

# INTERNATIONAL STANDARD

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

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

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

PRICE CODE **XG**

## CONTENTS

FOREWORD.....	9
INTRODUCTION.....	11
1 Scope.....	12
2 Normative references .....	12
3 Terms, definitions and abbreviated terms .....	12
4 CPF 2: Overview of installation profiles .....	12
5 Installation profile conventions .....	13
6 Conformance to installation profiles.....	13
Annex A (normative) CP 2/1 (ControlNet™) specific installation profile.....	14
A.1 Installation profile scope.....	14
A.2 Normative references .....	14
A.3 Installation profile terms, definitions, and abbreviated terms.....	14
A.3.1 Terms and definitions .....	14
A.3.2 Abbreviated terms .....	14
A.3.3 Conventions for installation profiles.....	14
A.4 Installation planning .....	15
A.4.1 Introduction .....	15
A.4.2 Planning requirements.....	16
A.4.3 Network capabilities .....	17
A.4.4 Selection and use of cabling components .....	22
A.4.5 Cabling planning documentation.....	38
A.4.6 Verification of planning specification.....	38
A.5 Installation implementation.....	39
A.5.1 General requirements.....	39
A.5.2 Cable installation.....	39
A.5.3 Connector installation.....	40
A.5.4 Terminator installation .....	49
A.5.5 Device installation .....	49
A.5.6 Coding and labelling.....	51
A.5.7 Earthing and bonding of equipment and devices and shield cabling.....	51
A.5.8 As-implemented cabling documentation.....	52
A.6 Installation verification and installation acceptance test.....	53
A.6.1 Introduction .....	53
A.6.2 Installation verification.....	53
A.6.3 Installation acceptance test .....	55
A.7 Installation administration.....	57
A.8 Installation maintenance and installation troubleshooting .....	57
A.8.1 General .....	57
A.8.2 Maintenance.....	57
A.8.3 Troubleshooting.....	57
Annex B (normative) CP 2/2 (EtherNet/IP™) specific installation profile.....	62
B.1 Installation profile scope.....	62
B.2 Normative references .....	62
B.3 Installation profile terms, definitions, and abbreviated terms.....	62
B.3.1 Terms and definitions .....	62
B.3.2 Abbreviated terms .....	62

B.3.3	Conventions for installation profiles .....	63
B.4	Installation planning .....	63
B.4.1	Introduction .....	63
B.4.2	Planning requirements .....	64
B.4.3	Network capabilities .....	64
B.4.4	Selection and use of cabling components .....	66
B.4.5	Cabling planning documentation .....	78
B.4.6	Verification of cabling planning specification .....	78
B.5	Installation implementation .....	79
B.5.1	General requirements .....	79
B.5.2	Cable installation .....	79
B.5.3	Connector installation .....	80
B.5.4	Terminator installation .....	81
B.5.5	Device installation .....	81
B.5.6	Coding and labelling .....	81
B.5.7	Earthing and bonding of equipment and devices and shield cabling .....	81
B.5.8	As-implemented cabling documentation .....	83
B.6	Installation verification and installation acceptance test .....	84
B.6.1	Introduction .....	84
B.6.2	Installation verification .....	84
B.6.3	Installation acceptance test .....	85
B.7	Installation administration .....	86
B.8	Installation maintenance and installation troubleshooting .....	86
Annex C (normative)	CP 2/3 (DeviceNet™) specific installation profile .....	87
C.1	Installation profile scope .....	87
C.2	Normative references .....	87
C.3	Installation profile terms, definitions, and abbreviated terms .....	87
C.3.1	Terms and definitions .....	87
C.3.2	Abbreviated terms .....	87
C.3.3	Conventions for installation profiles .....	87
C.4	Installation planning .....	88
C.4.1	Introduction .....	88
C.4.2	Planning requirements .....	89
C.4.3	Network capabilities .....	90
C.4.4	Selection and use of cabling components .....	103
C.4.5	Cabling planning documentation .....	112
C.4.6	Verification of cabling planning specification .....	112
C.5	Installation implementation .....	113
C.5.1	General requirements .....	113
C.5.2	Cable installation .....	113
C.5.3	Connector installation .....	115
C.5.4	Terminator installation .....	125
C.5.5	Device installation .....	126
C.5.6	Coding and labelling .....	129
C.5.7	Earthing and bonding of equipment and devices and shield cabling .....	129
C.5.8	As-implemented cabling documentation .....	130
C.6	Installation verification and installation acceptance test .....	130
C.6.1	Introduction .....	130
C.6.2	Installation verification .....	130

C.6.3	Installation acceptance test .....	133
C.7	Installation administration.....	134
C.8	Installation maintenance and installation troubleshooting .....	134
C.8.1	General .....	134
C.8.2	Maintenance.....	134
C.8.3	Troubleshooting.....	134
C.8.4	Specific requirements for maintenance and troubleshooting .....	134
Annex D (informative)	Additional information .....	137
D.1	Network validation check sheet for CP 2/3 (DeviceNet) .....	137
Bibliography	.....	141
Table A.1	– Basic network characteristics for copper cabling not based on Ethernet (ISO/IEC 8802-3).....	21
Table A.2	– Allowable fibre lengths .....	21
Table A.3	– Power budgets for ControlNet fibre networks .....	21
Table A.4	– RG6 coaxial electrical properties.....	22
Table A.5	– RG6 coaxial physical parameters .....	23
Table A.6	– Cable type selection.....	23
Table A.7	– Information relevant to optical fibre cables .....	24
Table A.8	– Copper connectors for ControlNet.....	25
Table A.9	– Fibre connectors for fieldbus systems .....	25
Table A.10	– Separation from other circuits inside enclosures .....	34
Table A.11	– Pulling and bend radius for coaxial cables .....	39
Table A.12	– Bend radius for coaxial cables .....	39
Table A.13	– Spacing from other circuits inside and outside wire ways or conduit.....	40
Table A.14	– Separation from Category-1 conductors for coax cables inside enclosures.....	40
Table A.15	– Test matrix for BNC/TNC connectors.....	54
Table A.16	– Wave length and fibre types .....	57
Table A.17	– LED status table.....	59
Table A.18	– Repeater adapter and module diagnostic .....	59
Table A.19	– Repeater adapter indicator diagnostic .....	59
Table A.20	– Repeater module indicator .....	60
Table A.21	– Short and medium distance troubleshooting chart .....	60
Table A.22	– Long and extra long troubleshooting chart.....	61
Table B.1	– Network characteristics for balanced cabling based on Ethernet .....	65
Table B.2	– Network characteristics for optical fibre cabling.....	66
Table B.3	– Information relevant to balanced cable: fixed cables .....	66
Table B.4	– Information relevant to balanced cable: cords .....	67
Table B.5	– TCL limits for unshielded twisted-pair cabling .....	67
Table B.6	– ELTCTL limits for unshielded twisted-pair cabling .....	68
Table B.7	– Coupling attenuation limits for screened twisted-pair cabling.....	68
Table B.8	– 4 pair colour codes and pair assignment .....	68
Table B.9	– 2 pair colour codes and pair assignment .....	68
Table B.10	– Fibre type and bandwidth .....	69

Table B.11 – Connectors for balanced cabling CPs based on Ethernet .....	69
Table B.12 – Industrial EtherNet/IP 8-way modular connector parameters .....	70
Table B.13 – Industrial EtherNet/IP M12-4 D-coding connector parameters .....	71
Table B.14 – Optical fibre connectors for fieldbus systems .....	71
Table B.15 – Supported fibre types .....	72
Table B.16 – Connector insertion loss .....	73
Table B.17 – Routing communications cabling in contiguous metallic pathways .....	77
Table B.18 – Parameters for balanced cables .....	79
Table B.19 – Parameters for silica optical fibre cables .....	79
Table C.1 – Basic network characteristics for copper cabling not based on Ethernet (ISO/IEC-8802-3) .....	91
Table C.2 – Cable trunk and drop lengths for CP 2/3 .....	91
Table C.3 – Summary of available current for trunk cables (CP 2/3) .....	95
Table C.4 – Available current for thin cable drop lines .....	95
Table C.5 – Power supply specification for DeviceNet .....	96
Table C.6 – Power supply tolerance stack up for DeviceNet .....	96
Table C.7 – Current versus cable length for one power supply thick cable .....	98
Table C.8 – Current versus length for two power supplies .....	99
Table C.9 – Definition of equation variables .....	101
Table C.10 – Information relevant to copper cable: fixed cables .....	104
Table C.11 – Information relevant to copper cable: cords .....	104
Table C.12 – DeviceNet cables and connector support cross reference .....	104
Table C.13 – DeviceNet cable profiles .....	105
Table C.14 – Copper connectors for non-Ethernet based fieldbus .....	108
Table C.15 – Additional connectors for CP 2/3 (DeviceNet) .....	108
Table C.16 – Parameters for balanced cables .....	113
Table C.17 – Wire colour code and function .....	118
Table C.18 – Auxiliary power cable colour code .....	123
Table C.19 – Network power supply requirements .....	123
Table C.20 – Signal wire verification .....	131
Table C.21 – Shield to earth .....	132
Table C.22 – Connector pin out .....	133
Figure 1 – Standards relationships .....	11
Figure A.1 – Interconnection of CPF 2 networks .....	15
Figure A.2 – Overview of CPF 2 networks .....	16
Figure A.3 – Drop cable requirements .....	17
Figure A.4 – Placement of BNC/TNC plugs .....	18
Figure A.5 – Placement of terminators .....	18
Figure A.6 – Extending a network using repeaters .....	19
Figure A.7 – Extending a network using active star topology .....	19
Figure A.8 – Links .....	20
Figure A.9 – Extending the network beyond 99 nodes .....	20

Figure A.10 – Maximum allowable taps per segment.....	26
Figure A.11 – Example of repeaters in star configuration .....	28
Figure A.12 – Repeater in parallel.....	29
Figure A.13 – Repeater in combination series and parallel .....	29
Figure A.14 – Ring repeater.....	30
Figure A.15 – Installing bulkheads .....	31
Figure A.16 – Coaxial BNC and TNC terminators .....	32
Figure A.17 – Terminator placement in a segment .....	32
Figure A.18 – Redundant network icons.....	35
Figure A.19 – Redundant coax media .....	35
Figure A.20 – Redundant fibre media.....	35
Figure A.21 – Repeater in series versus length difference for coax media.....	36
Figure A.22 – Repeater in series versus length difference for fibre media.....	36
Figure A.23 – Example of redundant coax network with repeaters.....	37
Figure A.24 – Example of improper redundant node connection.....	37
Figure A.25 – Example tool kit for installing BNC connectors .....	41
Figure A.26 – Calibration of coaxial stripper.....	41
Figure A.27 – Coax PVC strip length detail.....	42
Figure A.28 – Memory cartridge and blade.....	43
Figure A.29 – Cable position.....	43
Figure A.30 – Locking the cable.....	43
Figure A.31 – Stripping the cable.....	44
Figure A.32 – Install the crimp ferrule.....	44
Figure A.33 – Cable preparation for PVC type cables .....	44
Figure A.34 – Cable preparation for FEP type cables.....	45
Figure A.35 – Strip guides.....	45
Figure A.36 – Using the flare tool.....	46
Figure A.37 – Expanding the shields.....	46
Figure A.38 – Install the centre pin .....	46
Figure A.39 – Crimping the centre pin.....	47
Figure A.40 – Installing the connector body .....	47
Figure A.41 – Installing the ferrule .....	47
Figure A.42 – Crimp tool .....	48
Figure A.43 – Sealed IP67 cable.....	48
Figure A.44 – Terminator placement .....	49
Figure A.45 – Mounting the taps .....	50
Figure A.46 – Mounting the tap assembly using the universal mounting bracket .....	50
Figure A.47 – Mounting the tap using tie wraps or screws.....	51
Figure A.48 – Redundant network icons.....	51
Figure A.49 – Network test tool.....	54
Figure A.50 – Shorting the cable to test for continuity .....	54
Figure A.51 – Testing fibre segments.....	56
Figure A.52 – Multi-fibre backbone cable housing .....	58

Figure A.53 – Repeater adapter module.....	58
Figure A.54 – Short and medium distance fibre module LEDs .....	60
Figure A.55 – Long and extra long repeater module LEDs .....	61
Figure B.1 – Interconnection of CPF 2 networks .....	63
Figure B.2 – Peer to peer connections .....	65
Figure B.3 – The 8-way modular sealed jack & plug (plastic housing) .....	70
Figure B.4 – The 8-way modular sealed jack & plug (metal housing).....	70
Figure B.5 – M12-4 connectors .....	71
Figure B.6 – Simplex LC connector .....	72
Figure B.7 – Duplex LC connector .....	72
Figure B.8 – IP65/IP67 sealed duplex LC connector .....	72
Figure B.9 – M12-4 to 8-way modular bulkhead .....	74
Figure B.10 – The 8-way modular sealed jack & plug (plastic housing) .....	80
Figure B.11 – The 8-way modular sealed jack & plug (metal housing).....	80
Figure B.12 – M12-4 connectors .....	80
Figure B.13 – Wiring standard (connector back end).....	81
Figure B.14 – Earthing of cable shield .....	83
Figure B.15 – Open shield example .....	83
Figure C.1 – Interconnection of CPF 2 networks.....	88
Figure C.2 – Connection to generic cabling.....	89
Figure C.3 – DeviceNet cable system uses a trunk/drop line topology.....	90
Figure C.4 – Measuring the trunk length.....	92
Figure C.5 – Measuring the trunk and drop length.....	92
Figure C.6 – Measuring drop cable in a network with multiports .....	93
Figure C.7 – Removable device using open style connectors .....	93
Figure C.8 – Fixed connection using open style connector.....	94
Figure C.9 – Open style connector pin out .....	94
Figure C.10 – Open style connector pin out 10 position .....	94
Figure C.11 – Power supply sizing example.....	97
Figure C.12 – Current limit for thick cable for one power supply.....	98
Figure C.13 – Current for thick cable and two power supplies .....	99
Figure C.14 – Worst case scenario .....	100
Figure C.15 – Example using the lookup method .....	100
Figure C.16 – One power supply end connected .....	102
Figure C.17 – Segmenting power in the power bus .....	103
Figure C.18 – Segmenting the power bus using power taps .....	103
Figure C.19 – Thick cable construction .....	113
Figure C.20 – Mid cable construction .....	114
Figure C.21 – Thin cable construction.....	114
Figure C.22 – Flat cable construction.....	114
Figure C.23 – Cable preparation .....	115
Figure C.24 – Connector assembly .....	115
Figure C.25 – Micro connector pin assignment.....	116

Figure C.26 – Mini connector pin assignment.....	116
Figure C.27 – Preparation of cable end.....	116
Figure C.28 – Shrink wrap installation.....	117
Figure C.29 – Wire preparation.....	117
Figure C.30 – Open-style connector (female).....	117
Figure C.31 – Open style (male plug).....	117
Figure C.32 – Flat cable.....	118
Figure C.33 – Aligning the cable.....	119
Figure C.34 – Closing the assembly.....	119
Figure C.35 – Proper orientation of cable.....	119
Figure C.36 – Locking the assembly.....	119
Figure C.37 – Driving the IDC contacts in to the cable.....	120
Figure C.38 – End cap placement.....	120
Figure C.39 – End cap seated.....	121
Figure C.40 – End cap installation alternate side of cable.....	121
Figure C.41 – Flat cable IDC connectors.....	121
Figure C.42 – Installing the connectors.....	122
Figure C.43 – Cable wiring to open style terminals.....	122
Figure C.44 – Auxiliary power cable profile.....	123
Figure C.45 – Pin out auxiliary power connectors.....	123
Figure C.46 – Sealed terminator.....	125
Figure C.47 – Open-style terminator.....	126
Figure C.48 – Open-style IDC terminator.....	126
Figure C.49 – Sealed terminator IDC cable.....	126
Figure C.50 – Direct connection to the trunk.....	127
Figure C.51 – Wiring of open-style connector.....	127
Figure C.52 – Wiring of open-style 10-position connector.....	127
Figure C.53 – Diagnostic temporary connections.....	128
Figure C.54 – Thick cable preterminated cables (cord sets).....	128
Figure C.55 – Thin cable preterminated cables (cord sets).....	129

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## INDUSTRIAL COMMUNICATION NETWORKS – PROFILES

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

## FOREWORD

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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 standard is to be used in conjunction with IEC 61918:2007.

The text of this standard is based on the following documents:

FDIS	Report on voting
65C/471/FDIS	65C/482/RVD

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

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

A list of all parts of the 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 publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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

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**Withdrawn**

## INTRODUCTION

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

IEC 61918:2007 (Ed. 1.0) 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 standard, see IEC/TR 61158-1.

Each CP installation profile is specified in a separate annex of this standard. 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 standard are defined in Clause 5.

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

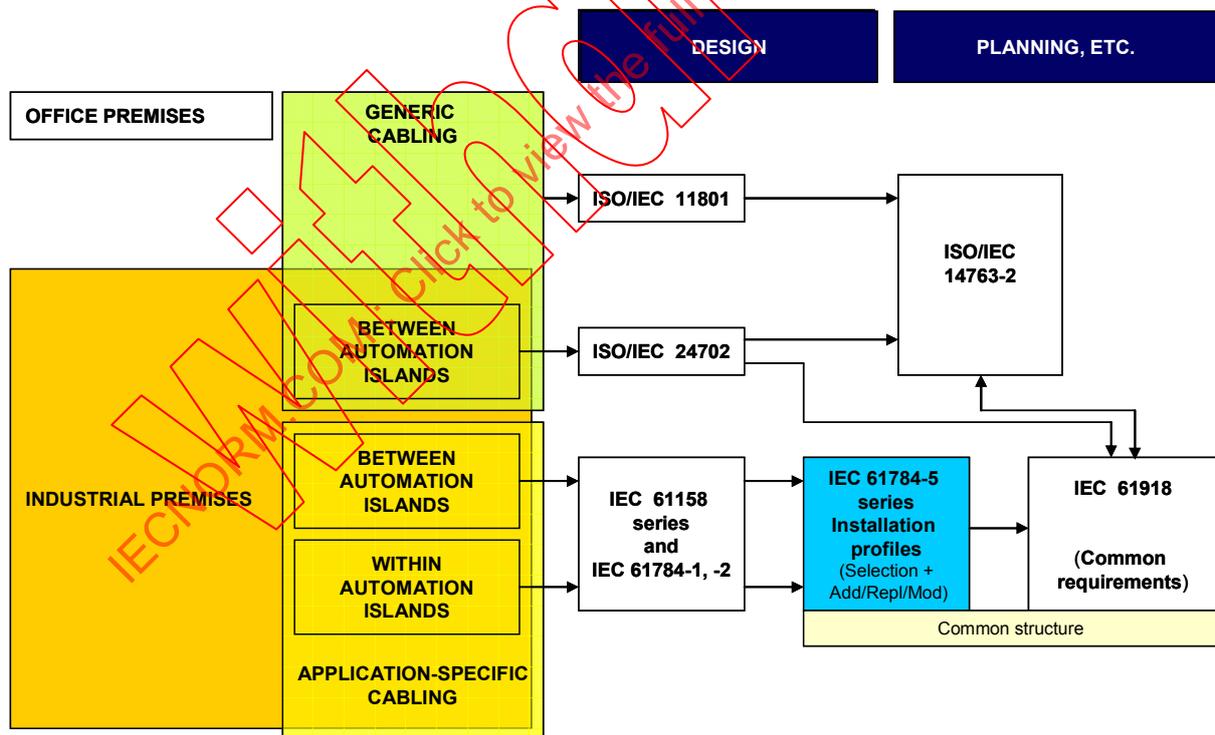


Figure 1 – Standards relationships

## INDUSTRIAL COMMUNICATION NETWORKS – PROFILES

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

#### 1 Scope

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

The installation profiles are specified in the annexes. These annexes are read in conjunction with IEC 61918:2007.

#### 2 Normative references

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

IEC 61918:2007, *Industrial communication networks – Installation of communication networks in industrial premises*

The normative references of IEC 61918:2007, Clause 2, apply. For profile specific normative references, see Clauses A.2, B.2, and C.2.

#### 3 Terms, definitions and abbreviated terms

The terms, definitions and abbreviated terms of IEC 61918:2007, Clause 3, apply. 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™<sup>2</sup>) are specified in Annex A.

The installation requirements for CP 2/2 (EtherNet/IP™<sup>3</sup>) are specified in Annex B.

The installation requirements for CP 2/3 (DeviceNet™<sup>4</sup>) are specified in Annex C.

---

<sup>1</sup> CIP™ (Common Industrial Protocol) is a trade name of Open DeviceNet Vendor Association, 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 standard does not require use of the trade name CIP™. Use of the trade name CIP™ requires permission of Open DeviceNet Vendor Association, Inc.

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## 5 Installation profile conventions

The numbering of the clauses and subclauses in the annexes of this standard corresponds to the numbering of IEC 61918:2007 main clauses and subclauses.

The annex clauses and subclauses of this standard supplement, modify, or replace the respective clauses and subclauses in IEC 61918:2007.

Where there is no corresponding subclause of IEC 61918:2007 in the normative annexes in this standard, the subclause of IEC 61918:2007 applies without modification.

The annex heading letter represents the installation profile assigned in Clause 4. The annex heading number shall represent the corresponding numbering of IEC 61918:2007.

EXAMPLE “Annex B.4.4” in IEC 61784-5-2 means that CP 2/2 specifies the Subclause 4.4 of IEC 61918:2007.

All main clauses of IEC 61918:2007 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 x has “Addition” (or “Replacement”, or “Modification”) or is “Not applicable””, then (sub)clause x becomes valid as declared and all the other corresponding IEC 61918 (sub)clauses apply.

## 6 Conformance to installation profiles

Each installation profile within this standard includes part of IEC 61918:2007. It may also include defined additional specifications.

A statement of compliance to an installation profile of this standard shall be stated<sup>5</sup> as either

Compliance to IEC 61784-5-2:2007<sup>6</sup> for CP 2/n <name> or

Compliance to IEC 61784-5-2 (Ed.1.0) for CP 2/n <name>

where the name within the angle brackets < > is optional and the angle brackets are not to be included. The n within CP 2/n 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).

