | IEC 61076-3-117[b] | IEC 61076-2-101 | IEC 61076-2-109 |
|---|---|---|---|---|---|---|---|
| | shielded | unshielded | Var. 1 | Var. 6 | Var. 14 | M12-4 with D-coding | M12-8 with X-coding |
| CP 2/2 | IEC 60603-7 or IEC 60603-7 | IEC 60603-7 or IEC 60603-7 | Yes | No | No | Yes | Yes |

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

[b] 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 | | |
|---|---|---|---|---|---|
| | | | E1 | E2 | E3 |
| 6 | E | $1 \leq f < 250$ | Not defined | Not defined | $94 - 20 \times \log_{10}(f)$ |

*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 |

| Parameter | Type | |
|---|---|---|
| | M12 shielded | M12 unshielded |
| 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.<br>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.<br>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.

IEC

**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.<br>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.<br>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.

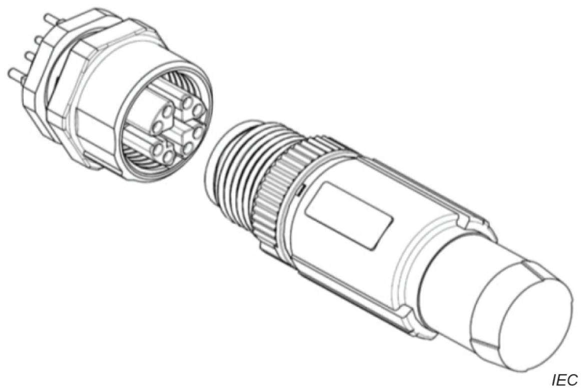



**Figure B.8 – Example of a metallic shell M12-8 X-coding connectors**

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 |
| CP 2/2 | 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.


**Figure B.9 – Simplex LC connector**


**Figure B.10 – Duplex LC connector**


**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.

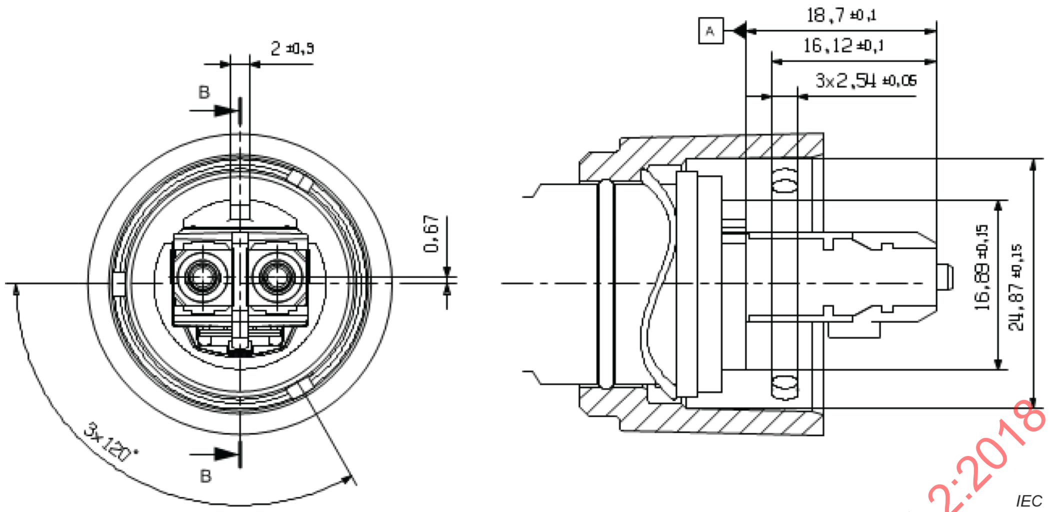



**Figure B.12 – IP65/67 sealed duplex SC-RJ connector**

*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 cladded silica | Others |
| SC | Yes | Yes | Yes | Yes | No | – |
| ST | Yes | Yes | Yes | Yes | No | – |
| LC | Yes | Yes | Yes | No | No | – |
| SC-RJ | Yes | Yes | Yes | Yes | No | – |
| 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<br>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 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.

##### 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.

IEC

**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. 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 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.

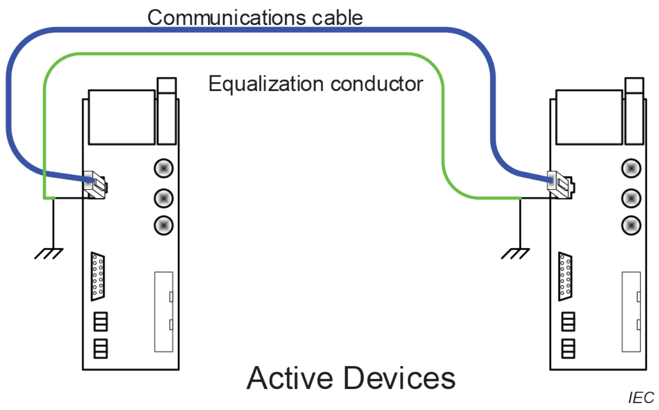



**Figure B.17 – Earthing of cable shield**

*Addition:*

If the active device is other than a switch (or hub) and provides a low DC resistance (less than 500 kΩ) earth at the 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. The sizing of the conductor shall be in accordance with Table 14 of IEC 61918:2018.

#### 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 connectorized cabling;
- labelling per design documentation (outlets and cables);
- routing of cables with respect to other EMC 1, 2 and 3 circuits.

#### 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 link/channel is the sum of the lengths of the fixed horizontal cables and cords between the two end points. Length of the permanent link/channel may 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 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.

###### 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.

# 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.

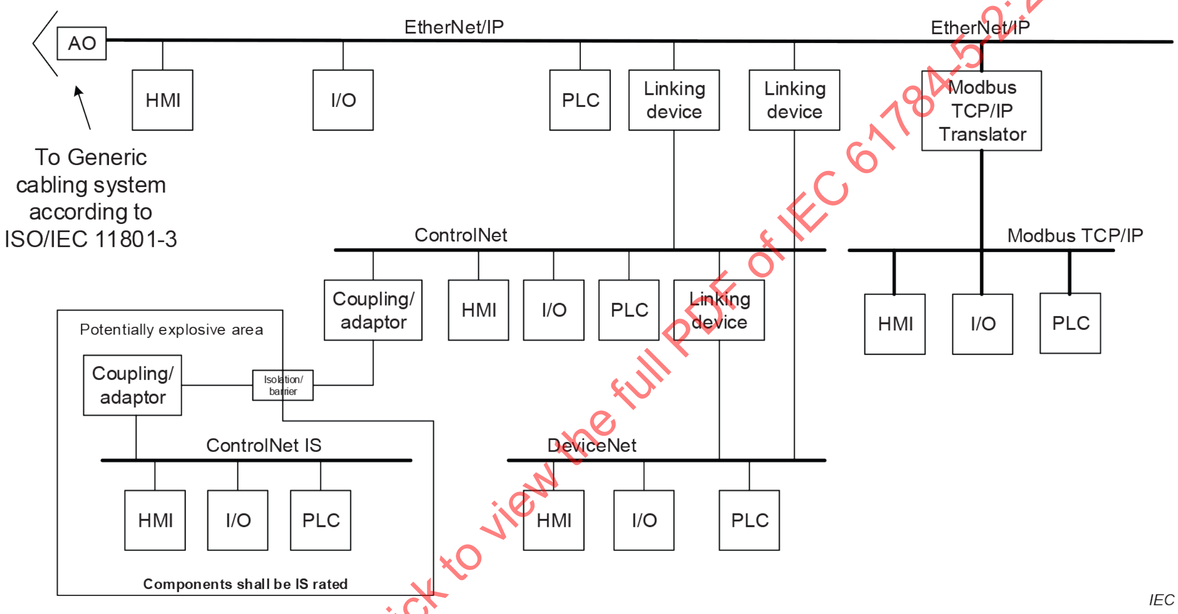



**Figure C.1 – Interconnection of CPF 2 networks**

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).

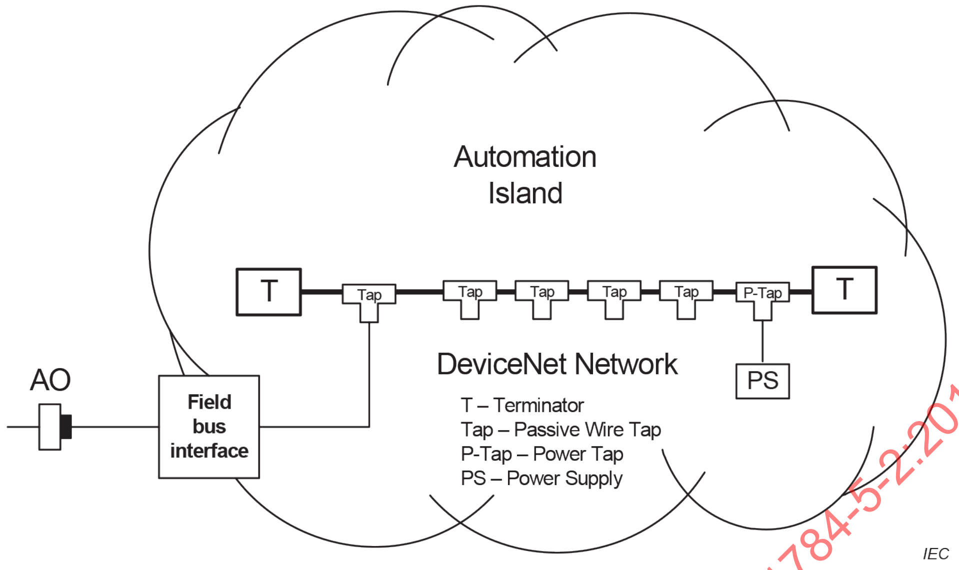



**Figure C.2 – Connection to generic cabling**

### 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 ≤ 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.

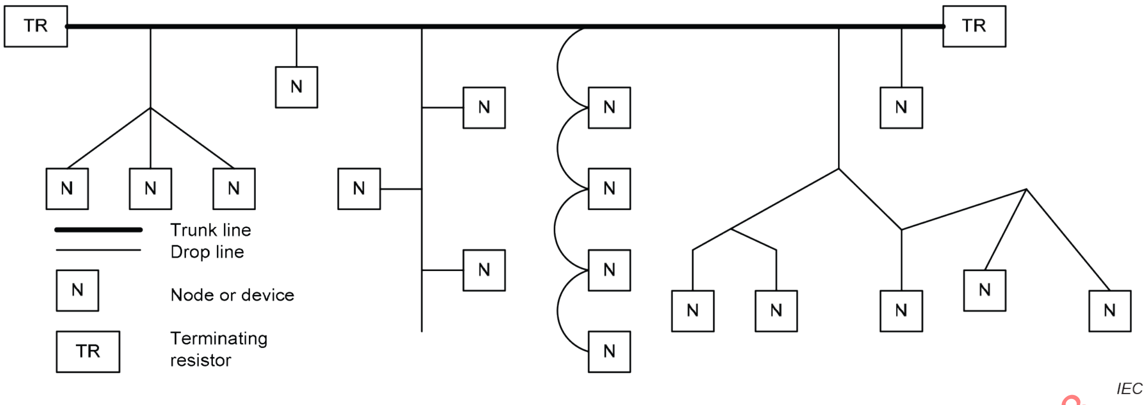



**Figure C.3 – DeviceNet cable system uses a trunk/drop line topology**

#### 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 |
|---|---|
| **Basic transmission technology** | ISO 11898-1 and ISO 11898-2 (CAN) |
| **Length / transmission speed** | **Segment length**<br>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) |
| **Maximum capacity** | **Max. no.** |
| Devices / segment | 64 |
| Devices / network | 64 [a] |
| [a] 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 [a] | | |
|---|---|---|---|---|---|---|
| | 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<br>m | | | Cumulative drop length at data rate[a]<br>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 |

[a] 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.