<sup>5</sup> In accordance with ISO/IEC Directives.

<sup>6</sup> The date should not be used when the edition number is used.

## **Annex A** (normative)

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

#### **A.1 Installation profile scope**

*Addition:*

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

#### **A.2 Normative references**

*Addition:*

IEC 60096-2, *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:*

BNC	Bayonet Neill Concelman (connector for coaxial cable having a bayonet-type shell)
DVM	Digital voltmeter
MM	Multi mode
NAP	Network access port (local access to a device, i.e. not via the bus)
OTDR	Optical time domain reflectometer
POF	Plastic optical fibre
PVC	Polyvinyl chloride
RG6	Coaxial cable
SM	Single mode
TNC	Threaded Neill Concelman (threaded version of the BNC connector)

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

Not applicable.

## A.4 Installation planning

### A.4.1 Introduction

#### A.4.1.1 Objective

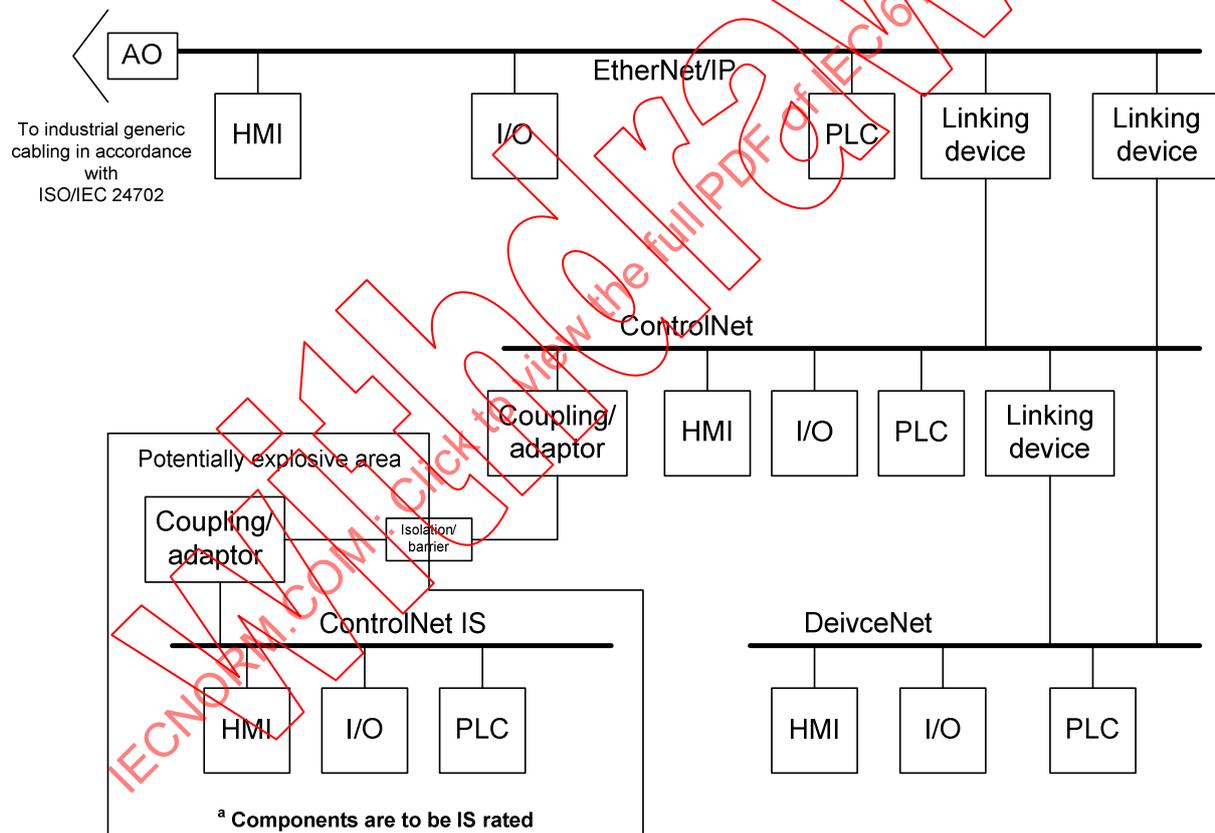
#### A.4.1.2 Cabling in industrial premises

*Addition:*

CP 2/1 networks can be connected to generic cabling via a converter/adaptor as mentioned in IEC 61918:2007, 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 61918:2007, 4.1.2, Figure 5. 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 coax 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).

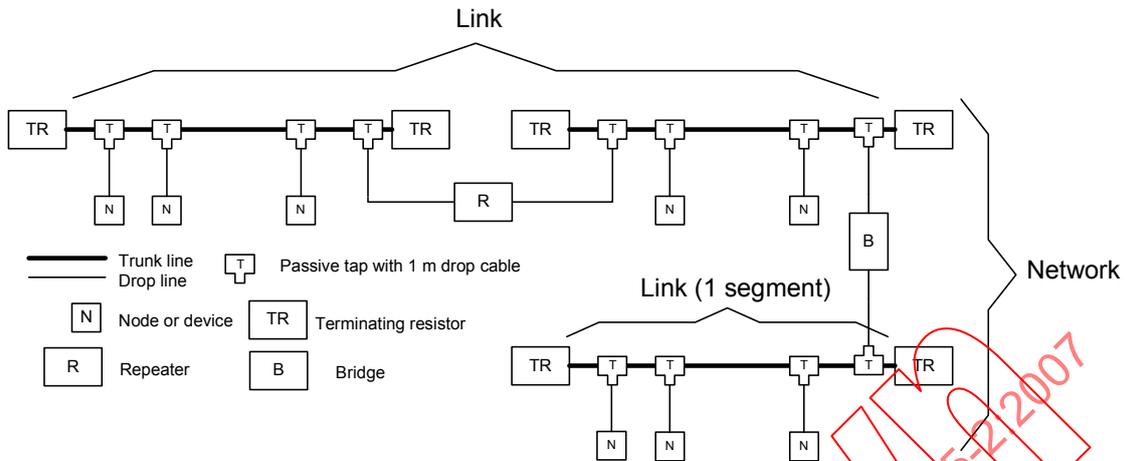


Figure A.2 – Overview of CPF 2 networks

**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 (OFCS)**

Not applicable.

**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 61918:2007, 4.4.7 and A.4.4.7.3 of this standard.

This network uses a parallel RC between earth and the shield of the coaxial cable. The shields are not directly referenced to earth at any point in the system, 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 24702**

Not applicable.

### A.4.3 Network capabilities

#### A.4.3.1 Network topology

##### A.4.3.1.1 Common description

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

*Modification:*

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

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

*Modification:*

ControlNet supports active linear, star and ring topologies.

##### A.4.3.1.4 Combination of basic topologies

*Addition:*

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

##### A.4.3.1.5 Specific requirements for CPs

*Addition:*

##### A.4.3.1.5.1 General

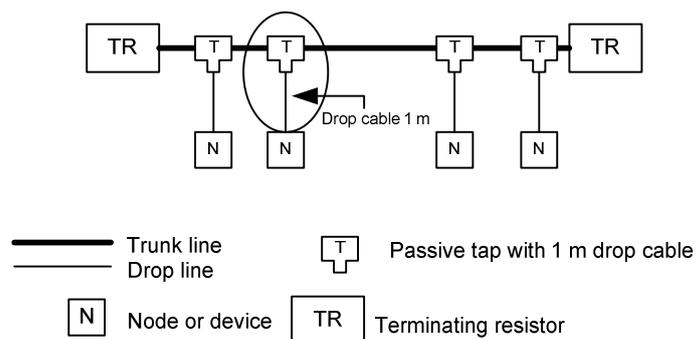
CP 2/1 supports both coaxial and fibre media in the trunk segments. Drop cables shall be coaxial. The network is an amplitude and delay limited network. In general, for the coaxial variant, amplitude is the limiting factor. Fibre trunk segments have much less loss so delay limits can be readily exceeded.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

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

The following subclauses describes 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.



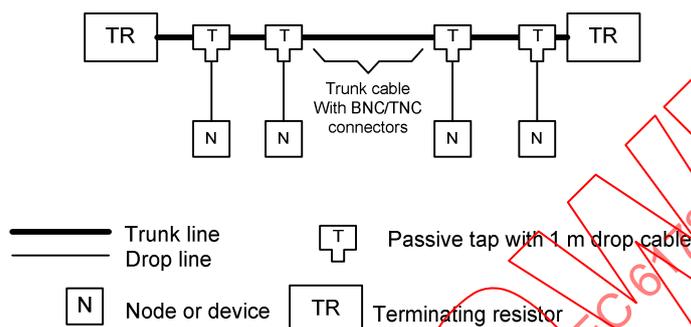
**Figure A.3 – Drop cable requirements**

**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 segment shall have a BNC or TNC plug installed on each end as shown in Figure A.4.

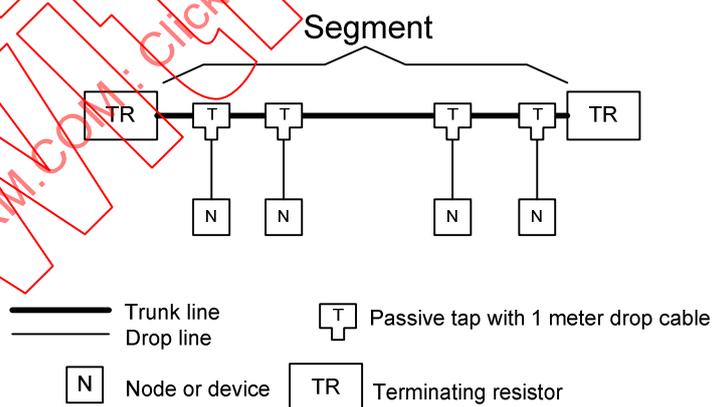


**Figure A.4 – Placement of BNC/TNC plugs**

**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.

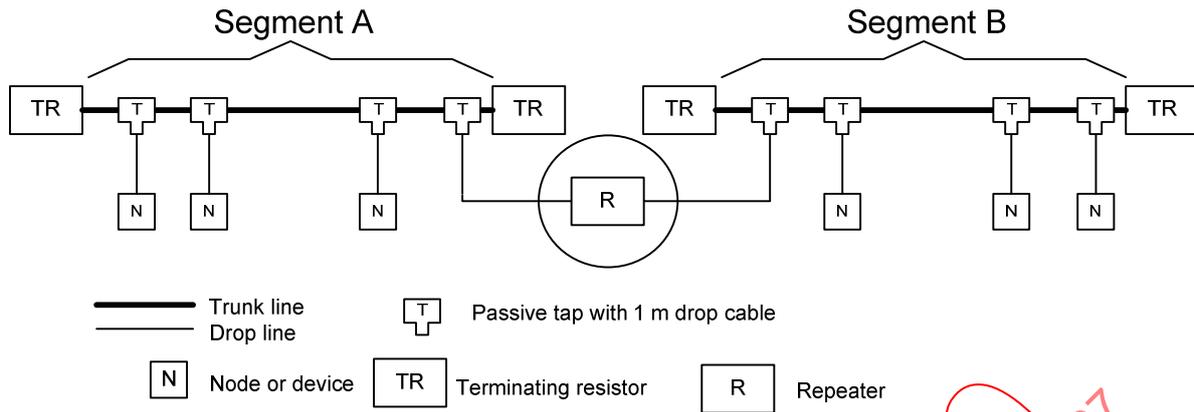


Figure A.6 – Extending a network using repeaters

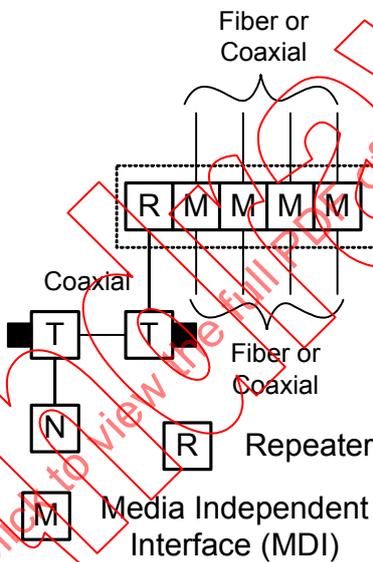


Figure A.7 – Extending a network using active star topology

**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 0-99. Node address 0 shall be reserved for devices auto address nodes or nodes without address switches.

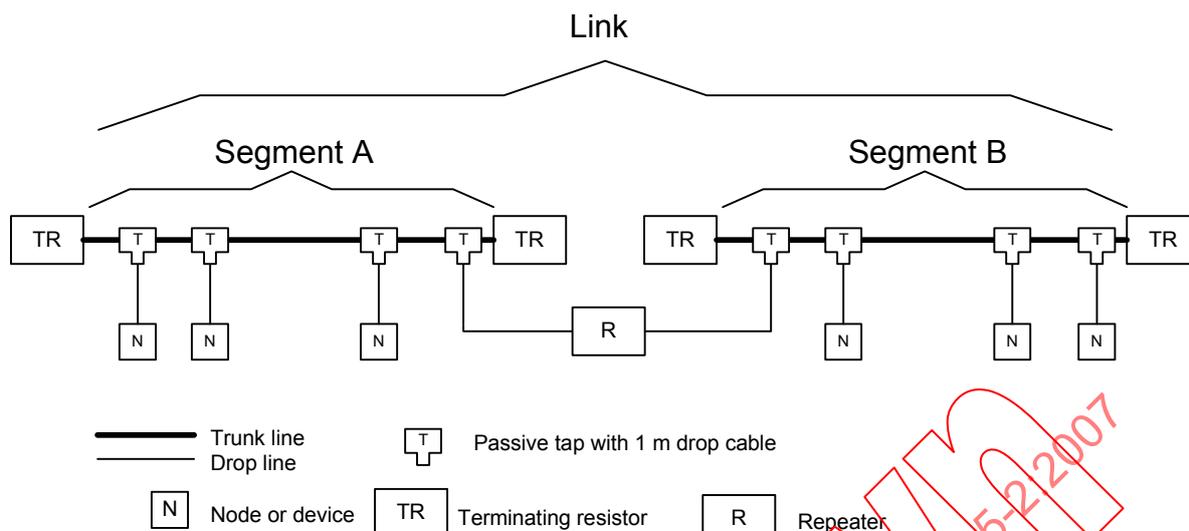


Figure A.8 – Links

**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.

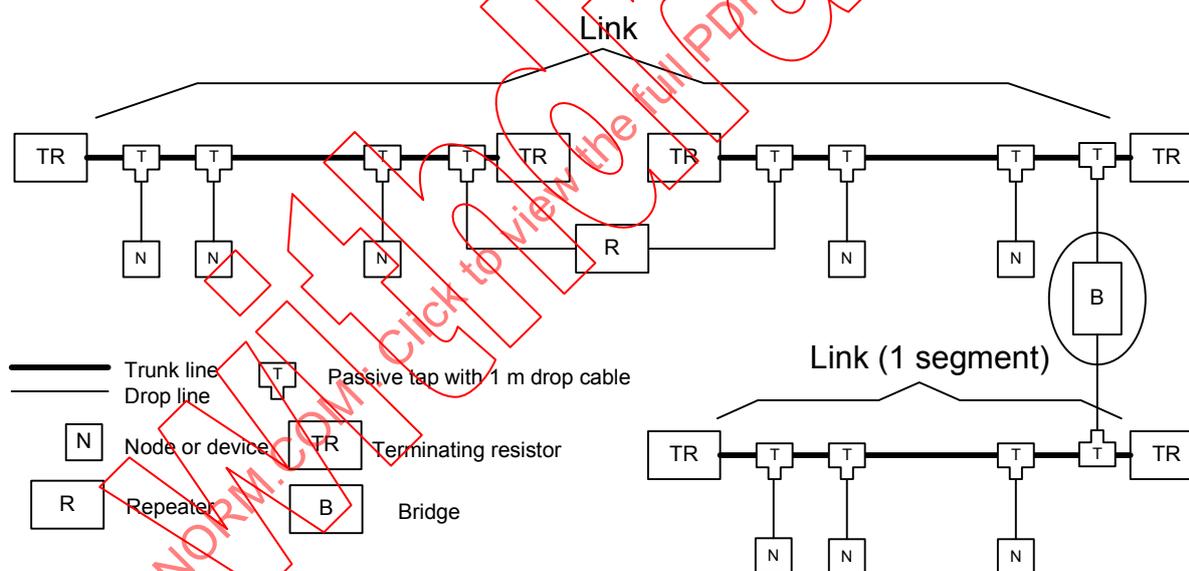


Figure A.9 – Extending the network beyond 99 nodes

**A.4.3.1.6 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**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 61918:2007, Table 1.

**Table A.1 – Basic network characteristics for copper cabling not based on Ethernet (ISO/IEC 8802-3)**

Characteristics	CP 2/1
Basic transmission technology	Linear bus
<b>Length / transmission speed</b>	
Transmission speed	5 Mbit/s
Segment length	1 000 m maximum (see Figure A.10)
Link length	20 km maximum <sup>a</sup>
<b>Maximum capacity</b>	
	<b>Max. No.</b>
Devices / segment	48
Devices / link	99
Devices / network	Unlimited
<sup>a</sup> The total link length is limited by the maximum allowable link round trip delay (242 µs).	

**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 are detailed in Table A.2 for CP 2/1 based on the template given in IEC 61918:2007, Table 3.

**Table A.2 – Allowable fibre lengths**

Characteristic	CP 2/1		
Optical fibre type Min. modal bandwidth	Minimum length m	Maximum length km	$\Lambda$ nm
200/230 µm MM	0	0,3	650
62,5/125 µm MM	0	3/10	1300
9/125 µm SM	0	20 <sup>a</sup>	1300
NOTE All these lengths are dependant on path losses in Table A.3.			
<sup>a</sup> The total link length is limited to 20 km due to delay limitations of 121 µs each way (242 µs round trip).			

*Addition:*

Table A.3 provides power budget values for network design. The insertion loss for each segment shall not be exceeded. A 1 dB margin is recommended for aging.

**Table A.3 – Power budgets for ControlNet fibre networks**

Characteristic	Cable type	Power budget dB
Short-distance fibre repeater	200/230 µm MM	4,2
Medium-distance fibre repeater	62,5/125 µm MM	13,3
Long-distance fibre repeater	62,5/125 µm MM	15
Extra-long distance fibre repeater	62,5/125 µm MM	10,5
Extra-long distance fibre repeater	9/125 µm SM	10,5

**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 line 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 24702**

Not applicable.

**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.4. The mechanical properties for the standard coaxial cable are described in Table A.5. These parameters (electrical and mechanical) can be used to procure the proper cable for standard installations. Specialty cables as described in Table A.6 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.4 shall be met in order to maintain standard network configurations as described in this installation profile.

**Table A.4 – 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 d.c. resistance	92 Ω/km nominal
Shield d.c. resistance	24 Ω/km nominal
Capacitance	53,2 pF/m

The physical parameters listed in Table A.5 shall be met in order to maintain noise immunity and connector compatibility.

**Table A.5 – RG6 coaxial physical parameters**

Specification	Characteristics
Center conductor material and diameter	18 AWG solid bare copper covered steel 0,823 mm <sup>2</sup> ± 0,003 mm <sup>2</sup>
Dielectric material and diameter	4,65 mm ± 0,13 mm
Shield construction 4 layers	Layer 1: foil Layer 2: 60 % braid Layer 3: foil 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.6 provides guidance for application specific cables.

**Table A.6 – Cable type selection**

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

#### **A.4.4.1.3 Cables for wireless installation**

Not applicable.

#### **A.4.4.1.4 Optical fibre cables**

*Addition:*

For optical fibre, cabling shall conform to the requirements given in Table A.2 and Table A.3. 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 a 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.7.

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

Table A.7 provides values based on the template given in IEC 61918:2007, Table 6.

**Table A.7 – 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 cladded silica
Attenuation per km (650 nm)	n/a	n/a	n/a	n/a	≤ 6,0 dB
Attenuation per km (820 nm)	n/a	n/a	n/a	n/a	n/a
Attenuation per km (1 310 nm)	≤ 1,0 dB	≤ 2,5 dB	≤ 3,5 dB	n/a	n/a
Number of optical fibres	2		2	n/a	2
Connector type (e.g. duplex or simplex)	BFOC 2,5	BFOC 2,5	BFOC 2,5	n/a	V-Pin
Jacket colour requirements	User defined	User defined	User defined	n/a	User defined
Jacket material	Application specific	Application specific	Application specific	n/a	Application specific
Resistance to harsh environment (e.g. UV, oil resist, LS0H)	Yes <sup>a</sup>	Yes <sup>a</sup>	Yes <sup>a</sup>	n/a	Yes <sup>a</sup>
Breakout (Y/N)	Yes <sup>b</sup>	Yes <sup>b</sup>	Yes <sup>b</sup>	n/a	Yes <sup>b</sup>
<sup>a</sup> If application requires. <sup>b</sup> Duplex and simplex cords/cables are supported.					

**A.4.4.1.5 Special purpose copper 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 24702**

Not applicable.

**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.8.

**Table A.8 – Copper connectors for ControlNet**

CP 2/1	Coaxial EN 122120	Others
Characteristics for CP 2/1 (ControlNet)	BNC	TNC RJ45 (NAP)

**Addition:**

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

- 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 d.c. to 50 MHz.

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

Passive taps are used to connect the cable segments 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.

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

Not applicable.

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

Table A.9 provides values based on the template given in IEC 61918:2007, Table 9.

**Table A.9 – Fibre connectors for fieldbus systems**

	IEC 61754-2	IEC 61754-4	EN 50377-6-1	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	200/230 µm

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

**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 24702**

Not applicable.

**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 for CPs based on Ethernet**

Not applicable.

**A.4.4.3.3 Copper cabling connections for CPs not based on Ethernet**

**A.4.4.3.3.1 Common description**

**A.4.4.3.3.2 Connections minimum distance**

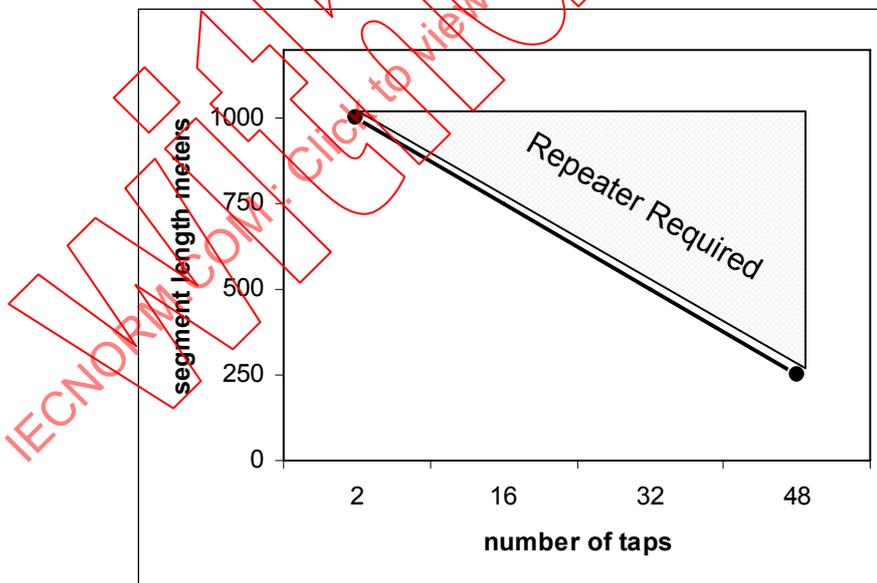
*Replacement:*

**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.4, and of the number of taps in the segment. There is no minimum trunk-cable section length requirement. The maximum allowable total length of a segment is 1 000 m with two taps connected. Each additional tap decreases the maximum length of the segment by 16,3 m. The maximum number of taps allowed on a segment is 48. With 48 taps the maximum segment length is limited to 250 m. Figure A.10 details the relationship between the number of taps allowed in a segment and the segment length. If the network design falls in the grey area then a repeater is required.



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

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

**EXAMPLE 1**

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

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

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

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

The amount of high-flex RG6 cable that can be used in a system is less than the amount of standard RG6 cable. The designer is encouraged to keep the length of high-flex cable use to a minimum. BNC bullet connectors or isolated bulkhead connectors shall be used to isolate areas that require high-flex RG6 cable from areas that require standard RG6 cable; this allows the high-flex RG6 section to be replaced before flex life is exhausted. An allowable total length of RG6 flex cable segment in the application can be determined using the equation below. Each additional tap decreases the maximum length of the segment. The maximum number of taps allowed on a segment is 48. The maximum segment length is depending on the attenuation of the high-flex cable used. The maximum allowable segment length is then as follows:

$$\text{Segment\_Length} = [20,29 \text{ dB} - (\text{Number\_taps} \times 0,32 \text{ dB})] / \text{cable\_atten@10MHz}$$

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

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

#### EXAMPLE 2

For a high flex coaxial cable that has attenuation of 2,36 dB per 100 m at 10 MHz, a segment that requires 3 taps using high flex cable, the maximum segment length is:

$$\text{Maximum\_Segment\_Length} = [(20,29 \text{ dB} - 3 \times 0,32 \text{ dB}) / 2,36 \text{ dB}] \times 100 \text{ m}$$

or

$$[19,33 \text{ dB} / 2,356 \text{ dB}] \times 100 = 820 \text{ m}$$

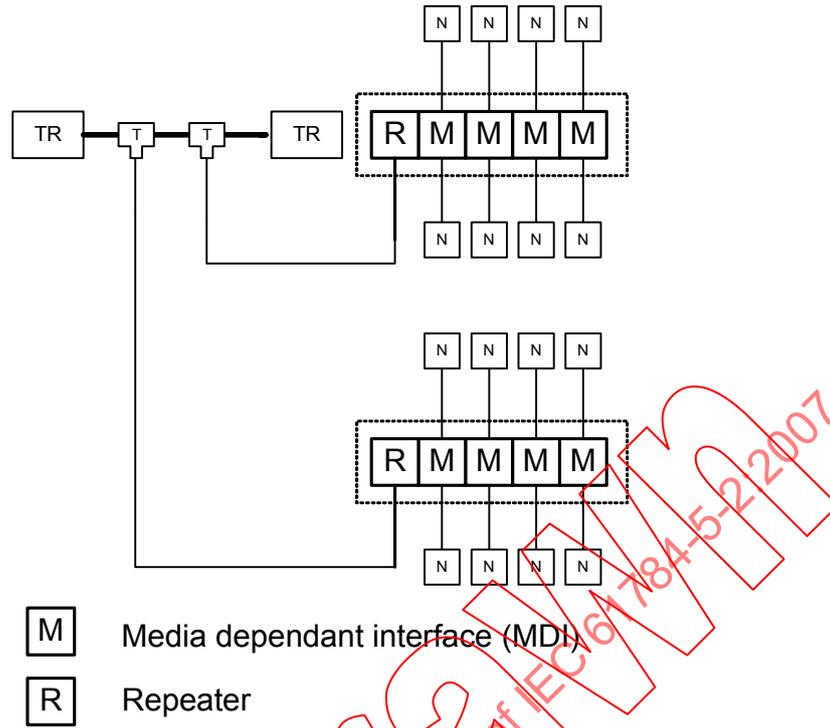
The total trunk-cable length or number of taps (connections) can be increased by breaking up the segment into smaller segments.

#### 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 one of five ways:

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



**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. Fiber repeaters may be connected in series through the fiber ports.

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

**c) Series connected repeaters**

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

**d) Parallel connected repeaters**

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

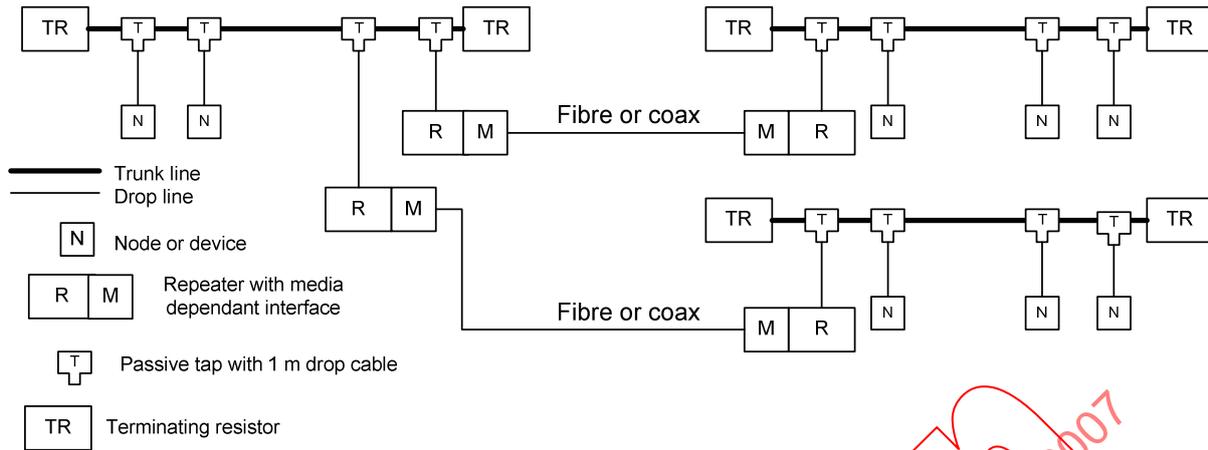


Figure A.12 – Repeaters in parallel

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

Repeaters shall 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 shall 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.

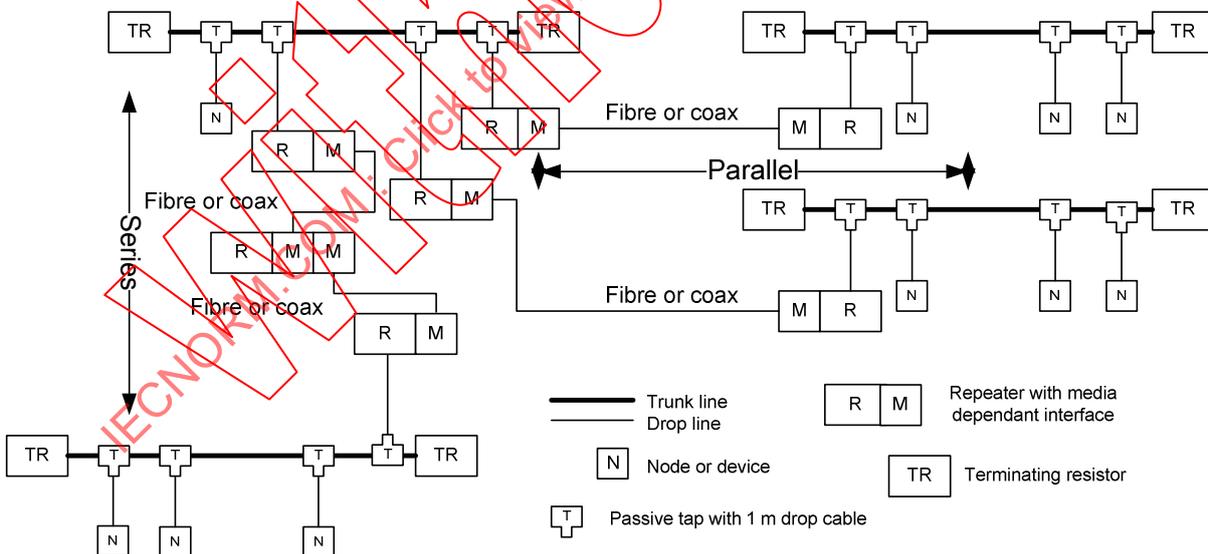


Figure A.13 – Repeaters in combination series and parallel

**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. The network shall not be designed as a redundant ring (two parallel rings).

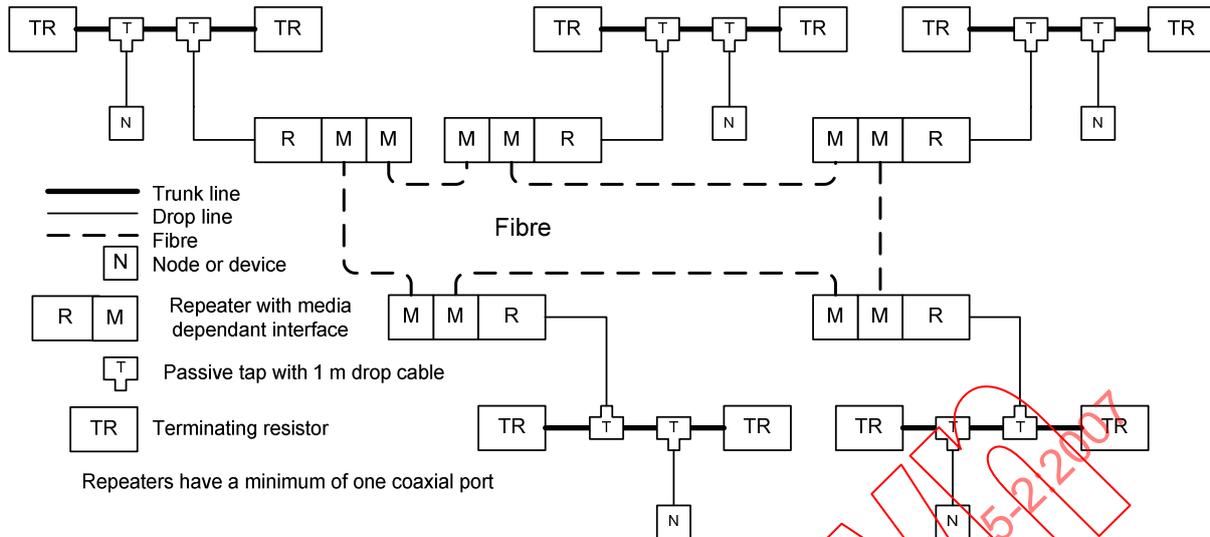


Figure A.14 – Ring repeater

**A.4.4.3.3 Copper cabling splices**

*Replacement:*

Coaxial splices are not allowed. The planner shall specify J-J BNC or TNC adaptors.

**A.4.4.3.3.4 Copper cabling bulkhead connections**

*Replacement:*

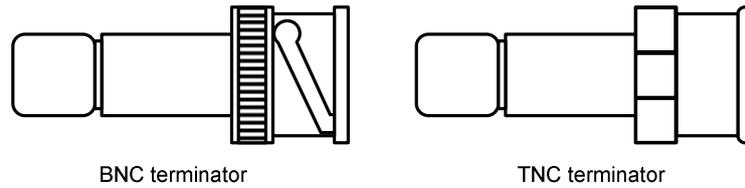
Copper bulkheads shall be isolated from earth. Copper bulkhead shall be constructed of back to back BNC jacks, TNC jacks or a combination of BNC and TNC jacks. They shall provide environmental isolation. Examples of how bulkheads are used in this profile are shown in Figure A.15.

Copper adaptors shall have a characteristic impedance of  $75 \Omega \pm 3 \Omega$ .

In this example, ControlNet cable:

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

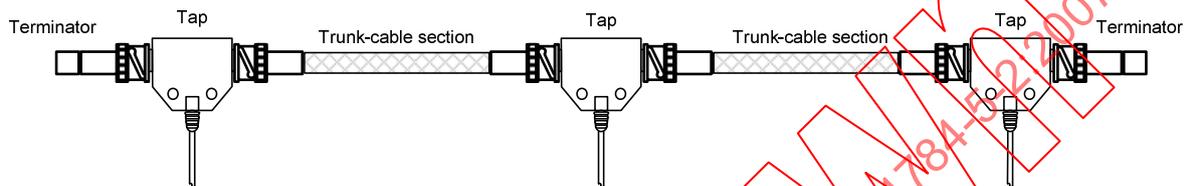




**Figure A.16 – Coaxial BNC and TNC terminators**

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 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 24702**

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.

**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 24702**

Not applicable.

**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 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 within the communications coverage area.

#### **A.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 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 61918:2007, Table 15.

#### **A.4.4.7.3 Earthing methods**

##### **A.4.4.7.3.1 Mesh, equipotential**

*Addition:*

If the building does not have an adequate or has an unknown equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets within the communications coverage area. There shall be no noise currents in the communications shields as a result of earth potential offsets in the communications coverage area. An alternate media such as fibre may be considered as part of a mitigation technique.

##### **A.4.4.7.3.2 Star**

*Addition:*

If the building does not have an adequate or has an unknown equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets within the communications coverage area. There shall be no noise currents in the communications shields as a result of earth potential offsets in the communications coverage area. An alternate media such as fibre may be considered as part of a mitigation technique.

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

*Replacement:*

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

##### **A.4.4.7.3.4 Installing copper bus bars**

*Addition:*

In some cases it may be necessary to install copper bus bars in accordance with the star earthing system. When doing so insulators may be required to isolate the bus bar from the enclosure or building earth reference. When it is necessary to isolate the copper bus bar, the d.c. resistance to the local earth shall be 2 M $\Omega$  minimum. If the bus bar is plated, it shall be in accordance with IEC 61918:2007, Table 15.

The bus bar surface shall be prepared in accordance with IEC 61918:2007, 5.7.2.3. The conductor sizing shall be in accordance with IEC 61918:2007, 4.4.7.2.

#### **A.4.4.7.4 Shield earthing**

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

*Addition:*

ControlNet coaxial shields are connected to earth via a parallel RC circuit that is integral to the active devices. The coax shields shall not be directly bonded to earth as this will introduce noise in the network. It is not necessary to provide a parallel RC circuit for the shields as these are an integral part of each active interface.

##### **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 24702**

Not applicable.

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

**A.4.4.9 Routing of cables**

**A.4.4.9.1 Common description**

*Addition:*

ControlNet cabling shall be installed in accordance with local regulations. The planner shall specify the correct cable for the area to be installed. Table A.6 provides guidance on cable selection for specific applications.

**A.4.4.9.2 Cable routing of assemblies**

**A.4.4.9.3 Detailed 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 A.10. When running cable inside an enclosure, the installer shall route the conductors external to all raceways in the same enclosure, or in a raceway separate from Category-1 conductors.

**Table A.10 – Separation from other circuits inside enclosures**

Route cables at least this distance	From noise sources of this strength
0,08 m (3 in.)	Category-1 conductors of less than 20 A
0,15 m (6 in.)	a.c. power lines of 20 A or more, up to 100 kVA
0,6 m (24 in.)	a.c. power lines greater than 100 kVA

**A.4.4.9.4 Cable routing inside buildings**

**A.4.4.9.5 Cable routing outside buildings**

**A.4.4.9.6 Installing redundant communication cables**

*Addition:*

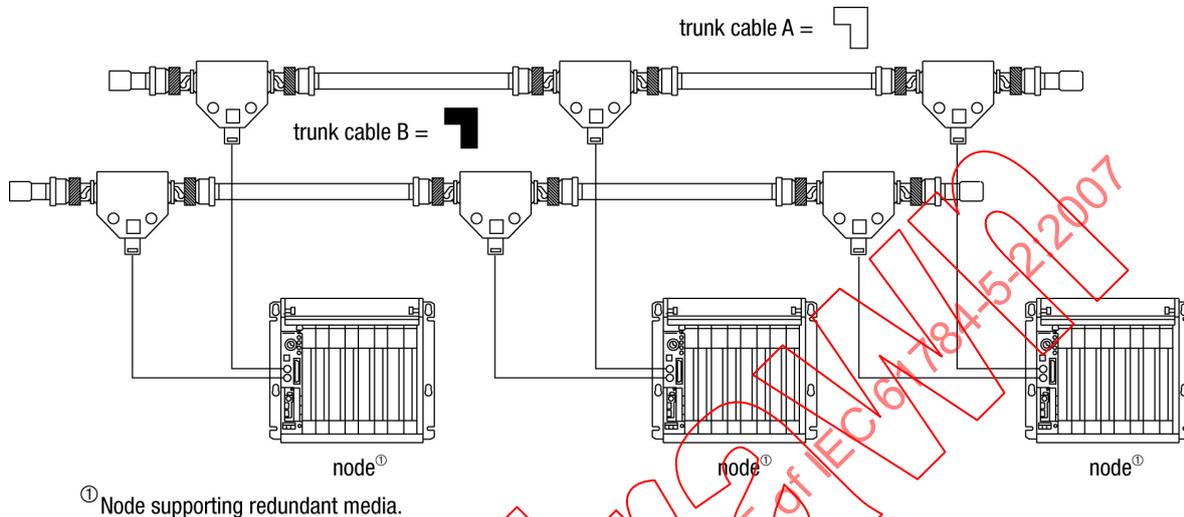
A second trunk cable is used between ControlNet nodes for redundant media. With redundant media, nodes send signals on two separate segments. The receiving node compares the quality of the two signals and accepts the better signal to permit use of the best signal. This also provides a backup cable if 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.18 with shaded icon representing redundant media. See Figure A.19 for redundant coaxial media example. Figure A.20 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.21 for coax repeaters and Figure A.22 for fibre repeaters.

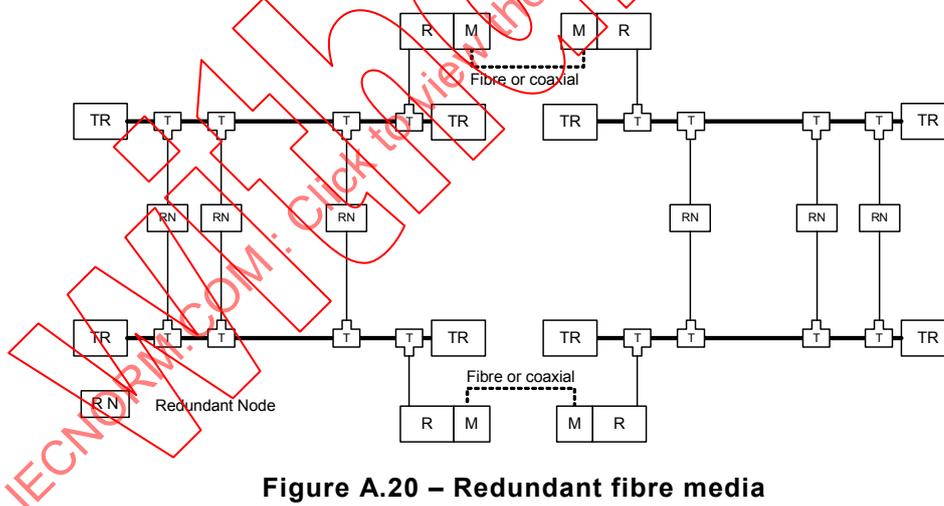


**Figure A.18 – Redundant network icons**

In Figure A.19, 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 proper icon or letter.



**Figure A.19 – Redundant coax media**



**Figure A.20 – 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 cable 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 identical 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 so that each cable is about the same length. As the number of repeaters in a network increase, the allowable difference in length of the two redundant cabling systems is decreased as shown in Figure A.21.
- 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.21 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.22 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.21 or Figure A.22.
- Both redundant connections of a node shall not be connected to the same network; doing so will cause erratic operation. See Figure A.23 and Figure A.24 for both proper and improper connection of redundant nodes.
- The two networks shall not be connected together.