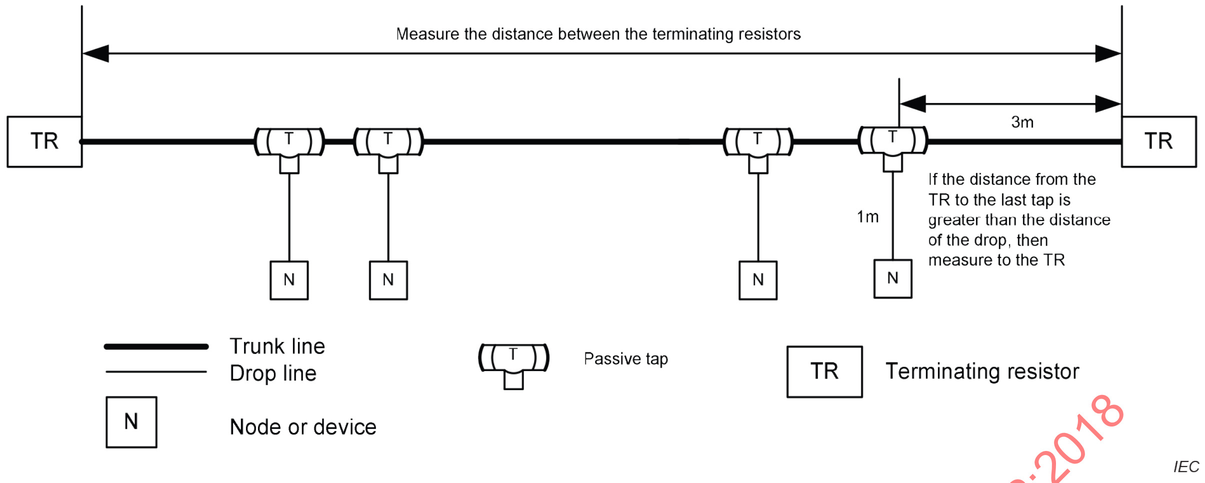



**Figure C.4 – Measuring the trunk length**

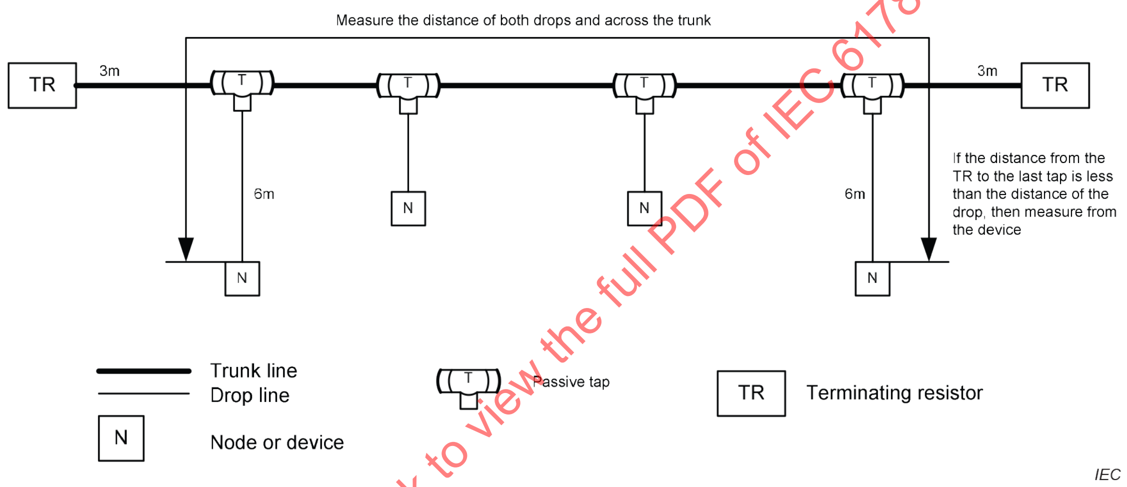



**Figure C.5 – Measuring the trunk and drop length**

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.

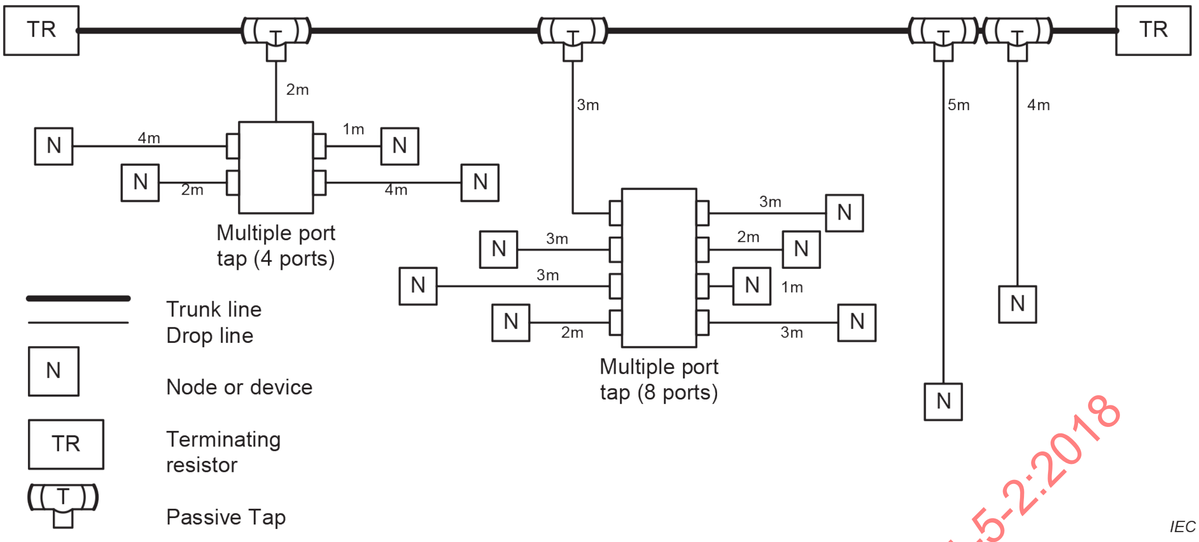



**Figure C.6 – Measuring drop cable in a network with multiports**

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.