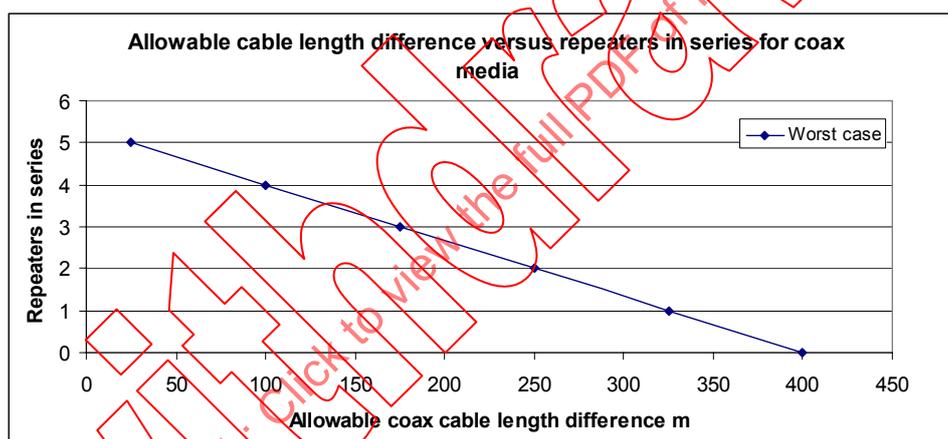


Figure A.21 – Repeaters in series versus length difference for coax media

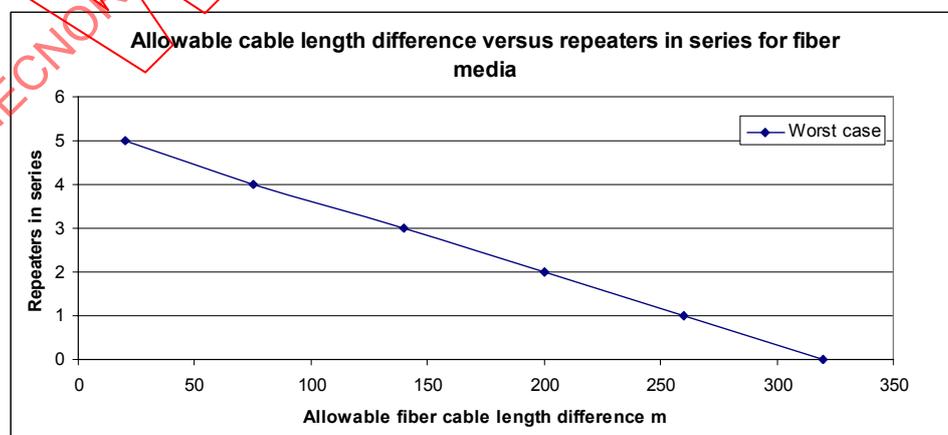
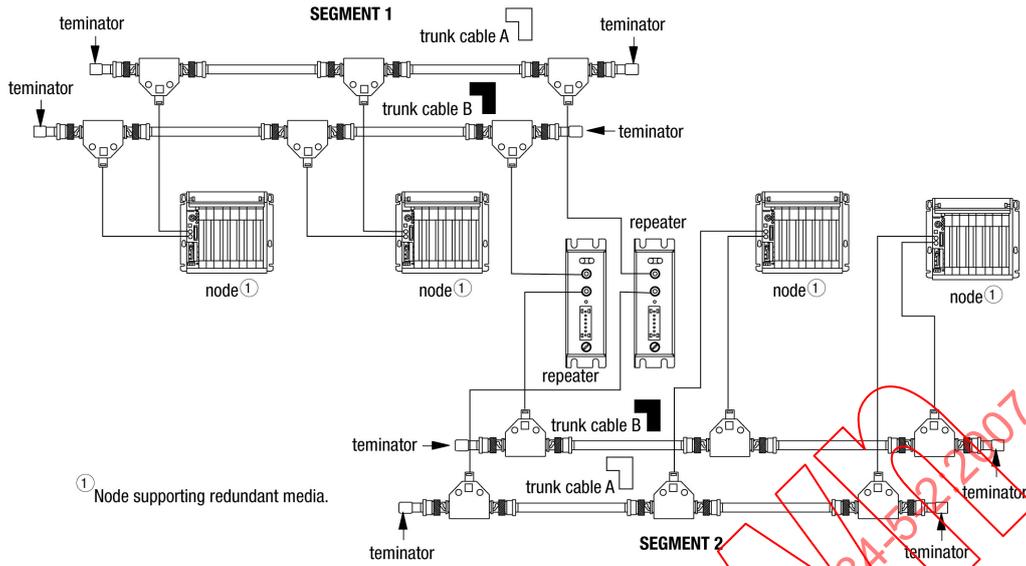
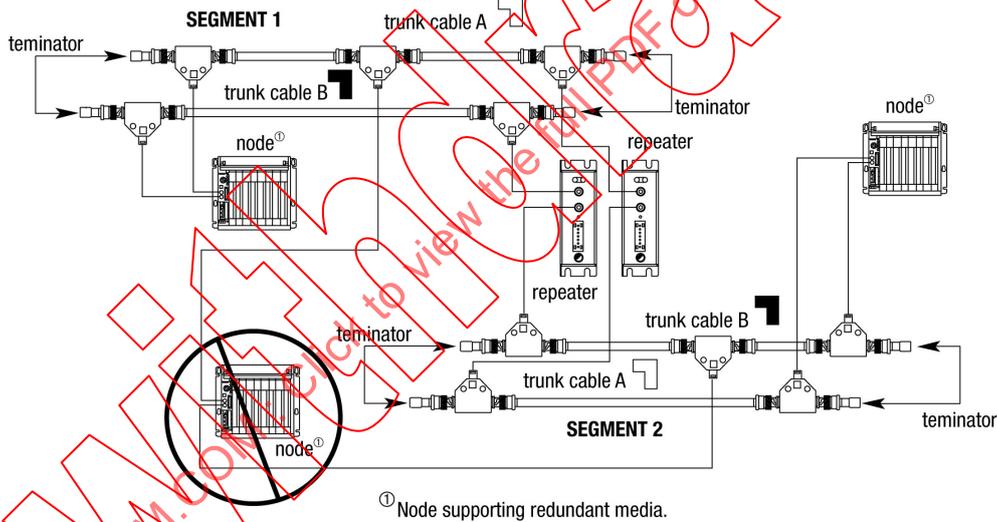


Figure A.22 – Repeaters in series versus length difference for fibre media



**Figure A.23 – Example of redundant coax network with repeaters**



**Figure A.24 – 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.23).

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 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 cable shall cross power feed lines, it 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**

**A.4.4.11.2 Specific requirements for CPs**

Not applicable.

**A.4.4.11.3 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**A.4.4.12 Installation in special areas**

**A.4.5 Cabling planning documentation**

**A.4.6 Verification of planning specification**

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## 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 communication cables against potential mechanical damage

*Replacement for Table 17:*

When pulling the RG6 type coax cable through multiple conduit bends, the specifications detailed in Table A.11 shall be followed.

**Table A.11 – Pulling and bend radius for coaxial cables**

For this coax cable	The pull force shall not exceed	The bend radius shall not exceed
PVC	400 N	76,2 mm
FEP	600 N	69,9 mm

*Addition:*

When pulling outside conduit the RG6 type coax cable, the specifications detailed in Table A.12 shall be followed.

**Table A.12 – Bend radius for coaxial cables**

For this coax cable	The bend radius shall not exceed
PVC	38,1 mm
FEP	35,6 mm
Tap drop-cable	25,4 mm

*Replacement for Tables 18 and 20:*

For all silica optical fibre cables and hard clad silica optical fibre cables, see the manufacturer's data sheets for pull force and bend radius.

*Modification:*

IEC 61918:2007, Table 19 does not apply.

#### A.5.2.2 Installation and routing

##### A.5.2.2.1 Common description

##### A.5.2.2.2 Separation of circuits

*Replacement:*

**A.5.2.2.2.1 Wiring 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 ControlNet cables and other potential noise carrying conductors.

When installing the cables near power conductors the installer shall follow the guidelines in Table A.13.

**Table A.13 – Spacing from other circuits inside and outside wire ways or conduit**

Cables separated in contiguous metallic wire way or conduit	Route the cable at least:	From noise sources of this strength:
Yes	0,08 m	Category-1 conductors less than 20 A
	0,15 m	a.c. power lines of 20 A or more, up to 100 kVA
	0,3 m	a.c. power lines greater than 100 kVA
No	0,15 m	Category-1 conductors of less than 20 A
	0,3 m	a.c. power lines of 20 A or more, up to 100 kVA
	0,6 m	a.c. power lines greater than 100 kVA

Table A.13 provides guidance on minimum separation, local regulations may require separation of greater distance from these circuits. Local regulations shall take priority over this standard.

**A.5.2.2.2.2 Wiring inside enclosures**

Cable sections that run inside equipment enclosures are relatively short. As with wiring external to enclosures, maximum separation shall be maintained between the ControlNet cable and other conductors.

When running cable inside an enclosure, conductors shall be routed external to all raceways in the same enclosure, or in a raceway separate from Category-1 conductors (see Table A.14 for separation distances).

**Table A.14 – Separation from Category-1 conductors for coax cables inside enclosures**

Route the cable at least this distance:	From noise sources of this strength
0,08 m	Category-1 conductors of less than 20 A
0,15 m	a.c. power lines of 20 A or more, up to 100 kVA
0,6 m	a.c. power lines greater than 100 kVA

**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 24702**

Not applicable.

**A.5.3 Connector installation**

**A.5.3.1 Common description**

**A.5.3.2 Shielded connectors**

**A.5.3.3 Unshielded connectors**

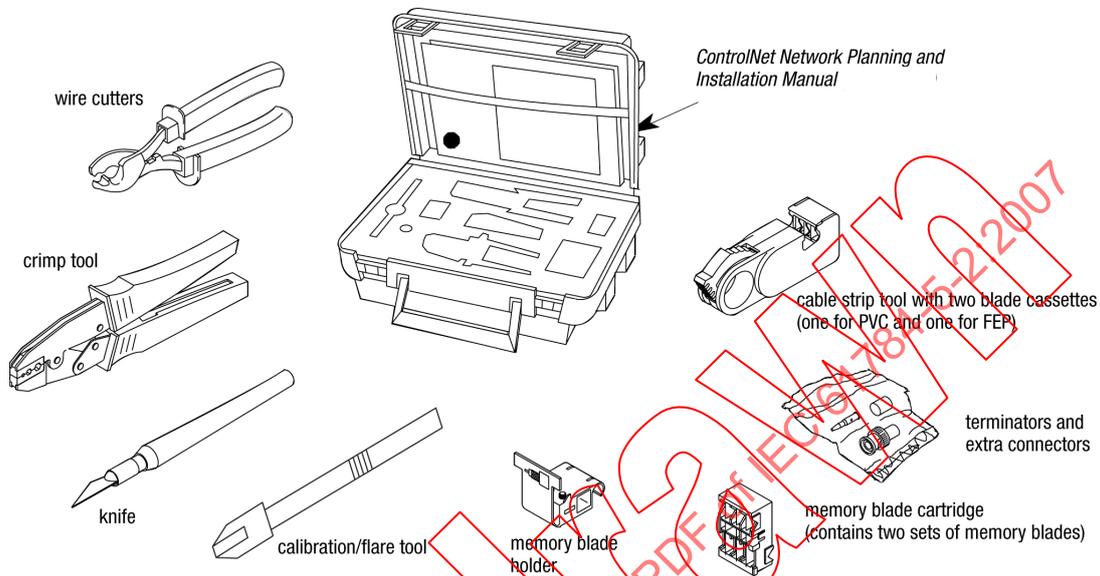
Not applicable.

### 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.25.



**Figure A.25 – Example tool kit for installing BNC connectors**

Additional tools:

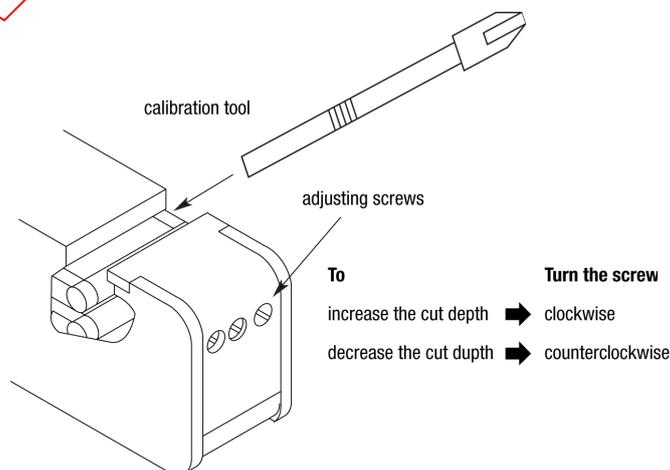
- Heat gun (for IP67 sealed connectors)

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.26.



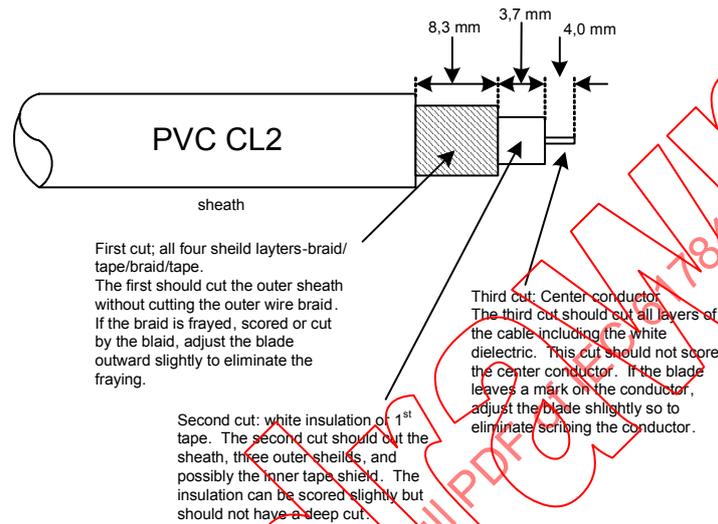
**Figure A.26 – Calibration of coaxial stripper**

- 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 shall be aligned with the blades.

- 4) Retract the handle of the cable strip tool
- 5) 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.27.



**Figure A.27 – Coax PVC strip length detail**

**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.

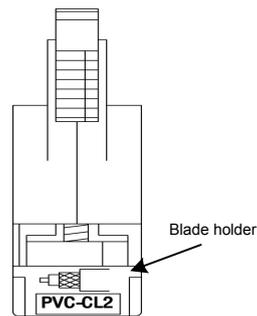
Check the outer braid of cable for cut or scored braid wire after stripping the cable. If the braid is damaged, cut the damaged end off and strip the cable again. If needed, adjust the appropriate cutting blade by backing the set screw out 1/8 of a turn. Do not crimp the BNC to a damaged braid. This 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:

- 78 mm for wiring external to enclosures;
- 39 mm for wiring inside enclosures.

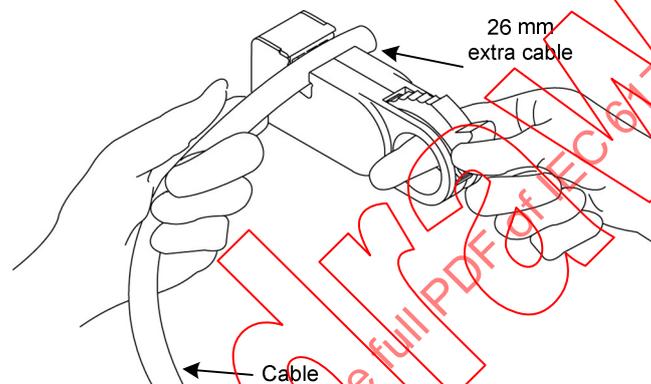
Proceed as follows.

- 1) Verify that the proper memory blade holder installed for the type of cable to be stripped (PVC-CL2 or FEP-CL2P), see Figure A.28. The blades shall be recalibrated if the memory cartridge is replaced, see the calibration procedure above.



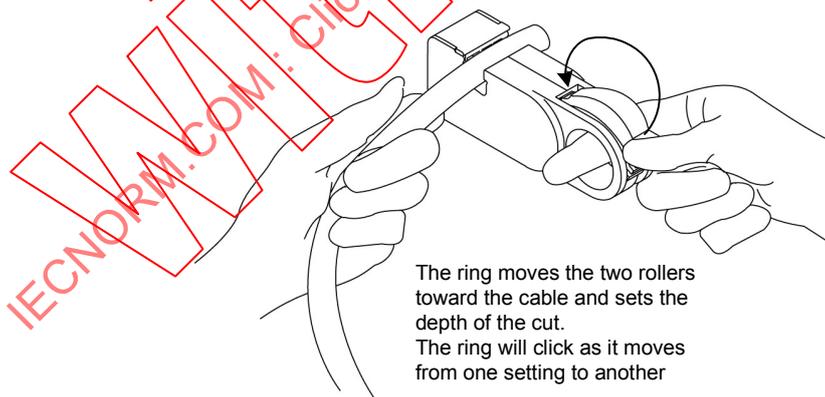
**Figure A.28 – Memory cartridge and blade**

- 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.29.



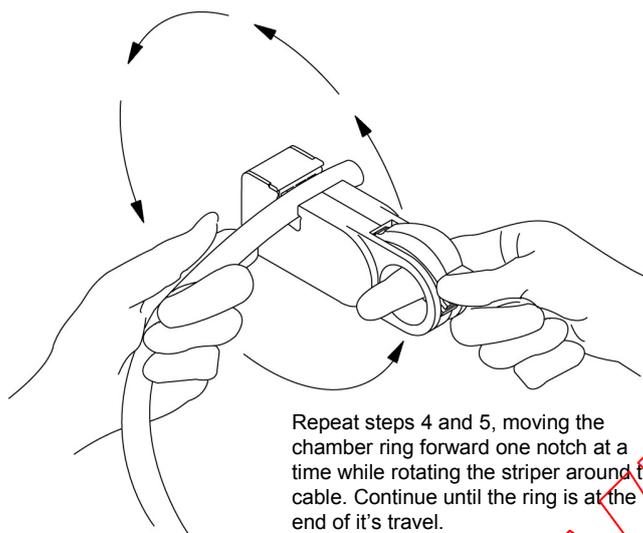
**Figure A.29 – Cable position**

- 4) Lock the cable into place by moving the chamber-gauge ring forward (see Figure A.30) until it meets the cable with slight resistance.



**Figure A.30 – Locking the cable**

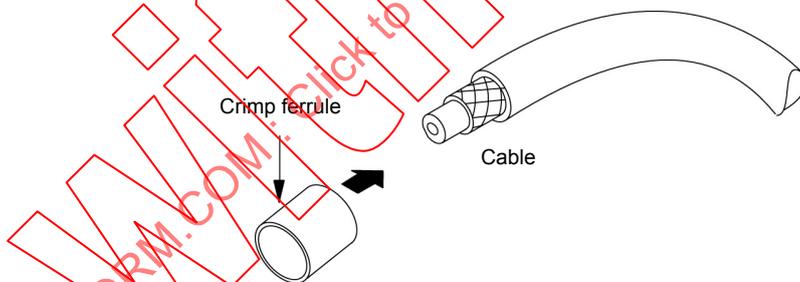
- 5) Holding the cable in one hand, place the index finger of the other hand inside the chamber-gauge ring and turn the strip tool 360° around the cable. Turn four or five full rotations until the strip tool glides easily around the cable as indicated in Figure A.31.



**Figure A.31 – 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.

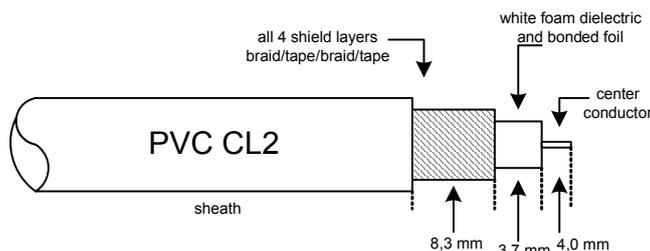
- 6) After the chamber ring has been moved to the last position and turned the strip tool the final time:
  - i) Move the chamber ring backward to release the strip tool and remove it from the cable.
  - ii) If using IP65 and IP67 corrosion-resistant connectors, slide the heat shrink tubing over the cable.
  - iii) Slip the crimp ferrule onto the cable as shown in Figure A.32. Push it back to the sheath area of the cable to keep it out of the way for the moment.



**Figure A.32 – 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.33.

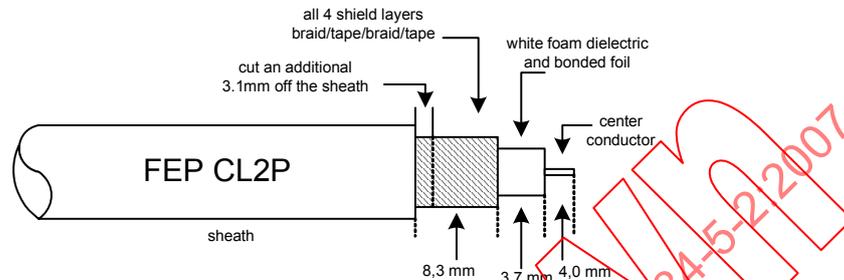


**Figure A.33 – Cable preparation for PVC type cables**

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.

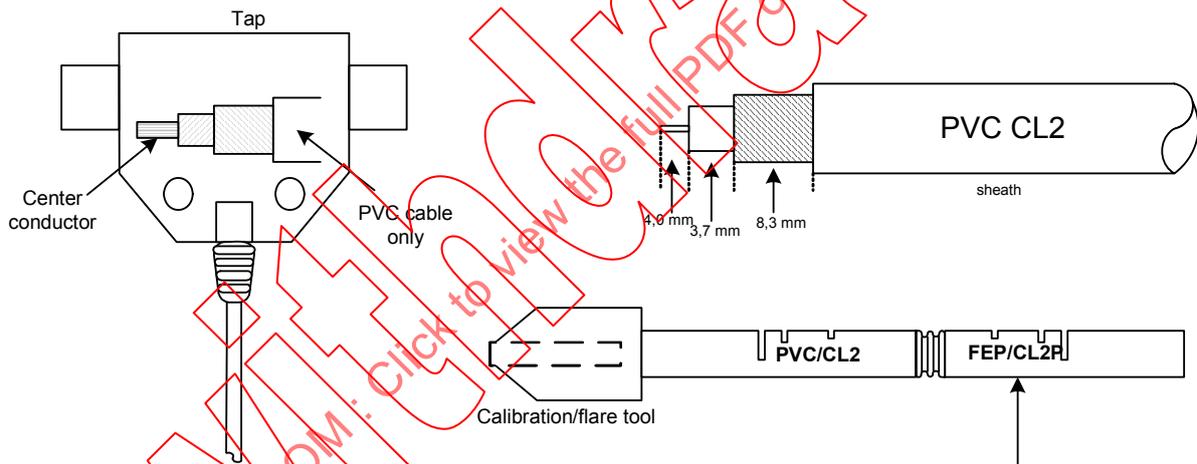
If stripping problems persist, the strip tool may need adjustment. See the calibration section for instructions on calibration.

- 7) For FEP cable cut off an additional 3,1 mm of the outer sheath with a knife as shown in Figure A.34.



**Figure A.34 – Cable preparation for FEP type cables**

- 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.35 provides two examples of guides available.



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

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

**Figure A.35 – Strip guides**

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

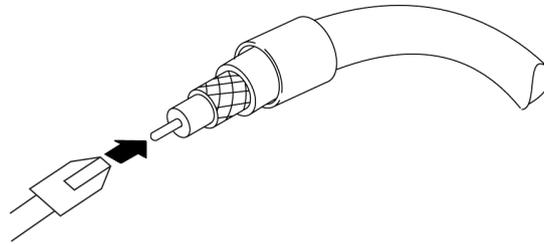
Important: Check the outer braid of cable for cut or scored braid wire after stripping the cable. If the braid is damaged, cut off the end and strip the cable again. Adjustment of the appropriate stripper blade by backing the set screw out 1/8 of a turn may be necessary. Do not crimp the BNC to a damaged 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

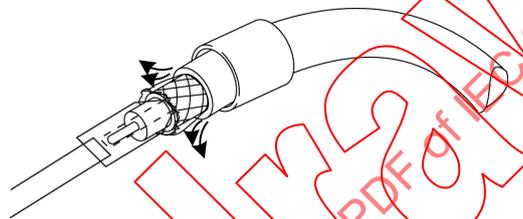
Proceed as follows.

- 1) Place the crimp ring over the cable if not already on the cable.

- 2) If installing a IP67 connector, slip the heat shrink tubing (provided by the connector manufacturer) on to 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.36 and Figure A.37.
- 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.

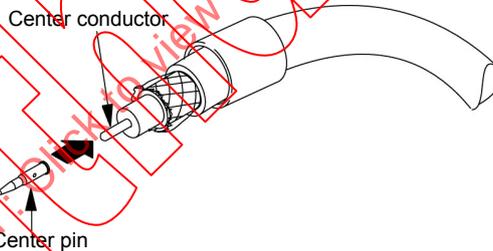


**Figure A.36 – Using the flare tool**



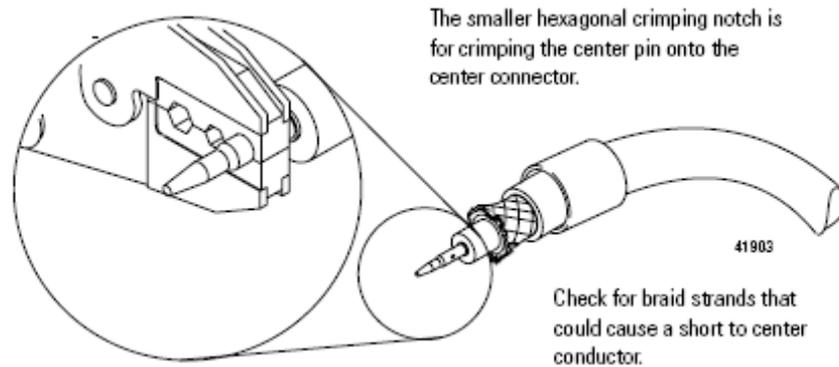
**Figure A.37 – Expanding the shields**

Figure A.38 shows the placement of the centre pin over the centre conductor.



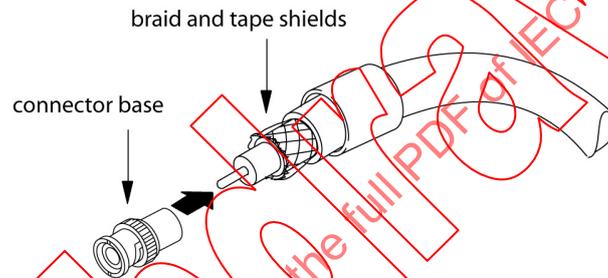
**Figure A.38 – Install the centre pin**

- 5) Check for strands of insulation or braid that are not cut properly. Remove any debris from the center conductor before installing the center 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.39.



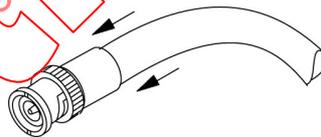
**Figure A.39 – Crimping the centre pin**

- 8) If the inner most 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 inner most 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.40).



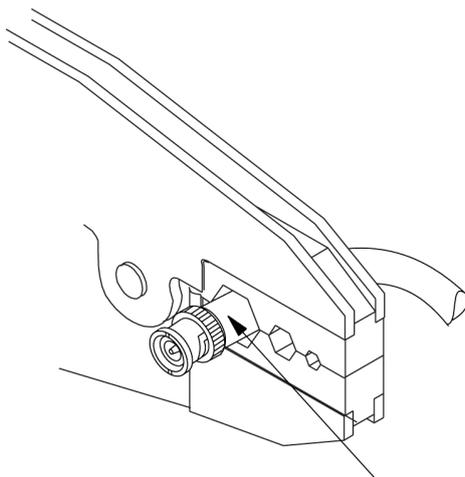
**Figure A.40 – Installing the connector body**

- 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.41.



**Figure A.41 – Installing the ferrule**

- 10) Using the crimp tool in Figure A.42, 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.42 – 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.

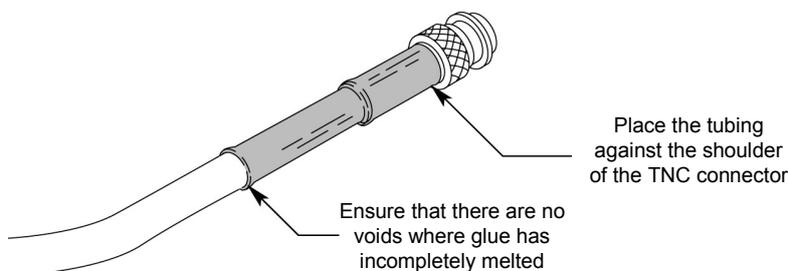
11) If installing IP67-rated connectors:

Use only the ACUM heat-shrink tubing provided in the IP67 Tap and Cable Kit. Do not substitute other types of heat-shrink tubing. Substitutions may cause a loss of the IP67 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.43):

- 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 50,8 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 mn.
- 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 IP67 rating.
- vi) Test the connection.
- vii) Test the final cable.



**Figure A.43 – Sealed IP67 cable**

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

Not applicable.

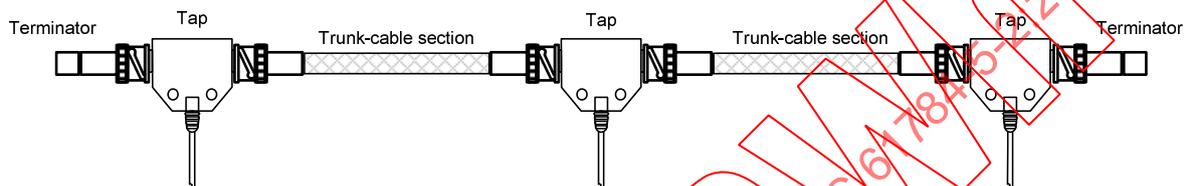
**A.5.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**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 outer most port of the passive tap as shown in Figure A.44. For more details see the planners documentation and Clause 4.



**Figure A.44 – 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 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;
- do not mount the tap in a position that routes the drop cable over any a.c. 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.

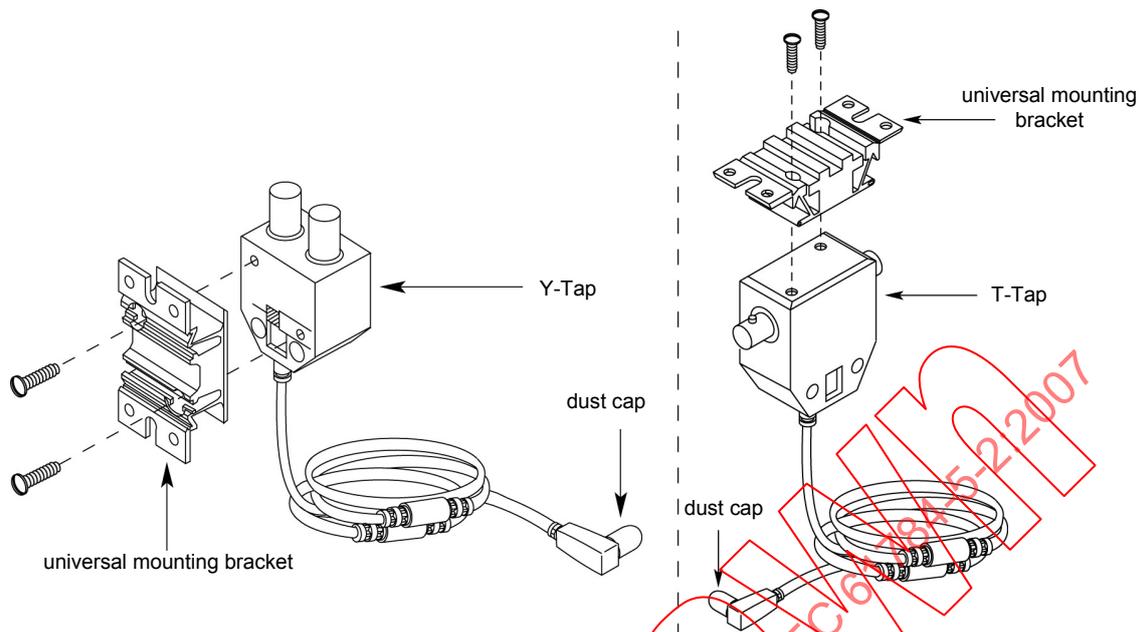
Mount the ControlNet taps (Y-tap and T-tap) options:

- 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.45, follow the steps below:

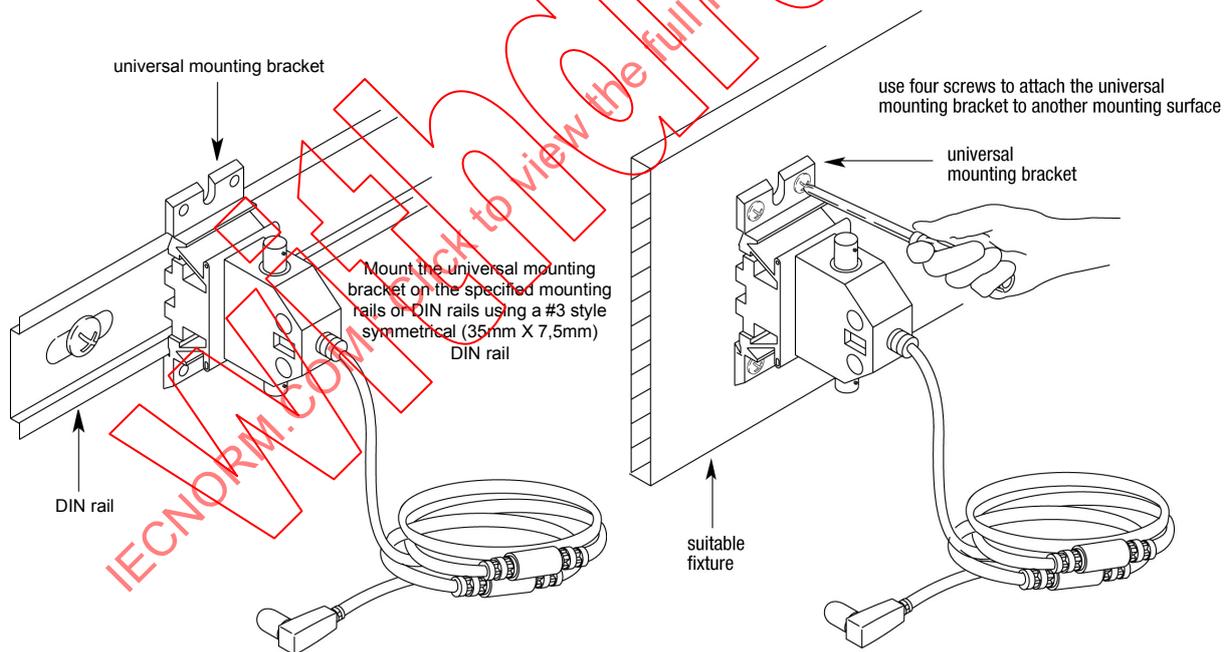
- 1) Align the universal mounting bracket with the mounting holes on the tap.

2) Using the screws provided with the tap, attach the tap to the universal mounting bracket.



**Figure A.45 – Mounting the taps**

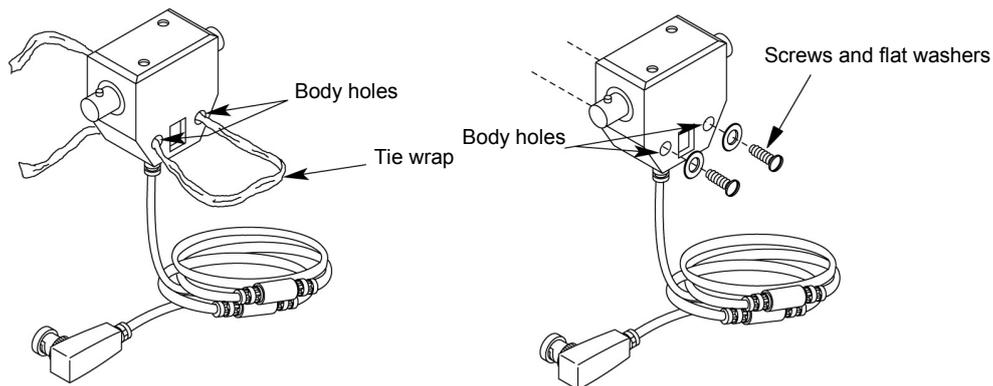
3) Figure A.46 shows how to mount the tap and bracket assembly to a DIN rail or flat surface.



**Figure A.46 – Mounting the tap assembly using the universal mounting bracket**

Figure A.47 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.47.



**Figure A.47 – 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.48 with shaded icon representing redundant media.



**Figure A.48 – 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 mesh**

*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 accordance with IEC 61918:2007, 4.4.7.2.1.

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

*Addition:*

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

Noise currents generated by earth potential offsets can be controlled by the means of a star earthing method and by isolating the signal earth from the equipment earth. This is accomplished by creating two star earthing systems (functional earth and protective earth), functional earth for the communications equipment and protective earth for the equipment. In some extreme cases the bus bars in the equipment enclosures may need to be insulated from the enclosure. This is done by using insulating standoffs between the bus bar and enclosure wall. The cross sectional area of the earthing conductors is dependant on the length (see IEC 61918:2007, 4.4.7.2.1). The cross sectional area shall be selected based on providing a maximum of  $1,0\Omega$  between the enclosure and the common bus. Shields for the communications equipment shall be referenced only to the signal earth (functional earth), and no equipment such as motors or motor controllers shall 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 61918:2007, Figure 16. Earthing connections for the cabinets shall not be daisy chained.

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

*Replacement:*

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

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

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

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

*Addition:*

Shields are terminated to earth via a parallel RC circuit that is integral to the active devices. It is not necessary to provide a parallel RC circuit for the shields as these are an integral part of each active interface. The coaxial cables are not connected directly to earth at any point in the system; doing so may cause ground loops in the network causing communications faults. The installer shall verify that the shield resistance to earth is greater than 2 M $\Omega$  when the active devices are disconnected using a suitable DVM. For each active device connected the shield resistance to earth shall follow the following formula.

$$\text{Shield\_to\_earth} = 1 \text{ M}\Omega / \text{number\_of\_nodes}$$

Since the repeaters are also required to have a 1 M $\Omega$  resistor to earth, they are also included in the number of 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 24702**

Not applicable.

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

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

### **A.6.1 Introduction**

### **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:

$$\text{Shield\_to\_earth} = 1\text{M}\Omega / \text{number\_of\_nodes}$$

Since the repeaters are also required to have a 1 MΩ resistor to earth, they are also included in the number of 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:*

All coaxial cables used in the ControlNet system shall meet the electrical requirements of 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 Clause A.4. If the attenuation is greater than listed in Clause A.4, additional length derating shall be determined by using the equations in Clause A.4. If the segment attenuation is too high the segment shall be divided using repeaters.

##### **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**

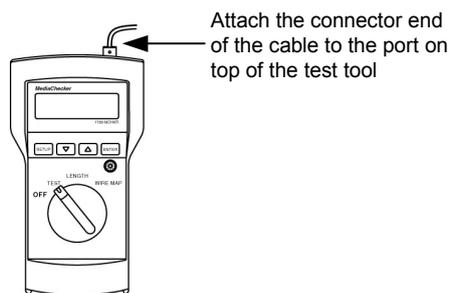
##### **A.6.2.7.2 Specific requirements for CPs**

*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.

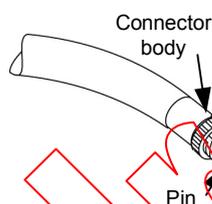
After installing the BNC or TNC connector use a suitable coaxial cable tester or a DVM or suitable network test tool as shown in Figure A.49 to confirm proper continuity.



**Figure A.49 – Network test tool**

An alternate method is to use an ohm-meter or continuity tester to test for a short between the connector body and center pin.

Use a shorting clips as shown Figure A.50 to connect a temporary short between the center pin and connector body at one end of the cable.



**Figure A.50 – Shorting the cable to test for continuity**

At the other end of the cable use a continuity tester or ohm-meter to test for electrical continuity. Use Table A.15 to determine the course of action to be taken depending on test results.

**Table A.15 – 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 problem persist 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 less than 270 N, it is either improperly installed or 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 manufacture’s data sheet;
- check the connector manufacture’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 Terminators verification**

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

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

*Addition:*

With an 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.

##### **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:*

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

- suitable coaxial cable test tool or TDR;
- suitable fibre optic 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.

When verified, 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 loss, then the connector attenuation may be too great and may necessitate re-termination or additional polishing.

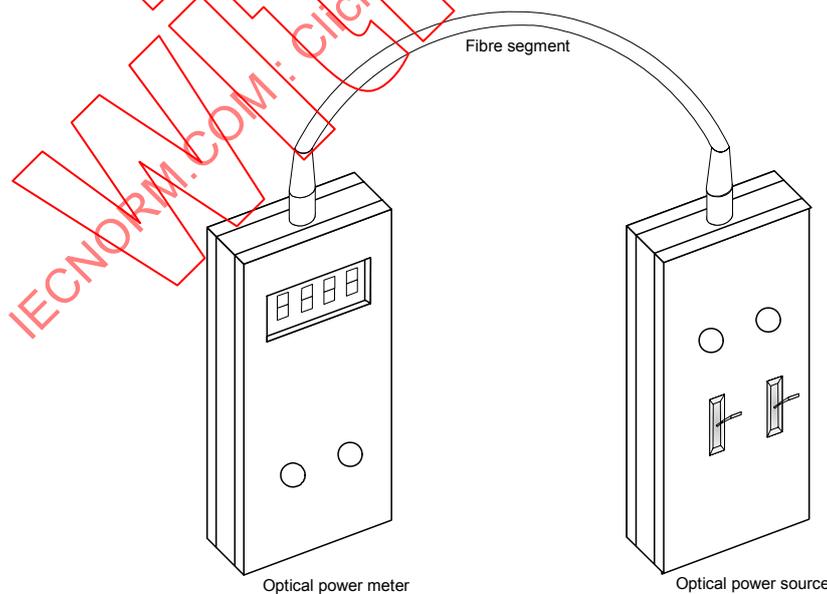
After the initial installation of fibre cable, the sections shall be checked using an optical power meter to verify that the attenuation is less than 13,3 dB (see Table A.3). The power source used to test the fibre shall match the power source rating of the cable being tested.

The power loss measurement shall be within the limits described in Table A.2, Table A.3 and Table A.7 for the types of fibres used as shown in Table A.16. 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.51, the insertion loss of the fibre optic segment can be determined.

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, 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.51 – Testing fibre segments**

**Table A.16 – Wave length and fibre types**

Wave length nm	Fibre type
640	200/230 µm GI MM
1300	62,5/125 µm MM
1300	62,5/125 µm MM
1300	62,5/125 µm and 9/125 µm SM

#### **A.6.3.3.3 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

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

Not applicable.

#### **A.6.3.5 Acceptance test report**

### **A.7 Installation administration**

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

#### **A.8.1 General**

#### **A.8.2 Maintenance**

#### **A.8.3 Troubleshooting**

##### **A.8.3.1 General description**

##### **A.8.3.2 Evaluation of the problem**

*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 module, 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;
- fibre bend radius;
- poorly polished connector.

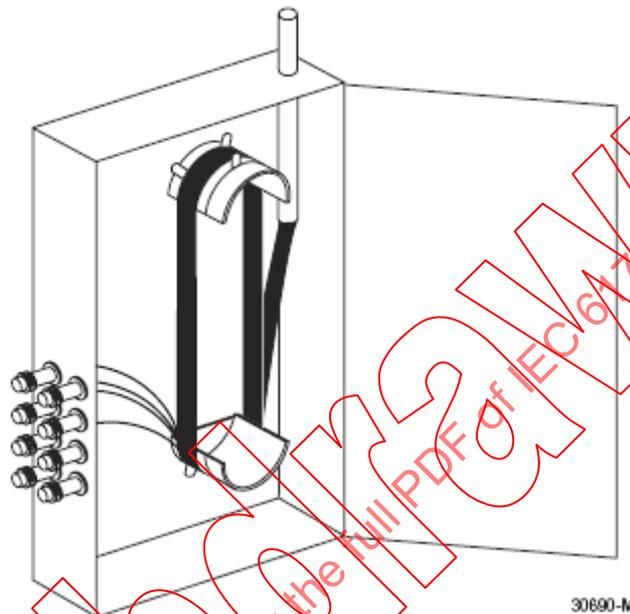
#### **a) OTDR measurement**

In addition to power loss measurement, the total fibre network should be examined using an optical time domain reflectometer (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.52 shows an example of a connector panel with incoming multi-fibre backbone cable and connectors for interconnect cables.