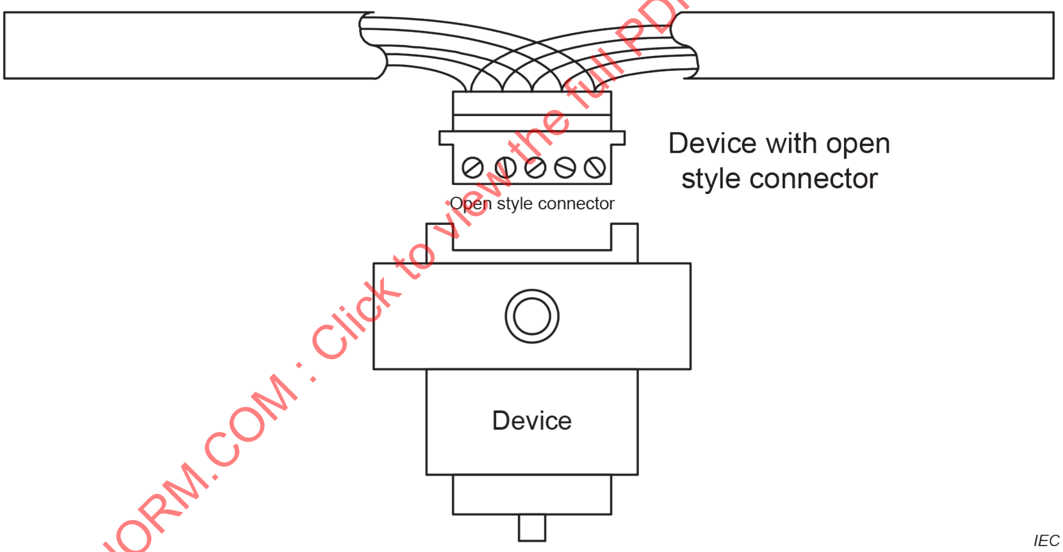



**Figure C.7 – Removable device using open-style connectors**

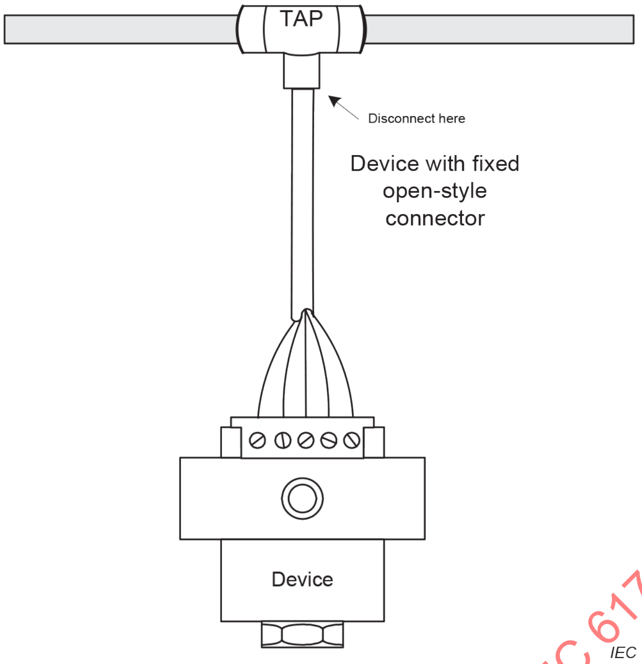



**Figure C.8 – Fixed connection using open-style connector**

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.

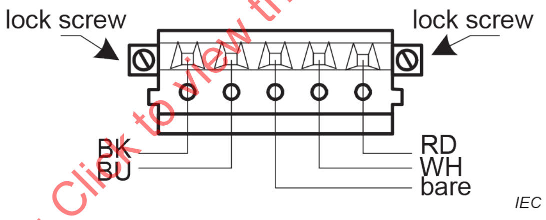



**Figure C.9 – Open-style connector pin out**

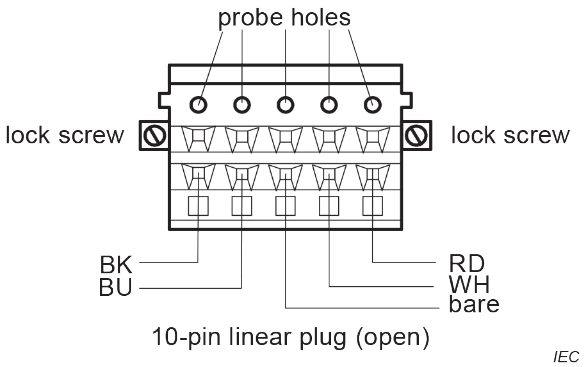



**Figure C.10 – Open-style connector pin out 10 position**

**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<br>m | Allowable current<br>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 [a]<br>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 |
| [a] 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[a] | 0,60 % (total) |
| Time drift | 1,05 % |
| Load regulation | 0,30 % |
| Schottky diode drop (0,65 V nominal) | 0,75 % (of 24 V) |
| **Total stack up** | **4 %** |

[a] 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:

$$I_{\text{total}}\left(Trunk_{\text{Len}}\right) = \frac{\left(V_{\text{low}} + V_{\text{cmm}} - V_{\text{high}}\right)}{\left[\left(DCR_{\text{contacts}} \times NUM_{\text{contacts}} \times DCR_{\text{cable@temp}}\,m\right)\right]}$$

As the difference in $V_{\text{low}}$ and $V_{\text{high}}$ increases, the available current decreases. Figure C.11 shows the effects of the temperature differential between two V+ connected power supplies.

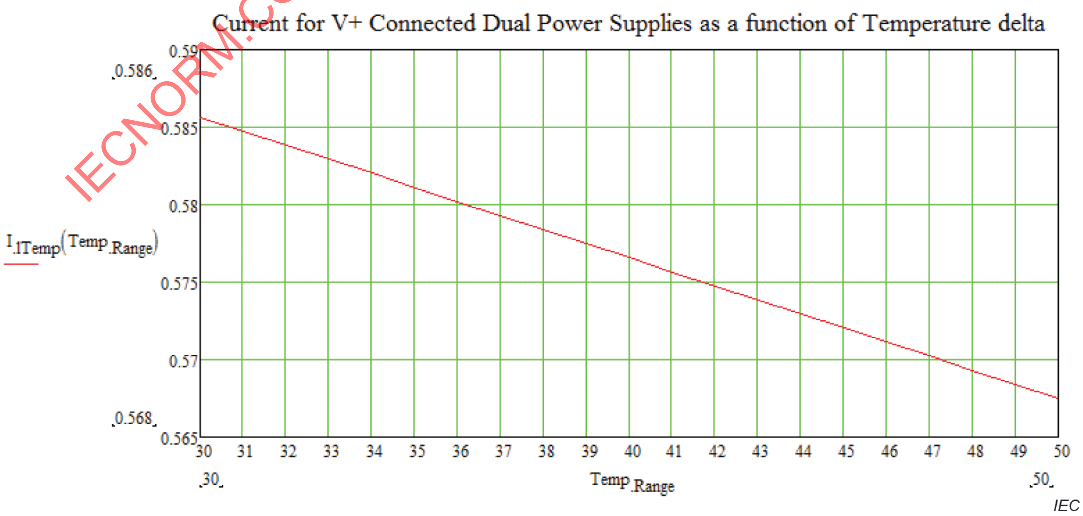



**Figure C.11 – Power Bus Current derate as a function of temperature differential**

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 µF.

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.

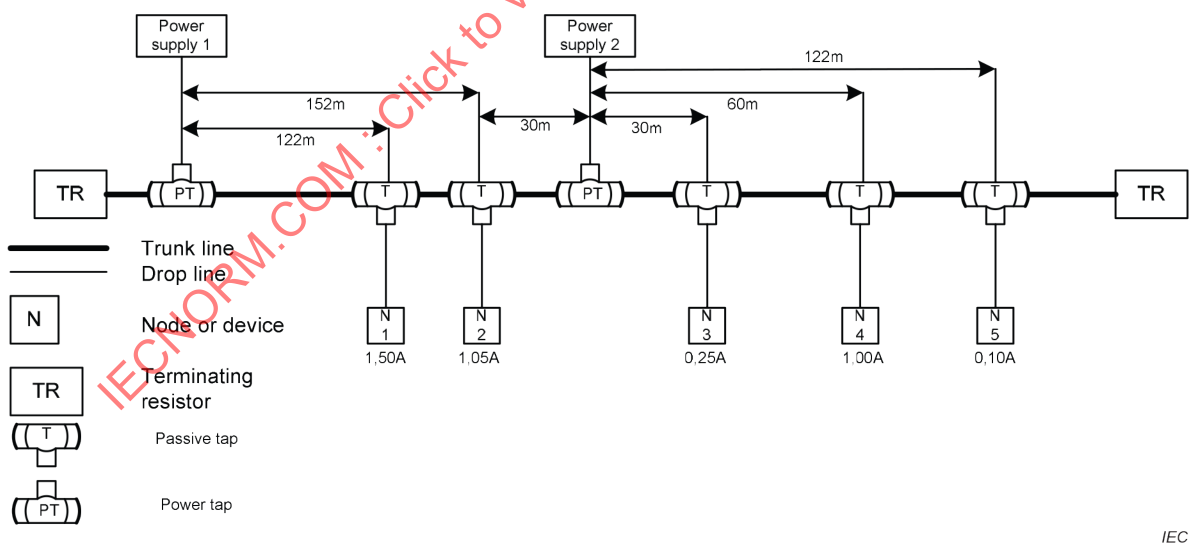



**Figure C.12 – Power supply sizing example**

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).