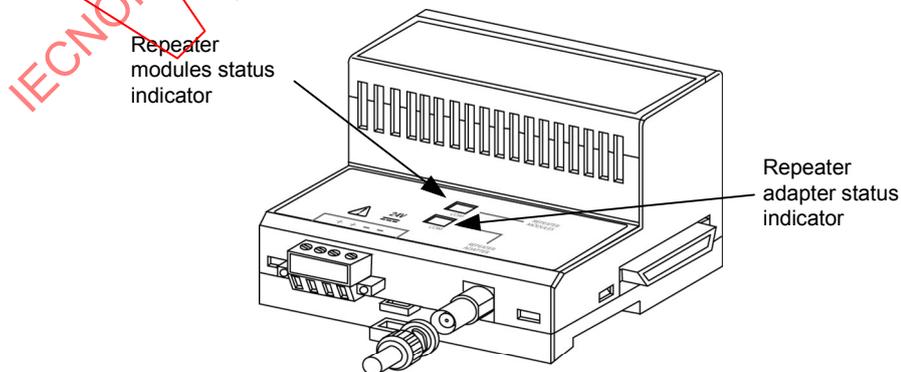


**Figure A.52 – Multi-fibre backbone cable housing**

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.53 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.53 – Repeater adapter module**

The status indicator LEDs in the repeater adapter module can be interpreted singly or together. Table A.17 to Table A.20 list different combinations of LEDs and their interpretations.

**Table A.17 – LED status table**

These status indicator LEDs and their interpretation	Are shown in
Repeater adapter and repeater modules	See Table A.18
Repeater adapter only	See Table A.19
Repeater modules only	See Table A.20

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.18 – 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.19 – Repeater adapter indicator diagnostic**

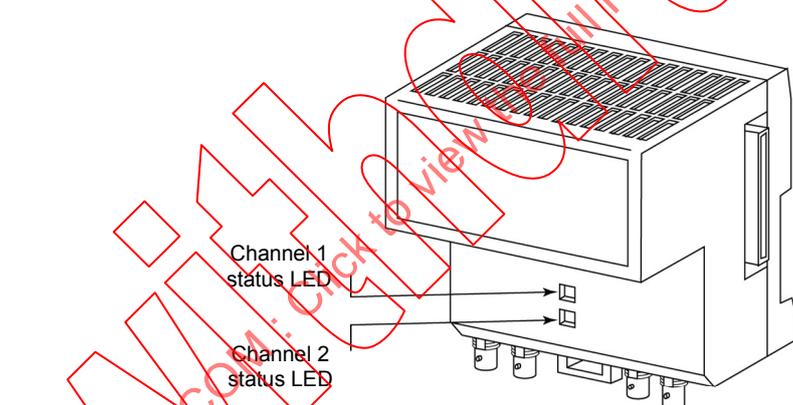
If the repeater adapter indicator is	This means	Resolution
Solid green	Error-free data is being recovered at the coax port of the repeater adapter	Do nothing. This is the normal operating mode
Flashing green/off	Data with errors is occasionally being recovered at the coax port of the repeater adapter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

**Table A.20 – Repeater module indicator**

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

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

See Figure A.54 and Table A.21 for the diagnostic LED description.



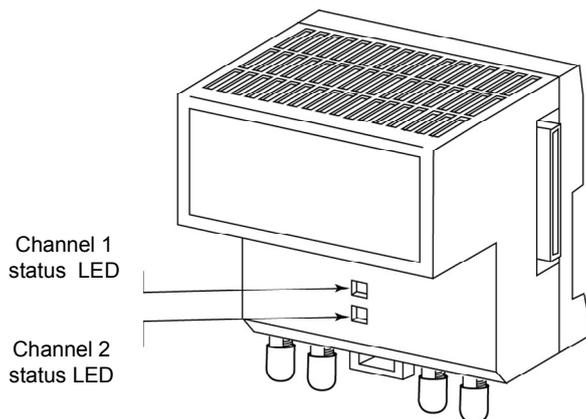
**Figure A.54 – Short and medium distance fibre module LEDs**

**Table A.21 – 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.
Green	Repeater is running without network errors	Do nothing
Flashing green/off	No data activity on network.	If the cable is attached: <ul style="list-style-type: none"> <li>- confirm that the receive channel is connected to the transmit channel on both modules</li> <li>- check for broken fibres</li> </ul>

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

See Figure A.55 and Table A.22 for the diagnostic LED description.



**Figure A.55 – Long and extra long repeater module LEDs**

**Table A.22 – Long and extra long troubleshooting chart**

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

## Annex B (normative)

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

#### B.1 Installation profile scope

*Addition:*

This standard 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 IEEE 802.3 TP-PMDs and FO-PMD such as 100BASE-FX.

#### 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/PAS 60603-7-3, *Connectors for electronic equipment – Part 7-3. Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 100 MHz*

IEC 61156-5, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 600 MHz – Horizontal floor wiring – Sectional specification*

ANSI/TIA/EIA 568-B.1: *Commercial building telecommunications cabling standards – Part 1: General requirements*

IEEE 802.3, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*

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

##### B.3.1 Terms and definitions

##### B.3.2 Abbreviated terms

*Addition:*

BN	Brown (colour code in accordance with IEC 61918:2007, Annex D)
BU	Blue (colour code in accordance with IEC 61918:2007, Annex D)
FO-PMD	Fibre optic – Physical layer medium dependent
GN	Green (colour code in accordance with IEC 61918:2007, Annex D)
LLCR	Low level contact resistance
n/a	Not applicable
OG	Orange (colour code in accordance with IEC 61918:2007, Annex D)
POF	Plastic optical fibre
RF	Radio frequency
ST	Optical fiber connector in accordance with IEC 61754-2
T568A / T568B	Wiring conventions (see ANSI/TIA/EIA 568-B.1)
TN-S	Terminal node – Separate earth
TP-PMD	Twisted pair – Physical layer medium dependent
WH	White (colour code in accordance with IEC 61918:2007, Annex D)

**B.3.3 Conventions for installation profiles**

Not applicable.

**B.4 Installation planning**

**B.4.1 Introduction**

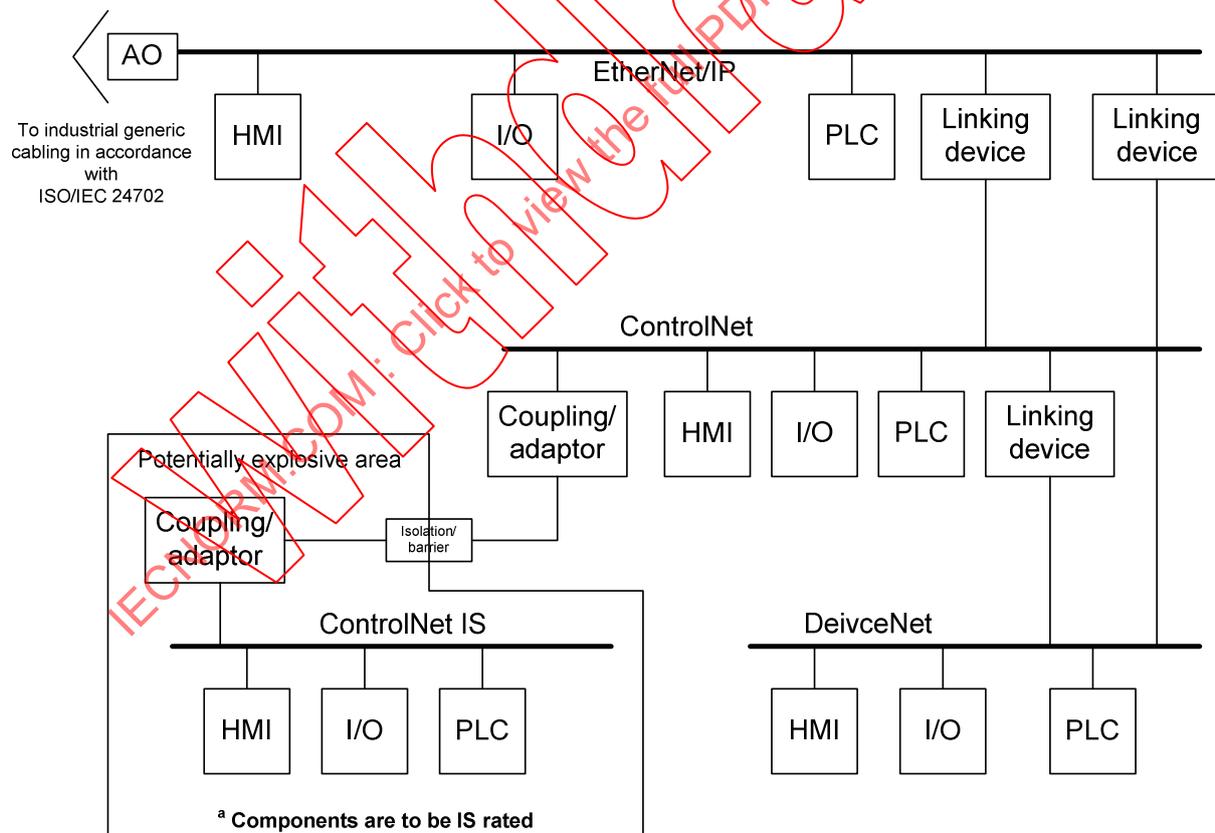
**B.4.1.1 Objective**

**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 61918:2007, 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 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.



**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**

*Modification:*

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 61918:2007, 4.4.7 and B.4.4.7.3 of this standard.

This network supports both star and equipotential earthing systems. When shielded media is used, the communications cable shields are isolated from functional earth at the device end of the cable. The parallel RC is integral to the active interfaces, therefore do not require external components. The TN-S power distribution system as described in IEC 61918:2007, Annex E is recommended but not required. Local regulations shall be observed for power distribution, earthing and bonding.

#### **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 (OFCS)**

### **B.4.2.2 Security**

*Addition:*

The control network shall be isolated from the office environment and the Internet. The designer shall provide appropriate security through the use of gateways, firewalls, routers and/or appropriate security software.

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 24702**

Not applicable.

## **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**

#### **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.2 through a crossover cable. The crossover cable shall meet the wiring scheme detailed in IEC 61918, Annex H.



**Figure B.2 – 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 61918:2007, 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**

<b>Characteristic</b>	<b>CP 2/2</b>
Supported data rates (Mbit/s)	10/100 Mbit/s and 1/10 Gbit/s
Supported channel length (m)	100 m maximum (see channel and link length and limits below)
Number of connections in the channel (max.)	6 <sup>a</sup>
Patch cord length (m)	See IEC 61918:2007, Clause 4 and ISO/IEC 24702
Channel class per ISO/IEC 11801:2002 and ISO/IEC 24702 (min.)	Class D
Cable category ISO/IEC 11801:2002 and ISO/IEC 24702 (min.)	5
Connecting HW category per IEC 11801:2002 and ISO/IEC 24702 (min.)	5
Cable types	As needed for application
<sup>a</sup> Category 5E channel requires Category 6A connectors with Category 5E cabling when there are more than 4 connections in a channel.	

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

*Replacement:*

Table B.2 provides values based on the template given in IEC 61918:2007, Table 3.

The fibre cables supported by EtherNet/IP are specified in Table B.2.

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

Characteristic	CP 2/2		
	Optical fibre type Min. modal bandwidth	Minimum length m	Maximum length km
9 $\mu\text{m}/125 \mu\text{m}$	0	10 minimum	1310 1550
50 $\mu\text{m}/125 \mu\text{m}$	0	2 minimum	850 1300
62,5 $\mu\text{m}/125 \mu\text{m}$	0	2 minimum	850 1300
0,980/1 mm POF step index 10 MHz x 100 m	For further study	For further study	650
200 $\mu\text{m}/230 \mu\text{m}$ step index hard cladded silica 17 MHz x km	For further study	For further study	650

**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 24702**

Not applicable.

**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:*

Table B.3 to Table B.8 provides values based on the template given in IEC 61918:2007, Table 4 and Table 5.

**Table B.3 – Information relevant to balanced cable: fixed cables**

Characteristic	CP 2/2
Nominal impedance of cable (tolerance)	95 $\Omega$ to 110 $\Omega$ from 1 MHz to 4 MHz 95 $\Omega$ to 107 $\Omega$ from 4 MHz to 100 MHz
Return loss (dB)	1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \log_{10}(f/20)$
NEXT	$\text{NEXT}(f) \geq 64 - 15 \times \log_{10}(f)$
Balanced or unbalanced	Balanced
DCR of conductors	Compliant to ISO/IEC 11801
DCR of shield	Compliant to ISO/IEC 11801
Number of conductors	4 <sup>a</sup> and 8 <sup>a</sup>
Shielding	User defined
Colour code for conductor	Compliant to Table B.8 and Table B.9
Jacket colour requirements	User defined
Jacket material	User and application defined

Characteristic	CP 2/2
Resistance to harsh environment (e.g.: UV, oil resist, LS0H)	User and application defined
Agency ratings	According to local regulations
<sup>a</sup> In pairs, star quad cable designs are not allowed.	

**Table B.4 – Information relevant to balanced cable: cords**

Characteristic	CP 2/2
Nominal impedance of cable (tolerance)	95 Ω to 110 Ω from 1 MHz to 4 MHz 95 Ω to 107 Ω from 4 MHz to 100 MHz
Return loss (dB)	1 MHz to 10 MHz: $20 + 6 \times \log_{10}(f)$ 10 MHz to 20 MHz: 26 20 MHz to 100 MHz: $26 - 5 \times \log_{10}(f/20)$
NEXT	$NEXT(f) \geq 64 - 15 \times \log_{10}(f)$
Balanced or unbalanced	Balanced
DCR of conductors	Compliant to ISO/IEC 11801
DCR of shield	Compliant to ISO/IEC 11801
Number of conductors	4 <sup>a</sup> and 8 <sup>a</sup>
Length	82 m maximum (see IEC 61918:2007, Clause 4)
Shielding	User defined
Colour code for conductor	Compliant to Table B.8 and Table B.9
Jacket colour requirements	User defined
Jacket material	User and application defined
Resistance to harsh environment (e.g.: UV, oil resist, LS0H)	User and application defined
Agency ratings	According to local regulations
<sup>a</sup> In pairs, star quad cable designs are not allowed.	

**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 TCL and ELTCTL requirements at both ends of the cabling in accordance with Table B.5 and Table B.6 and the environment local to the cabling.

**Table B.5 – TCL limits for unshielded twisted-pair cabling**

Category	Frequency MHz	Minimum TCL dB		
		E1	E2	E3
5e	$1 \leq f \leq 100$	$60 - 20 \times \log_{10}(f)$ (max. 45 dB)	$70 - 20 \times \log_{10}(f)$ (max. 45 dB)	$80 - 20 \times \log_{10}(f)$ (max. 45 dB)
6	$1 \leq f \leq 250$	$60 - 20 \times \log_{10}(f)$ (max. 45 dB)	$70 - 20 \times \log_{10}(f)$ (max. 45 dB)	$80 - 20 \times \log_{10}(f)$ (max. 45 dB)

**Table B.6 – ELTCTL limits for unshielded twisted-pair cabling**

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

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.7 and the environment local to the cabling. Coupling attenuation shall be measured in accordance with IEC 61156-5.

**Table B.7 – Coupling attenuation limits for screened twisted-pair cabling**

Frequency MHz	Minimum dB		
	E1	E2	E3
$30 \leq f \leq 100$	$30 - 20 \times \log_{10}(f/100)$ (max. 45 dB)	$40 - 20 \times \log_{10}(f/100)$ (max. 45 dB)	$50 - 20 \times \log_{10}(f/100)$ (max. 45 dB)

Colour codes for 4 pair cabling shall conform to the colour code in Table B.8 and for 2 pair cabling shall conform to Table B.9.

**Table B.8 – 4 pair colour codes and pair assignment**

Signal name	Pin T568A	Pair assignment	Pin T568B	Pair assignment
TXD+	WH/GN	Pair 2	WH/OG	Pair 1
TXD-	GN		OG	
RXD+	WH/OG	Pair 2	WH/GN	Pair 2
n/a	BU	Pair 1	BU	Pair 1
n/a	WH/BU		WH/BU	
RXD-	OG	Pair 2	GN	Pair 3
n/a	WH/BN	Pair 4	WH/BN	Pair 4
n/a	BN		BN	

NOTE Pairs 1 and 4 are not used for 10 Mbit/s and 100 Mbit/s networks.

**Table B.9 – 2 pair colour codes and pair assignment**

Signal name	Colour code	Pair assignment
TXD +	WH/OG	Pair 1
RXD +	OG	
TXD -	WH/GN	Pair 2
RXD -	GN	

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

Not applicable.

**B.4.4.1.3 Cables for wireless installation**

Not applicable.

**B.4.4.1.4 Optical fibre cables**

*Replacement:*

Table B.10 provides values based on the template given in IEC 61918:2007, Table 6.

**Table B.10 – Fibre type and bandwidth**

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 cladde silica
Attenuation per km (650 nm)	n/a	n/a	n/a	For further study	For further study
Attenuation per km (820 nm)	n/a	n/a	n/a	n/a	n/a
Attenuation per km (1 310 nm)	1,0 dB	2,0 dB	3,0 dB	n/a	n/a
Number of optical fibres	2 minimum	2 minimum	2 minimum	n/a	n/a
Connector type (e.g. duplex or simplex)	Duplex, duplex-able, simplex	Duplex, duplex-able, simplex	Duplex, duplex-able, simplex	n/a	n/a
Jacket colour requirements	User defined	User defined	User defined	n/a	n/a
Jacket material	User defined	User defined	User defined	n/a	n/a
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	n/a	n/a
Breakout (Y/N)	Yes	Yes	Yes	n/a	n/a

**B.4.4.1.5 Special purpose 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 24702**

Not applicable.

**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.11 provides values based on the template given in IEC 61918:2007, Table 7.

**Table B.11 –Connectors for balanced cabling CPs based on Ethernet**

	IEC 60603-7-x		IEC 61076-3-106		IEC PAS 61076-3-117	IEC 61076-2-101
	(shielded)	(unshielded)	Variant 1	Variant 6	Variant 14	(M12-4 with D-coding)
<b>CP 2/2</b>	IEC 60603-7-3 or IEC 60603-7-5	IEC 60603-7-2 or IEC 60603-7-4	Yes	No	No	Yes

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 international standard. 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.12 contains the connector parameters for the 8-way modular connectors for use in sealed and unsealed industrial EtherNet/IP systems.

**Table B.12 – Industrial EtherNet/IP 8-way modular connector parameters**

Parameter	Type	
	Shielded 8-way modular connector	8-way modular connector
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.

**b) EtherNet/IP sealed 8-way modular connector housing**

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.3 and Figure B.4 provide examples of the Variant 1 connector housing.



**Figure B.3 – The 8-way modular sealed jack & plug (plastic housing)**



**Figure B.4 – The 8-way modular sealed jack & plug (metal housing)**

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

4-Pole M12 D-coding connectors are sealed to meet the IP65/IP67 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 Gb/s and 10 Gb/s Ethernet) is required, 4-pair cables and 8-Way Modular connector and compatible components shall be used.

See IEC 61918:2007, 4.4.3 for rules on 2 and 4-pair cabling within a channel.

Table B.13 provides the contact requirements for the M12-4 D-coding connector to ensure network reliability and connector compatibility.

**Table B.13 – Industrial EtherNet/IP M12-4 D-coding connector parameters**

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

Figure B.5 is an example of a metallic shell M12-4 D-coding connector.

**Figure B.5 – M12-4 connectors**

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

#### **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**

Not applicable.

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

*Replacement:*

Table B.14 provides values based on the template given in IEC 61918:2007, Table 9.

**Table B.14 – Optical fibre connectors for fieldbus systems**

	IEC 61754-2	IEC 61754-4	EN 50377-6-1	IEC 61754-20	IEC 61754-22	Others
	BFOC/2,5	SC	SC-RJ	LC	F-SMA	
<b>CP 2/2 (example)</b>	Yes	Yes	No	Yes	No	No

*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.6 and Figure B.7). 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.8. The LC shall meet the requirements of IEC 61754-20.



**Figure B.6 – Simplex LC connector**



**Figure B.7 – Duplex LC connector**



**Figure B.8 – IP65/IP67 sealed duplex LC connector**

Table B.15 provides a cross reference for connectors and fibre types supported by EtherNet/IP.

**Table B.15 – Supported fibre types**

Connector type	Fibre type				
	POF 1 mm	Hard clad silica 200/230	50/125 µm	62,5/125 µm	9/125 µm
SC	Yes	Yes	Yes	Yes	Yes
ST	Yes	Yes	Yes	Yes	Yes
LC	No	No	Yes	Yes	Yes

The connector insertion loss shall be met by the connectors as shown in Table B.16.

**Table B.16 – Connector insertion loss**

Connector type	Insertion loss	Return loss
SC, ST and LC	0,75 dB maximum	Single-mode: 26 dB minimum Multimode 20 dB minimum

The installation of fibre connectors is manufacturer specific and require 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 24702**

Not applicable.

#### **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 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 61918:2007, 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 61918:2007, Annex J for the performance requirements of the bulkhead connector.

The designer shall be aware of metallic bulkhead feedthroughs that connect the cabling at the enclosure wall. This may form a ground loop that could disrupt communications. Where a ground loop is formed, a separate 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 cable glands provide entry/exit passages for permanently installed cables.

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 are used they need to be counted in the number of connections within a channel. See IEC 61918:2007, Annex J to determine how many connections are allowed in a channel.

Figure B.9 is an example of M12-4 D-coding EtherNet/IP bulkhead feedthrough connectors.



**Figure B.9 – 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. Ground 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 adaptors**

*Replacement for first paragraph:*

See IEC 61918:2007, Annex J for the performance requirements of the J-J adaptors.

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

Not applicable.

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

**B.4.4.3.4.1 Common description**

**B.4.4.3.4.2 Optical fibre-bulkhead connections**

**B.4.4.3.4.3 Optical fibre J-J adaptors (optical fibre couplers)**

*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 for CPs not based on Ethernet**

Not applicable.

**B.4.4.3.6 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**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 24702**

Not applicable.

**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 Equalization 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 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 61918:2007, Table 15.

**B.4.4.7.3 Earthing methods****B.4.4.7.3.1 Mesh, equipotential**

*Addition:*

If the building does not have an adequate or has an unknown equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets in the communications coverage area. There shall be no noise currents in the communications shields as a result of earth potential offsets in the communications coverage area. An alternate media such as fibre may be considered as part of a mitigation technique.