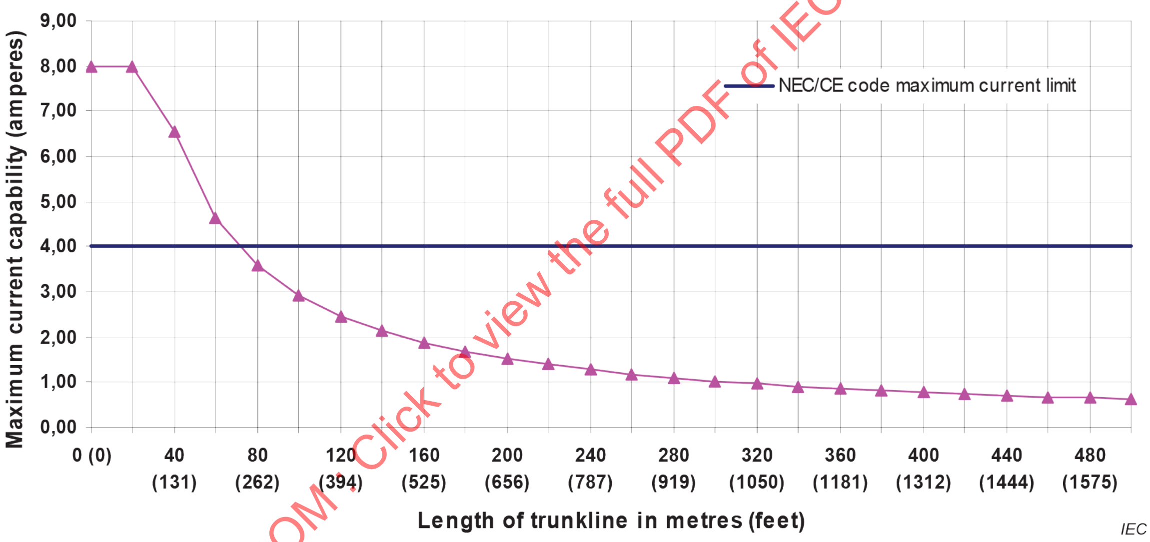
   1,35 A is the minimum rating of power supply #2.

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<br>m (ft.) | Maximum current<br>A | Network length<br>m (ft.) | Maximum current<br>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.

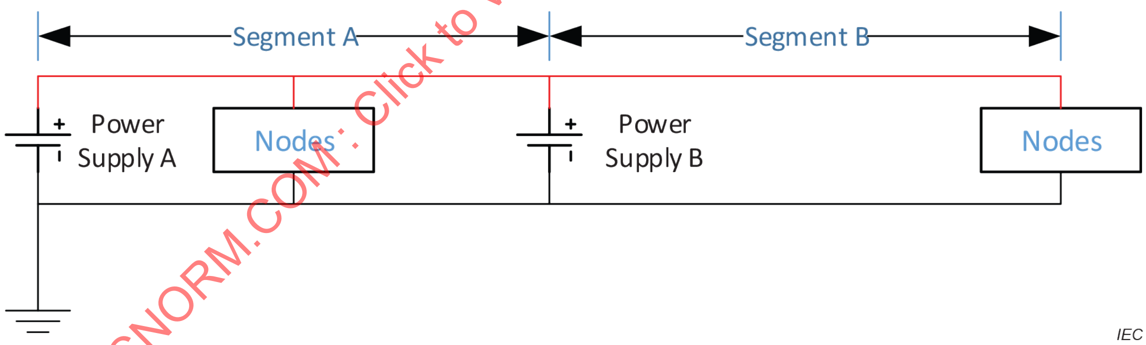
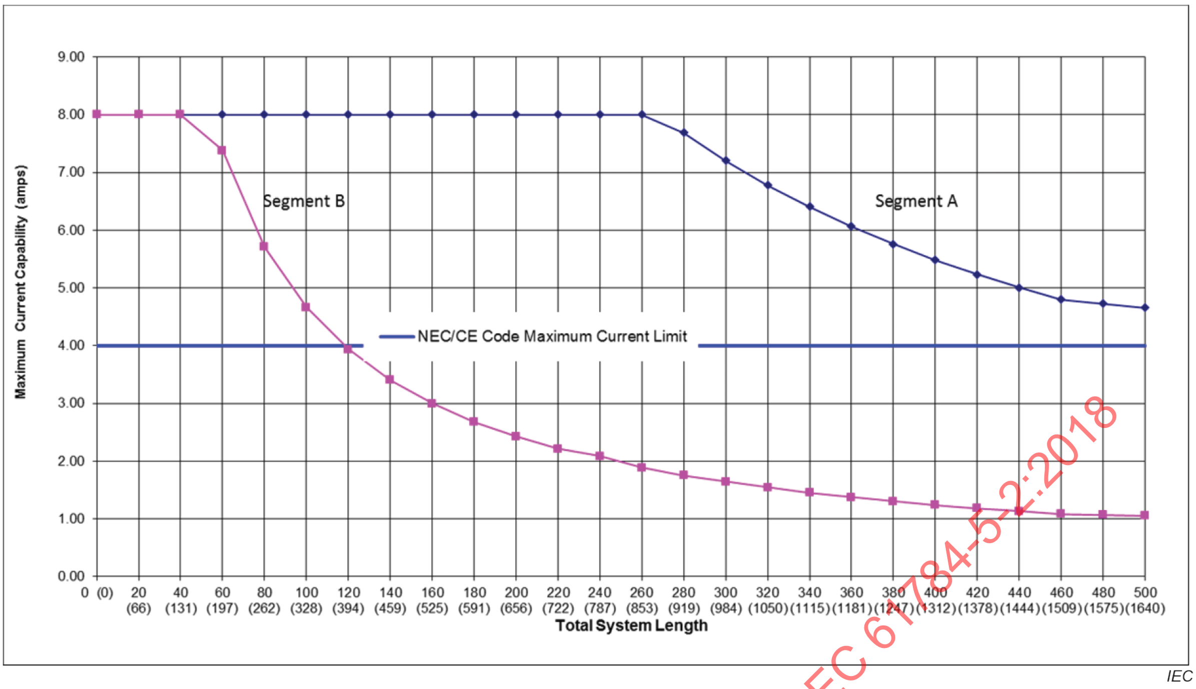



**Figure C.14 – Example of a continuous power bus**




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 m (ft) | Maximum current A | Network length m (ft) | Maximum current A | Network length m (ft) | Maximum current A | Network length m (ft) | Maximum current 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.