**B.4.4.7.3.2 Star**

*Addition:*

If the building does not have an adequate or has an unknown equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets in the communications coverage area. There shall be no noise currents in the communications shields as a result of earth potential offsets in the communications coverage area. An alternate media such as fibre may be considered as part of a mitigation technique.

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

*Replacement:*

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

**B.4.4.7.3.4 Installing copper bus bars**

*Addition:*

In some cases it may be necessary to install copper bus bars in accordance with the star earthing system. When doing so insulators may be required to isolate the bus bar from the enclosure or building earth. When it is necessary to isolate the copper bus bar, the d.c. resistance to the local earth shall be 2 MΩ minimum. If the bus bar is plated, it shall be in accordance with IEC 61918:2007, Table 15.

The bus bar surface shall be prepared in accordance with IEC 61918:2007, 5.7.2.3. The conductor sizing shall be in accordance with IEC 61918:2007, 4.4.7.2.

#### **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 earthed at the other end (see IEC 61918:2007, Figure 36). 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 24702**

Not applicable.

#### **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**

*Modification:*

The distances from other circuits specified in IEC 61918:2007, Table 16 apply.

The cable routing shall be planned very carefully and routing of cables near equipment that generates electromagnetic interference shall be avoided. The cables shall be grouped into similar circuits as shown in IEC 61918:2007, Table 16.

The designer shall avoid defining cable routes that require installing cables near and around:

- lights;
- motors;
- drive controllers;
- arc welders;
- induction heaters;
- RF fields (transmitters);
- conductors providing power to any of the above.

###### **B.4.4.9.3 Detailed requirements for cable routing inside enclosures**

*Addition:*

To guard against coupling noise from one conductor to another, the general guidelines in IEC 61918:2007, Table 16 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.

Cable sections that run inside protective equipment enclosures are relatively short. As with wiring external to enclosures, maximum separation between the EtherNet/IP cables and Category-1 conductors shall be maintained. IEC 61918:2007, Table 16 provides guidance for spacing of communications cables from power cables.

When running cable inside an enclosure:

- in a raceway, separate from Category-1 conductors;
- in a raceway, group with similar cables (i.e.; communications, power and I/O).

#### **B.4.4.9.4 Cable routing inside buildings**

*Replacement:*

##### **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 high voltages, the EtherNet/IP cables shall be routed following the guidelines in IEC 61918:2007, Table 16.

##### **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 in Table B.17.

**Table B.17 – Routing communications cabling in contiguous metallic pathways**

Route the cable at least this distance	From noise sources of this strength	From cables containing voltages
8,3 cm (3,25 in.)	EMC 1 conductors of less than 20 A	24 V – 100 V
15 cm (6 in.)	A.C. power lines of 20 A or more, up to 100 kVA	101 V – 200 V
30 cm (12 in.)	A.C. power lines greater than 100 kVA	201 V – 400 V

##### **B.4.4.9.5 Cable routing outside 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/IP67 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 24702**

Not applicable.

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

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

*Addition:*

When installing cables in the vicinity of welding equipment, cables that have weld splatter proof jackets or provide protective covering for the cable shall be used. Cables installed on moving machinery shall use flexible cable designs consistent with the flexing requirements of the application.

Cables installed in areas where liquids and chemicals are present shall have the appropriate jacket constructions to protect the cabling components.

Cables installed in environments where high UV shall have material constructions that provide the appropriate protection.

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

Not applicable.

##### **B.4.4.12.3 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

#### **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

*Modification:*

Table B.18 and Table B.19 provide values based on the template given in IEC 61918:2007, Table 17 and Table 18.

**Table B.18 – Parameters for balanced cables**

Characteristic		Value
Mechanical force	Minimum bending radius, single bending (mm)	25,4 mm at -20 °C
	Bending radius, multiple bending (mm)	User specified
	Pull forces (N)	110
	Permanent tensile forces (N)	n/a
	Maximum lateral forces (N)	400
	Temperature range during installation (°C)	Vendor specified

**Table B.19 – 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

#### 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 24702

Not applicable.

### 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 0 and IEC 61918:2007, Clause 4 and the environment as classified by MICE.

The connector housings in Figure B.10 and Figure B.11 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.10 – The 8-way modular sealed jack & plug (plastic housing)**



**Figure B.11 – The 8-way modular sealed jack & plug (metal housing)**

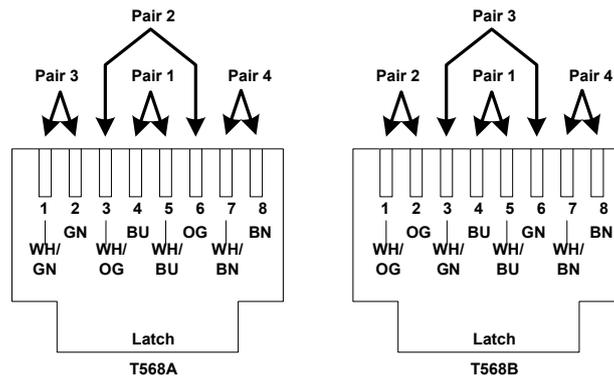
The EtherNet/IP specification provides for the use of small sealed connectors such as the M12-4 D-coding connector found in Figure B.12.



**Figure B.12 – 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 B.13).



**Figure B.13 – Wiring standard (connector back end)**

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 B.13 for wiring. The wiring scheme selected shall be used throughout the entire link and/or channel.

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

*Addition:*

Shielded connectors shall be installed in accordance with IEC 61918:2007, Annex I and Annex H for the connector and cordset termination procedures.

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

Unshielded connectors shall be installed in accordance with IEC 61918:2007, Annex I and Annex H for the connector and cordset termination procedures.

### **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 24702**

Not applicable.

### **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 mesh**

*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 accordance with IEC 61918:2007, 4.4.7.2.1, Table 13.

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

*Addition:*

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

Noise currents in earthing paths generated by earth potential offsets can be controlled by the means of a star earthing method and by isolating the signal earth from the equipment earth. This is accomplished by creating two star earthing systems (functional and protective earth), functional earth for the communications equipment and protective earth for the equipment. In some extreme cases the bus bars in the equipment enclosures may need to be insulated from the enclosure. This is done by using insulating standoffs between the bus bar and enclosure wall. The cross sectional area of the earthing conductors is dependant on the length (see IEC 61918:2007, 4.4.7.2.1, Table 13). The cross sectional area shall be selected based on providing a maximum of 1,0  $\Omega$  between the enclosure and the common bus. Shields for the communications equipment shall be referenced only to the signal earth (functional earth), and no equipment such as motors or motor controllers shall 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 61918:2007, Figure 16. Earthing connections for the cabinets shall not be daisy chained.

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

*Replacement:*

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**

Not applicable.

##### **B.5.7.4.3 Direct**

Not applicable.

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

*Modification:*

Figure B.15 only applies if both the switch and the device are directly earthed. In this case, see Figure B.15 for instructions on cable construction. EtherNet/IP requires that the active devices provide a parallel RC termination for the communications shield integral to the device. Therefore IEC 61918:2007, Figure 36 applies.

The switch provides direct connection to functional or protective earth as shown in Figure B.14.

*Addition:*

If the active device is other than a switch (or hub) and provides a low d.c. resistance (less than 500 k $\Omega$ ) earth at the jack, the communications shield shall not be connected at the device end of the cable. To break the shield, trim back the shield and insulate it from the connector's shell (see Figure B.14 and Figure B.15).

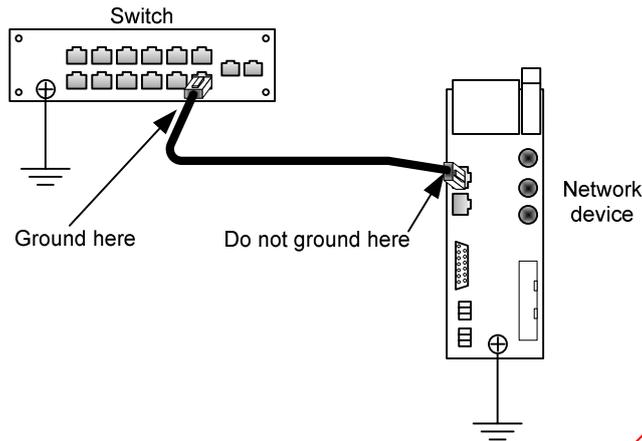


Figure B.14 – Earthing of cable shield

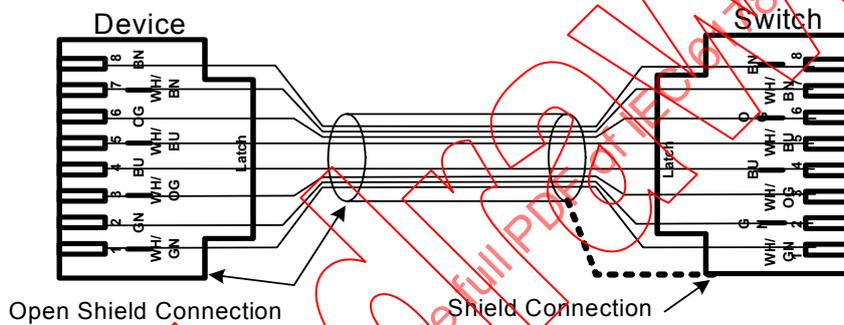


Figure B.15 – Open shield example

**B.5.7.5 Specific requirements for CPs**

Not applicable.

**B.5.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**B.5.8 As-implemented cabling documentation**

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

### **B.6.1 Introduction**

### **B.6.2 Installation verification**

#### **B.6.2.1 General**

*Addition:*

The following additional parameters shall be verified:

- jacketed length;
- shields floating or not floating (the shield may intentionally be open at one end (see Figure B.15.);
- 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 physical length of the permanent link/channel is the sum of the physical lengths of the fixed horizontal cables and cords between the two end points. Physical 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 physical 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 physical 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, 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 61918:2007, 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 Terminators 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 life of 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,
  - terminations,
  - 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.

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 d.c. 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 recommend in using either a Level III or IV tester for network certification. Additionally the test time and frequency range is 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 patch cords. It is important to have a tester that is capable of testing all components and parts of a channel, including patch 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 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 24702**

Not applicable.

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

## Annex C (normative)

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

#### C.1 Installation profile scope

*Addition:*

This standard 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, *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*

ANSI B93.55M-1981, *Hydraulic fluid power solenoid-piloted industrial valves – Interface dimensions for electrical connectors*

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

##### C.3.1 Terms and definitions

##### C.3.2 Abbreviated terms

*Addition:*

BK	Black (colour code in accordance with IEC 61918:2007, Annex D)
BU	Blue (colour code in accordance with IEC 61918:2007, Annex D)
CAN	Controller Area Network (ISO 11898)
CL2/CL3	Class 2/3 power limited circuits
DVM	Digital voltmeter
n/a	Not applicable
PELV	Protective extra low voltage
RD	Red (colour code in accordance with IEC 61918:2007, Annex D)
RF	Radio frequency
SELV	Safety extra low voltage
UL	Underwriters Laboratories
WH	White (colour code in accordance with IEC 61918:2007, Annex D)

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

Not applicable.

## C.4 Installation planning

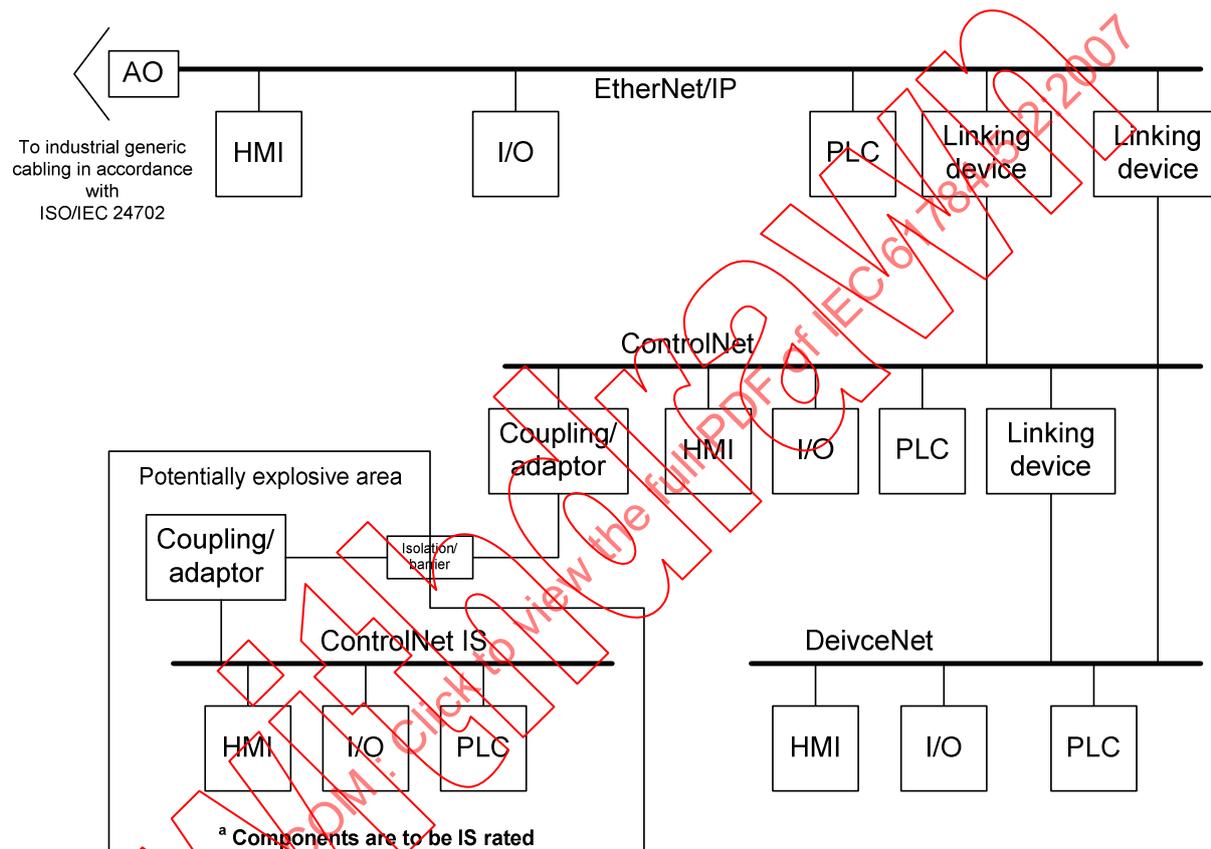
### C.4.1 Introduction

#### C.4.1.1 Objective

#### C.4.1.2 Cabling in industrial premises

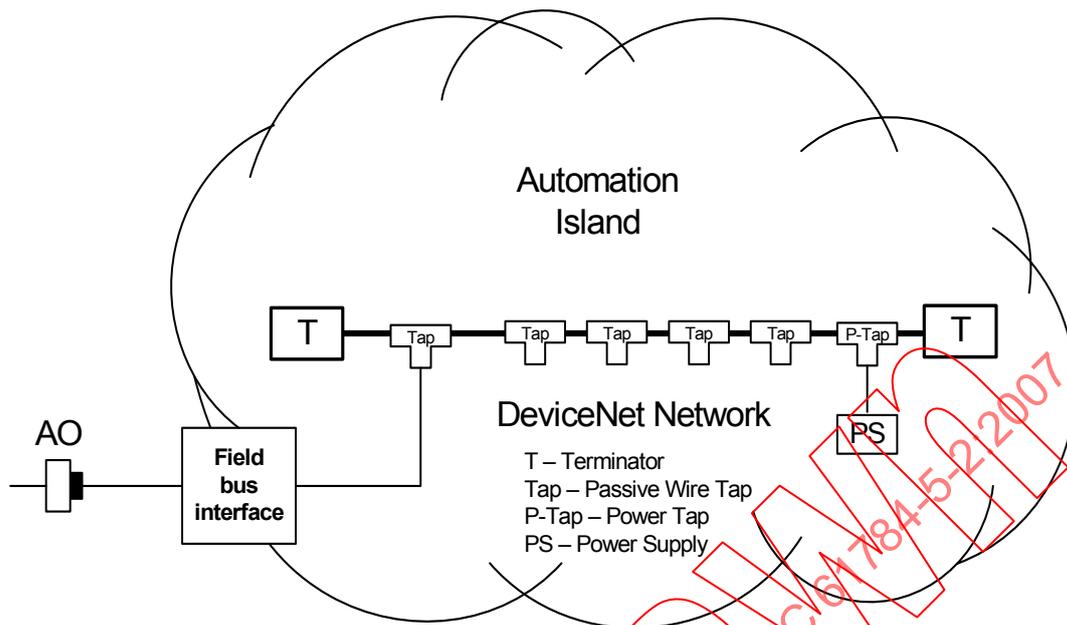
*Addition:*

DeviceNet is a fieldbus network, 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:*

##### **C.4.2.1.2.1 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 61918:2007, 4.4.7 and C.4.4.7.3 of this standard.

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 ground 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.

##### **C.4.2.1.2.2 Requirement 2 (Protection by extra-low-voltage: SELV and PELV)**

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

#### **C.4.2.1.3 Functional safety**

#### **C.4.2.1.4 Intrinsic safety**

Not applicable.

#### **C.4.2.1.5 Safety of optical fibre communication systems (OFCS)**

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 24702**

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.

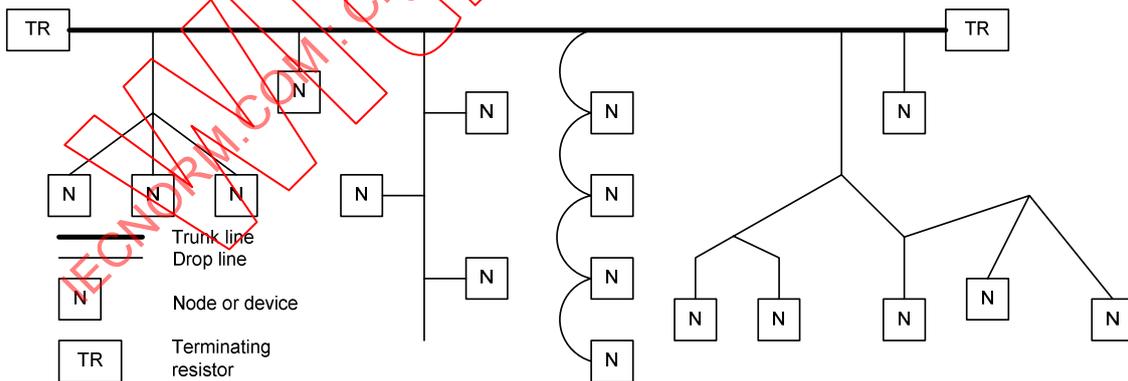
When repeaters are added to the network, the planner shall reduce the trunk length according to the delay of the repeater. Networks may be connected together through bridges. Each network will have its own independent addressing and timing constraints.

**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 addressing can 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 24702**

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 61918:2007, Table 1.

**Table C.1 – Basic network characteristics for copper cabling not based on Ethernet (ISO/IEC-8802-3)**

Characteristic	CP 2/3
<b>Basic transmission technology</b>	ISO 11898-1 and ISO 11898-2 (CAN)
<b>Length / transmission speed</b>	<b>Segment length</b> m
125 kbit/s	500 m maximum (see Table C.2)
250 kbit/s	250 m maximum (see Table C.2)
500 kbit/s	100 m maximum (see Table C.2)
<b>Maximum capacity</b>	<b>Max. No.</b>
Devices / segment	64
Devices / network	64 <sup>a</sup>
<sup>a</sup> Unlimited address and nodes with bridging.	

*Addition:*

Table C.2 provides guidance on selecting cables to support segment length and the required data rate.

**Table C.2 – Cable trunk and drop lengths for CP 2/3**

Cable profile	Trunk length			Cumulative drop length <sup>a</sup>		
	Data rate			Data rate		
	125 kbit/s	250 kbit/s	500 kbit/s	125 kbit/s	250 kbit/s	500 kbit/s
	Trunk length at data rate m			Cumulative drop length at data rate <sup>a</sup> m		
Thick	500	250	100	156	78	39
Thin	100	100	100	156	78	39
Flat	420	200	75	156	78	39
Flat II	265	150	75	135	48	35
Cable I	100	100	100	156	78	39
Cable II	500	250	100	156	78	39
Cable III	300	250	100	156	78	39
Cable IV	n/a	n/a	n/a	156	78	39
Cable V	420	200	75	156	78	39

<sup>a</sup> Maximum length of any individual drop cable is limited to 6 m maximum.

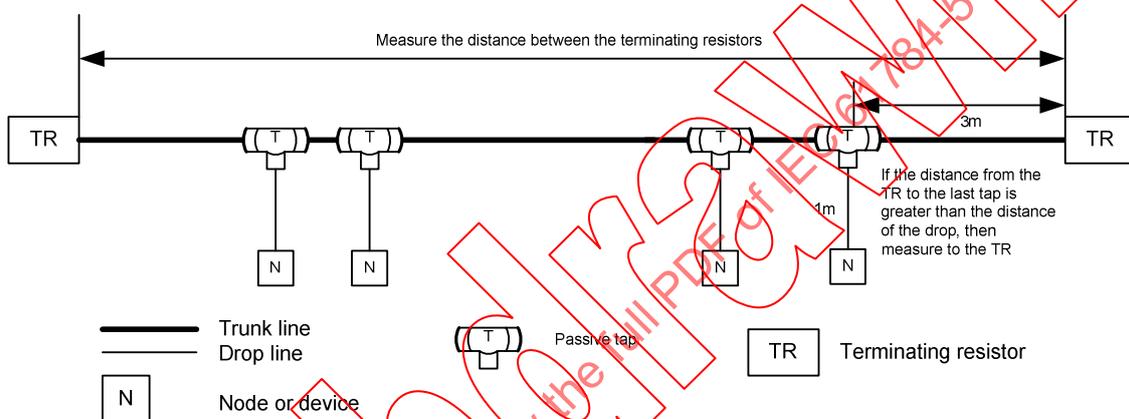
DeviceNet is a delay limited and attenuation limited network. In addition the connection of the taps and drop cables to the trunk cause reflections. The physical topology limits take into consideration 4 limiting parameters below:

- delay;

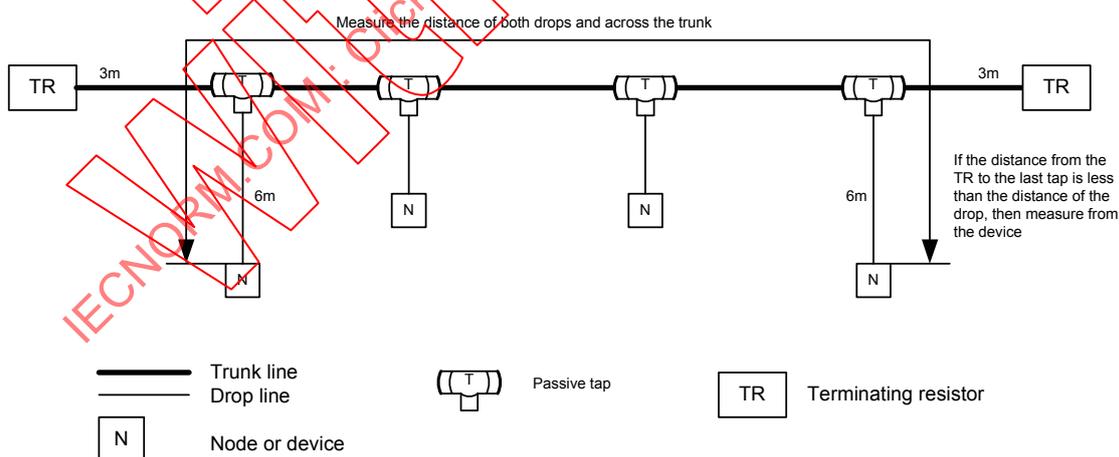
- attenuation;
- reflection amplitude and delay;
- V- common mode offset (IR drop).