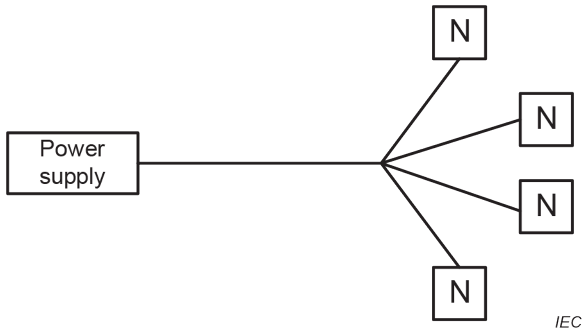



**Figure C.16 – Worst-case scenario**

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.

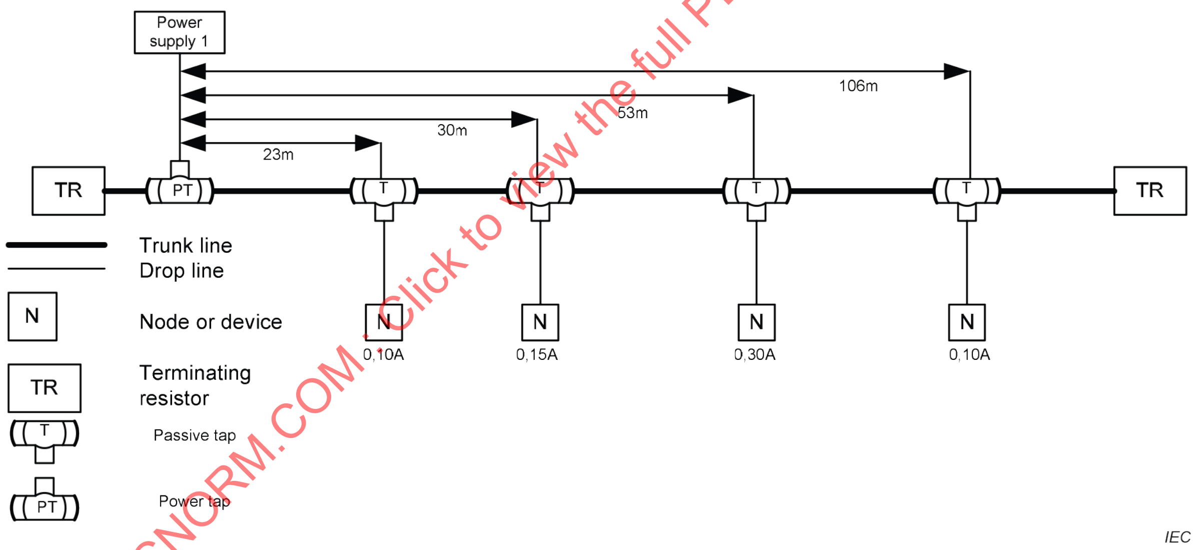



**Figure C.17 – Example using the lookup method**

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 A + 0,15 A + 0,30 A + 0,10 A = 0,65 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 ≤ 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<br>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 Ω/m<br>Cable Type I --- 0,023 Ω/m<br>Thin cable --- 0,069 Ω/m<br>Flat cable --- 0,019 Ω/m |
| $N_t$ | The number of taps between the device being evaluated and the power supply.<br>For example:<br>When a device is the first one closest to the power supply, this number is 1.<br>When a device has one device between it and the power supply, this number is 2.<br>When 10 devices exist between the evaluated device and the power supply, this number is 11.<br>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<br>$n$ = 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.

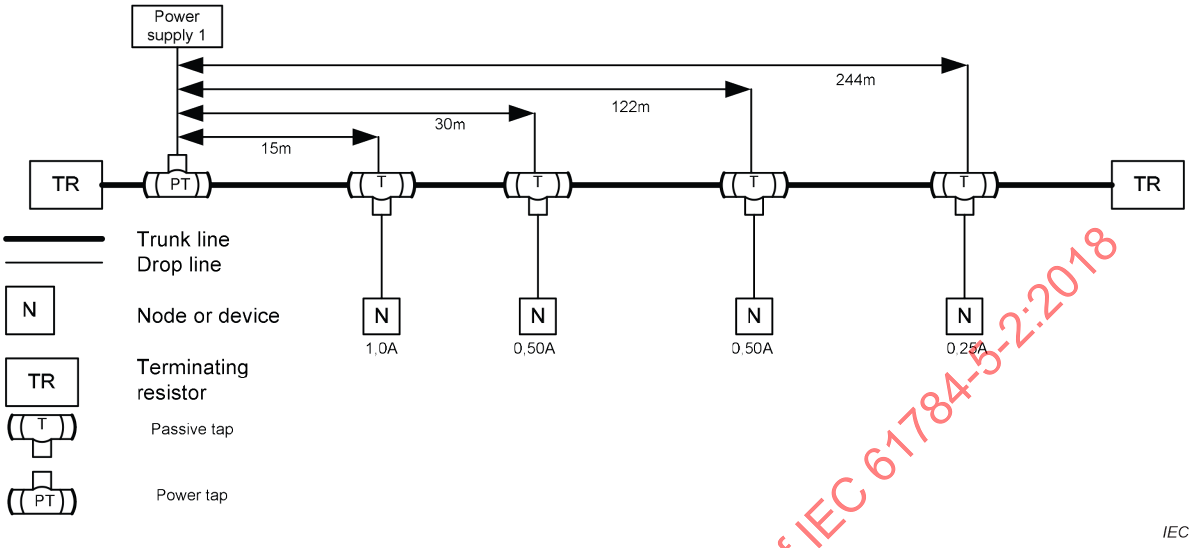



**Figure C.18 – One power supply end connected**



a) Find the voltages for each device using the equation for thick cable.

SUM {[($L_n$ × 0,015) + ($N_t$ × 0,005)] × $I_n$} ≤ 4,65 V.

**A**.[(**15** × 0,015) + (**1** × 0,005)] × **1,00 = 0,23 V**

**B**.[(**30** × 0,015) + (**2** × 0,005)] × **0,50 = 0,23 V**

**C**.[(**122** × 0,015) + (**3** × 0,005)] × **0,50 = 0,91 V**

**D**.[(**244** × 0,015) + (**4** × 0,005)] × **0,25 = 0,91 V**

b) Add each device's voltage together to find the total voltage.

0,23 V + 0,23 V + 0,91 V + 0,91 V = **2,28 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.

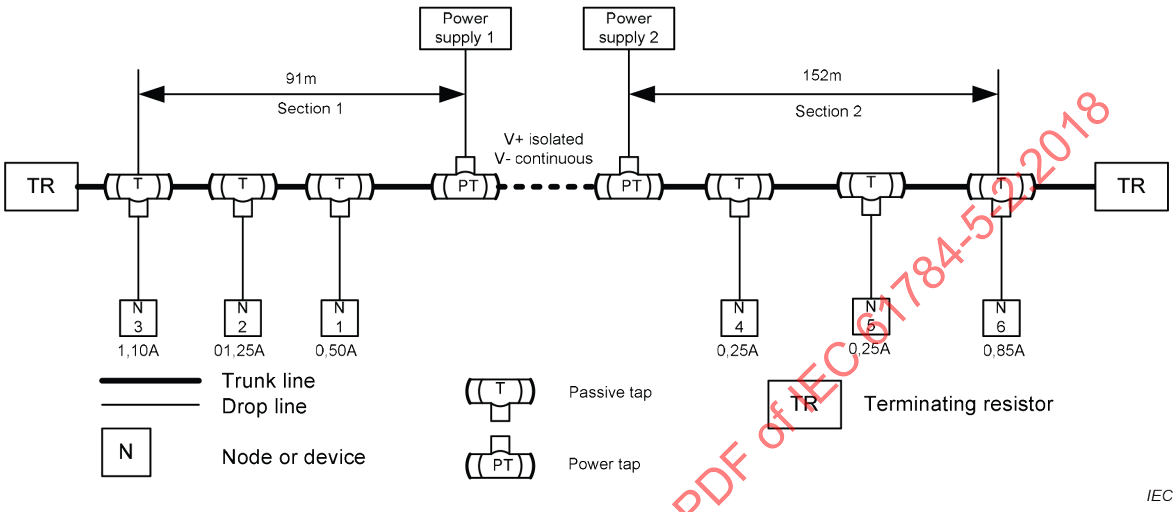



**Figure C.19 – Segmenting power in the power bus**

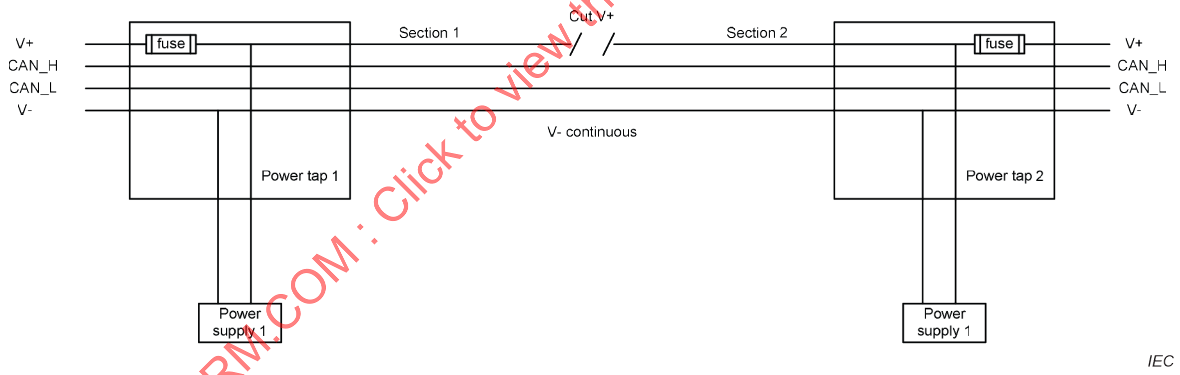



**Figure C.20 – Segmenting the power bus using power taps**



#### 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 |
| **Max. trunk length (m)** | | | | | | | | | | |
| 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 |
| **Connector support** | | | | | | | | | | |
| 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][8]) for other cable specifications.



8 Numbers in square brackets refer to the Bibliography.

**Table C.13 – DeviceNet cable profiles**

| | Cable profile | | |
|---|---|---|---|
| | **Thick** | **Thin** | **Flat** |
| **Data pair** | | | |
| **Physical characteristics** | **Specification** | | |
| Conductor pair size | 18 AWG or 0,82 mm$^2$ copper minimum; 19 strands minimum (individually tinned) | 24 AWG or 0,20 mm$^2$ copper minimum; 19 strands minimum (individually tinned) | 16 AWG or 1,3 mm$^2$ 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) | – |
| **Electrical characteristics** | **Specification** | | |
| 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)<br>0,82 dB/100 m at 500 kHz (maximum)<br>1,31 dB/100 m at 1,00 MHz (maximum) | 0,95 dB/100 m at 125 kHz (maximum)<br>1,64 dB/100 m at 500 kHz (maximum)<br>2,3 dB/100 m at 1,00 MHz (maximum) | 0,43 dB/100 m at 125 kHz (maximum)<br>0,82 dB/100 m at 250 kHz (maximum)<br>1,31 dB/100 m at 500 kHz (maximum) |
| **Power pair** | | | |
| **Physical characteristics** | **Specification** | | |
| Conductor pair size | 15 AWG or 1,65 mm$^2$ copper minimum; 19 strands minimum (individually tinned) | 22 AWG or 0,33 mm$^2$ copper minimum; 19 strands minimum (individually tinned) | 16 AWG or 1,3 mm$^2$ 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) | – |
| **Electrical characteristics** | **Specification** | | |
| 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** |
| **General specifications** | | | |
| **Physical characteristics** | **Specification** | | |
| 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 $mm^2$ tinned Cu braid minimum (individually tinned) | 65 % coverage 36 AWG or 0,012 $mm^2$ tinned Cu braid minimum (individually tinned) | – |
| Drain wire | 18 AWG or 0,82 $mm^2$ copper minimum; 19 strands minimum (individually tinned) | 22 AWG or 0,33 $mm^2$ 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 |
| **Electrical characteristics** | **Specification** | | |
| DCR (braid+tape+drain) | 5,74 Ω /1 000 m (nom. at 20 °C) | 10,5 Ω /1 000 m (nom. at 20 °C) | – |
| **Applicable environmental characteristics** | **Specification** | | |
| 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 | Terminal block | Others |
| 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 Figure 18 | 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 Ω. The terminator can be an integral part of a plug or a resistor. The terminator shall conform to the values below:

- Value: 121 Ω;
- Tolerance: ±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 MΩ resistor in parallel with a 0,01 μF 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 |
|---|---|---|
| Mechanical force | 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 |

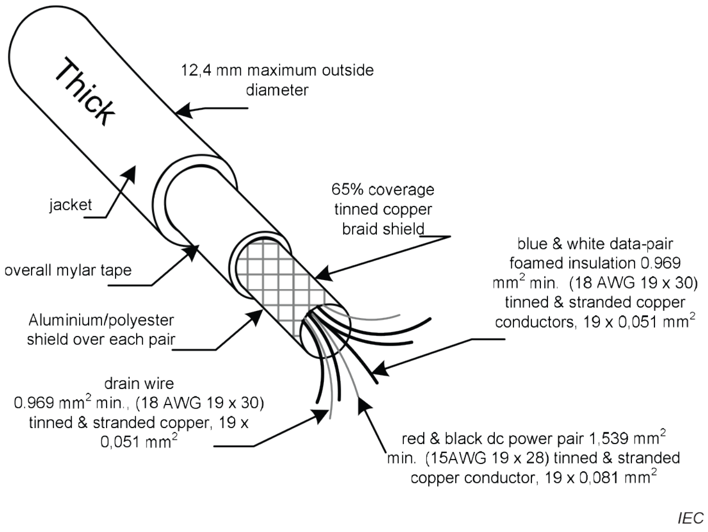
Tables 19 and 20 of IEC 61918:2018 are not applicable.

#### 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 $mm^2$ 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.

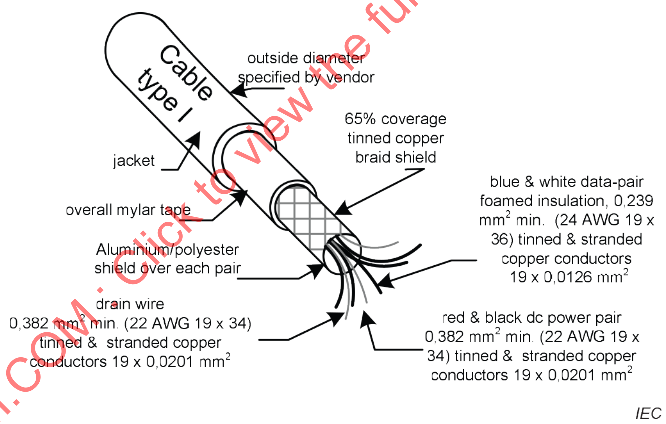



**Figure C.22 – Cable Type I construction**

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.

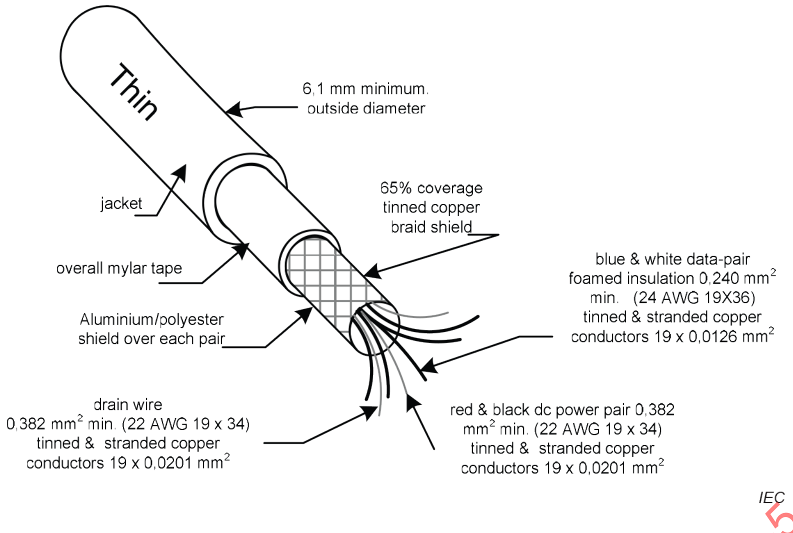



**Figure C.23 – Thin cable construction**

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.

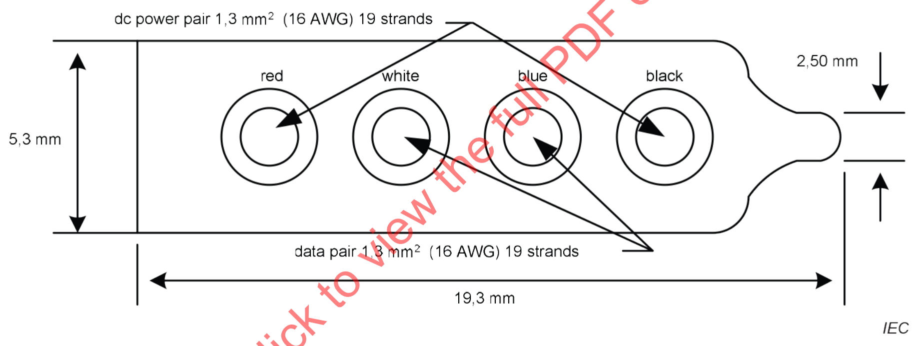



**Figure C.24 – Flat cable construction**

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.

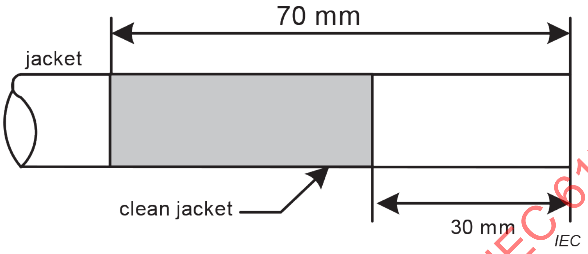



**Figure C.25 – Cable preparation**

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.

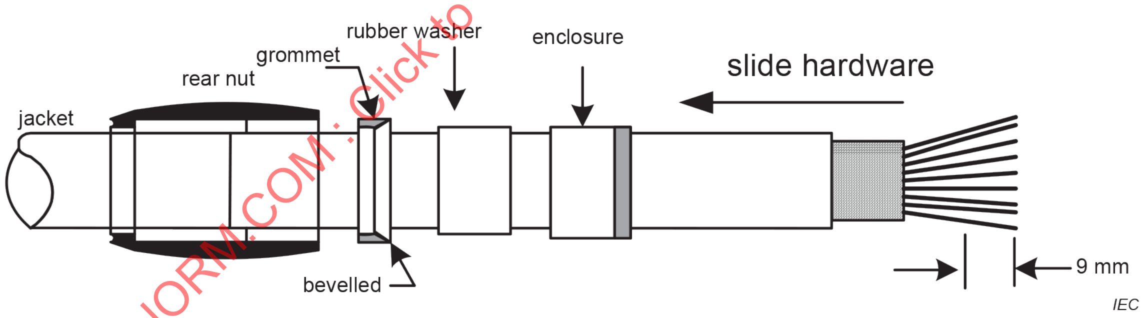



**Figure C.26 – Connector assembly**

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.