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 dependant 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.

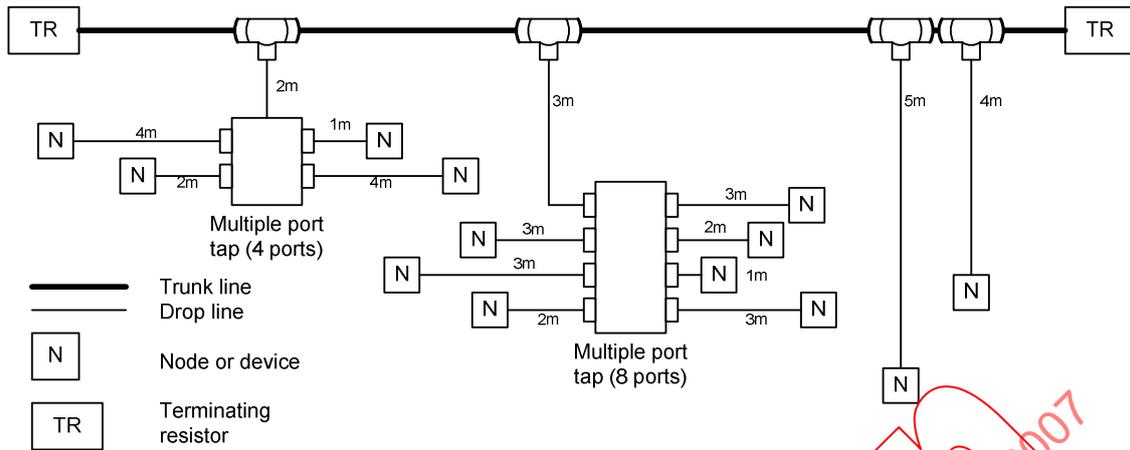


**Figure C.4 – Measuring the trunk length**



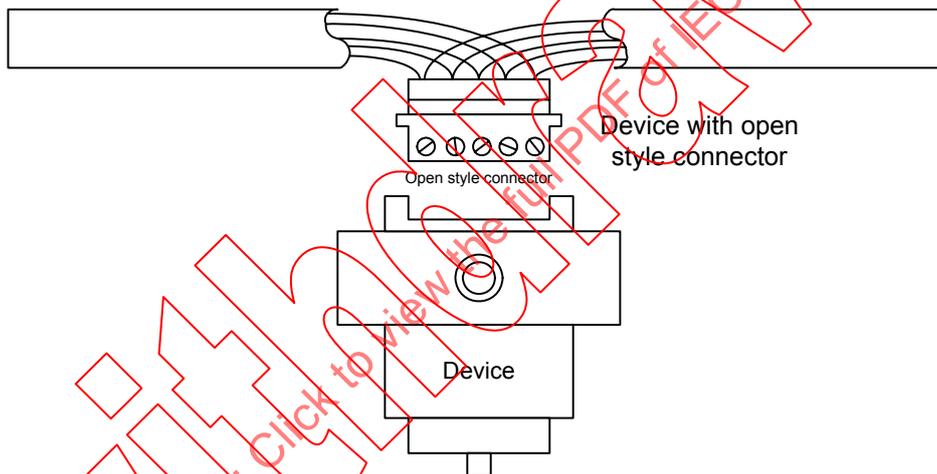
**Figure C.5 – Measuring the trunk and drop length**

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 that 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.

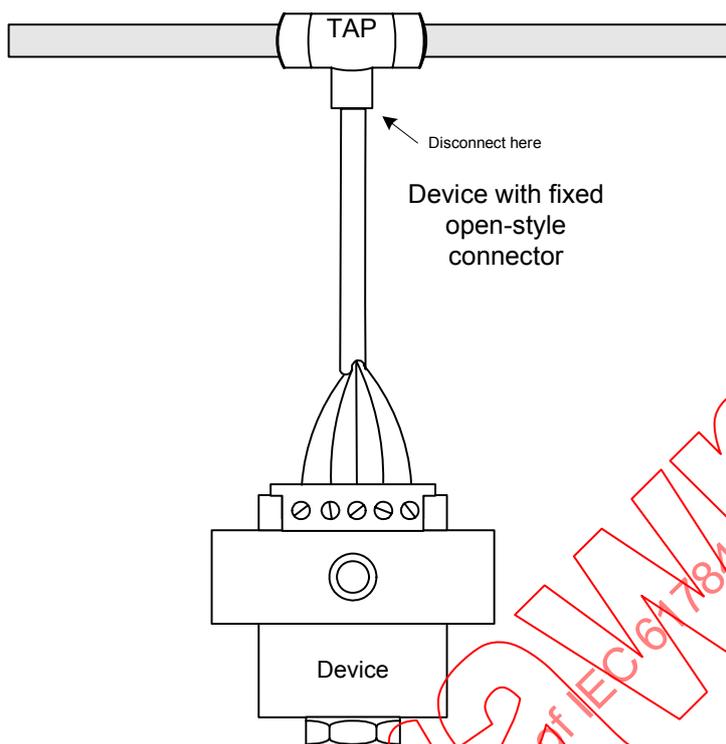


**Figure C.6 – Measuring drop cable in a network with multiports**

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.

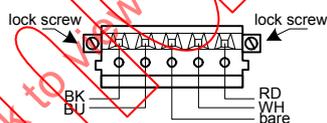


**Figure C.7 – Removable device using open style connectors**

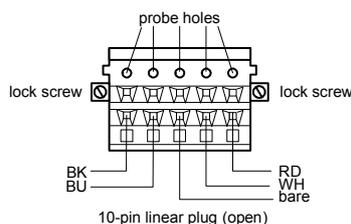


**Figure C.8 – Fixed connection using open style connector**

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 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 dependant 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 many cases the voltage drop will limit the length of the drop cable. Table C.4 provides current versus drop line length that shall be used by the planner in designing the cabling system.

**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							
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	5	4,4	2,2	1,5	1,1	0,9	0,8	n/a	n/a	n/a	n/a
Cable I	3,00	2,50	1,26	0,64	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	1,5	1,5	1,5	1,5	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 extrapolation.

**Table C.4 – Available current for thin cable drop lines**

Drop line length m	Allowable current A
1,5	3
2,0	2
3	1,5
4,5	1
6	0,75

The maximum current is calculated using the following formula:

$$I_{\max} = 4,57 / L$$

where

$I_{\max}$  is the maximum current in amperes;

L is the drop line length in meters.

**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	0,03 % per °C maximum
Output ripple	250 mV p-p
Load capacitance capability	7 000 µF maximum
Temperature range	Operating 0 °C to 60 °C <sup>a</sup> Non-operating -40 °C to 85 °C
Inrush current limit	Less than 65 A peak
Over voltage protection	Yes (no value specified)
Over current protection	Yes (current limit 25 % 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 a.c. and chassis earth
Output voltage	(24 ± 1 %) V
Output current	Up to 16 A
Surge current capability	10 % reserve capability
Agency ratings	Shall conform to local and national regulations
<sup>a</sup> Derating acceptable for 60 °C operation.	

**Table C.6 – Power supply tolerance stack up for DeviceNet**

Parameter	Specification
Initial power supply setting	1,00 %
Line regulation	0,30 %
Temperature coefficient <sup>a</sup>	0,60 % (total)
Time drift	1,05 %
Load regulation	0,30 %
Schottky diode drop (0,65 V nominal)	0,75 % (of 24 V)
<b>Total stack up</b>	<b>3,25 %</b>
<sup>a</sup> The temperature coefficient tolerance of 0,6 % is based on an actual rating of 0,03 % per °C and a 20 °C differential between supplies that are used on the bus. 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.

The d.c. output of all power supplies shall be isolated from the a.c. side of the power supply and the power supply case (earthing connection).

The cable system requires the power supply to have a rise time of less than 250 ms to within 5 % of its rated output voltage under a load of 7 000  $\mu\text{F}$ .

The designer shall verify the following:

- the power supply has its own current limit protection;
- fuse protection is provided for each segment of the cable system – any section leading away from a power supply shall have protection;
- the power supply is sized correctly to provide each device with its required power;
- derate the supply for temperature using the manufacturer's guidelines.

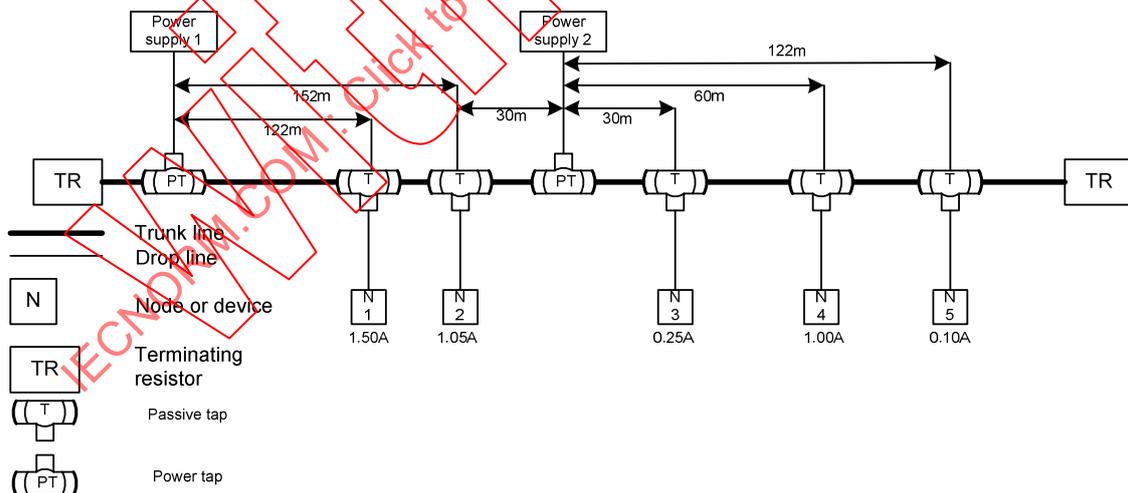
Some local regulations may not permit the full use of the power system capacity when installed as building wiring. The designer is strongly encouraged to consult national and local regulations for power restrictions. If local regulations restrict the power to levels less than needed to support the application, segmenting may be necessary (see Figure C.18).

#### C.4.3.2.5.3 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.11 will help to determine the minimum continuous current rating of a power supply servicing a common section.



**Figure C.11 – Power supply sizing example**

#### a) Power supply 1

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. Remember to consider temperature derating recommended by the manufacturer.

#### b) Power supply 2

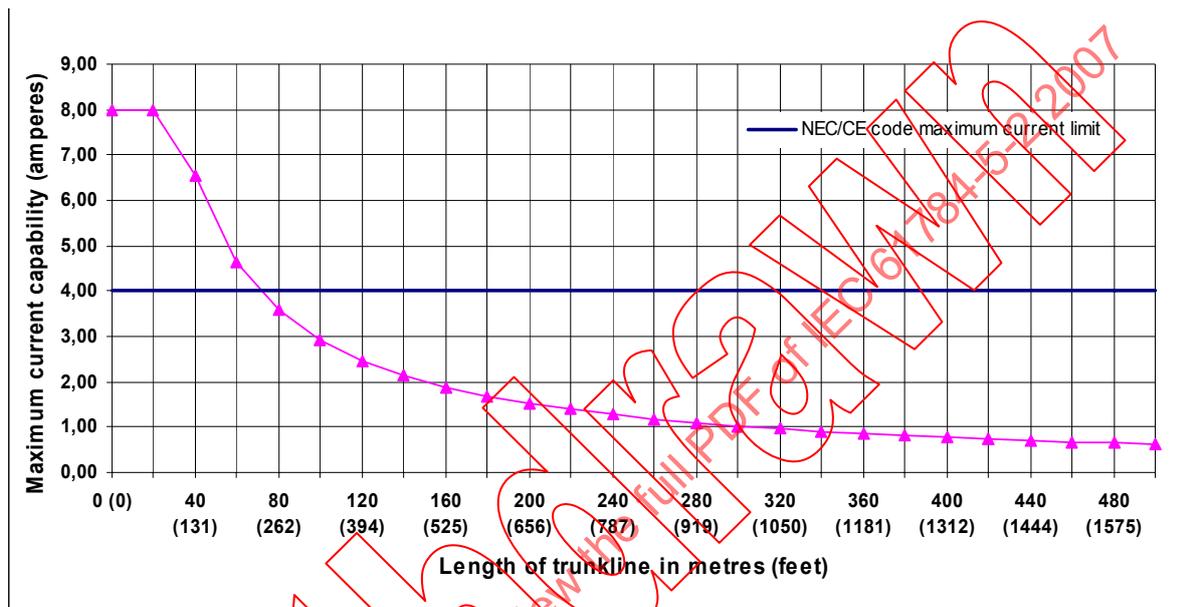
Add each device's (N3, N4, N5) current together for power supply 2 (0,25 A + 1,00 A + 0,10 A = 1,35 A).

1,35 A is the minimum rating of power supply 2. Remember to consider temperature derating recommended by the manufacturer.

**C.4.3.2.5.4 Examples of calculating network power**

Due to common mode off-set 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.12 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.12 – Current limit for thick cable for one power supply**

**Table C.7 – Current versus cable length for one power supply thick cable**

Network length m (ft.)	Maximum current A	Network length m (ft.)	Maximum current A
0 (0)	8,00	260 (853)	1,19
20 (66)	8,00	280 (919)	1,10
40 (131)	6,53	300 (984)	1,03
60 (197)	4,63	320 (1 050)	0,97
80 (262)	3,59	340 (1 115)	0,91
100 (328)	2,93	360 (1 181)	0,86
120 (394)	2,47	380 (1 247)	0,82
140 (459)	2,14	400 (1 312)	0,78
160 (525)	1,89	420 (1 378)	0,74
180 (591)	1,69	440 (1 444)	0,71
200 (656)	1,53	460 (1 509)	0,68
220 (722)	1,39	480 (1 575)	0,65
240 (787)	1,28	500 (1 640)	0,63

The graph specified in Figure C.13 and Table C.8 is an example of current versus cable length when there are two power supplies in the network.

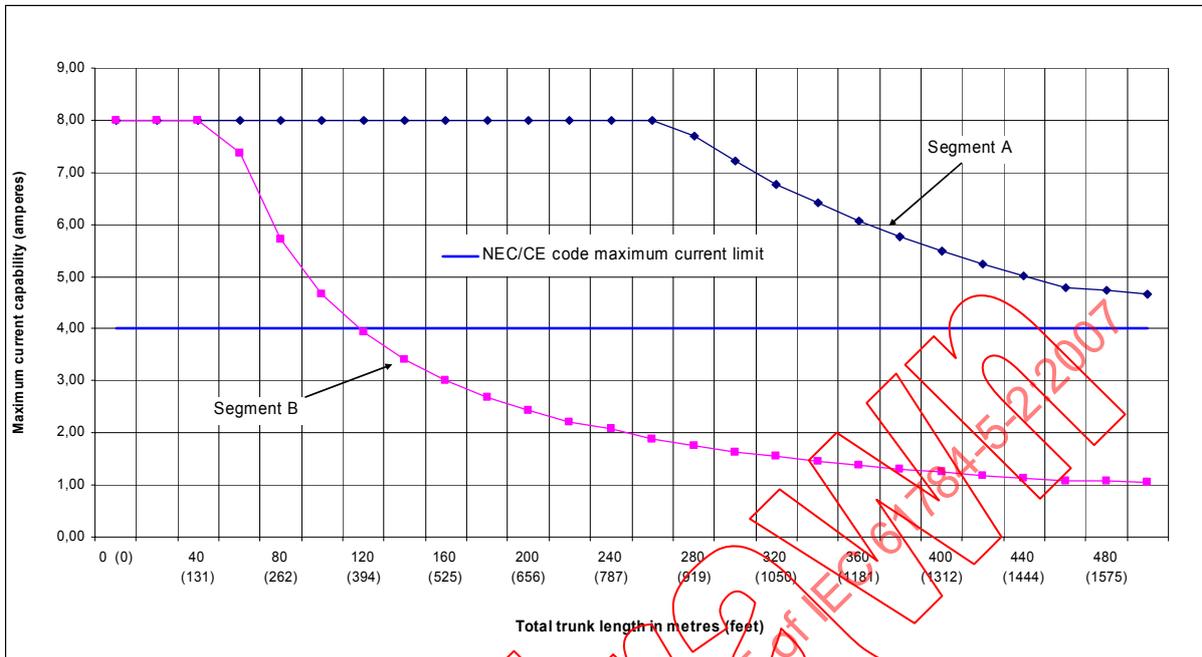


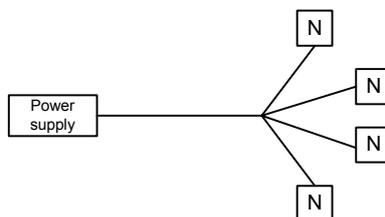
Figure C.13 – Current for thick cable and two power supplies

Table C.8 – Current versus length for two power supplies

Power supply A				Power supply B			
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 (1509)	4,80	200 (656)	2,43	460 (1509)	1,08
220 (722)	8,00	480 (1575)	4,73	220 (722)	2,22	480 (1575)	1,07
240 (787)	8,00	500 (1640)	4,66	240 (787)	2,08	500 (1640)	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 shall be used. See the example in Figure C.14 and Figure C.15. There is enough power if the total load does not exceed the value shown by the curve or the table.

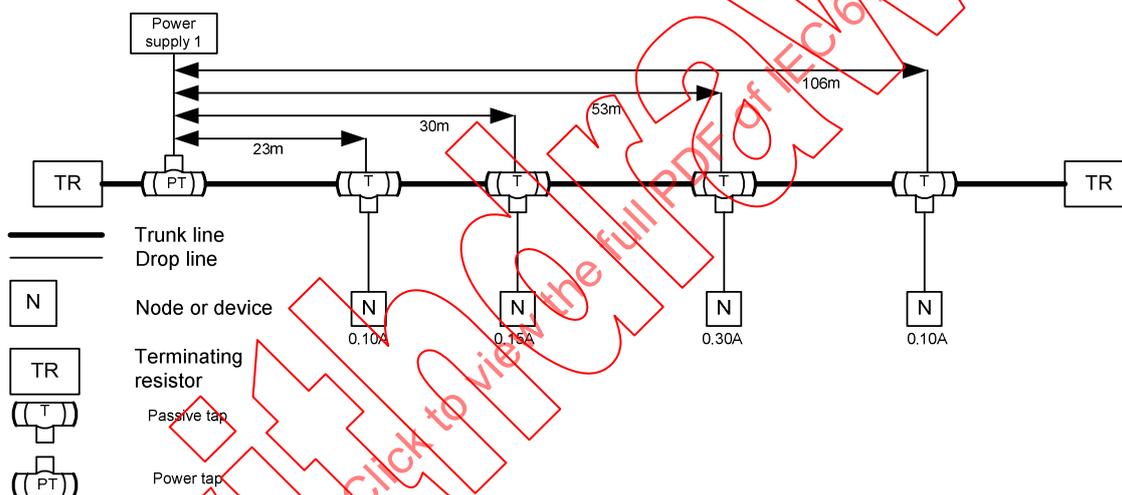
The worst-case scenario is when all of the nodes are together at one end of the cable and the power supply is at the opposite end (see Figure C.14), so all current flows over the longest distance of the trunk cable.



**Figure C.14 – Worst case scenario**

Important: This method may underestimate the capacity of the network by as much as 4 to 1. See C.4.3.2.5.5 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.15 – Example using the lookup method**

1) Using the example in Figure C.15, the total length of the network is  
106 m

2) Add each device's current together to find the total current.  
 $0,10\text{ A} + 0,15\text{ A} + 0,30\text{ A} + 0,10\text{ A} = 0,65\text{ A}$

Important: Make sure that the required power is less than the rating of the power supply. Power supply derating may be necessary if it is in an enclosure or elevated temperature.

3) Find the next largest network length using the table above 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:

- full-calculation method describe later;
- move the power supply to somewhere in the middle of the cable system and re-evaluation per the previous section.

#### C.4.3.2.5.5 Full calculation method

Use the full-calculation method if initial evaluation indicates that one section is overloaded or if the requirements of the configuration cannot be met by using the look-up method.

Important: Before construction of the cable system, repeat all calculations to avoid errors.

A supply that is not end-connected creates two sections of trunk line. Evaluate each section independently.

Use the following equation and Table C.9 to determine if the voltage drop for V- is within the specification limit of  $\leq 4,65$  V (trunk).

$$\text{Sum } \{[(L_n \times (R_c)) + N_t \times (0,005)] \times I_n\} \leq 4,65 \text{ V}$$

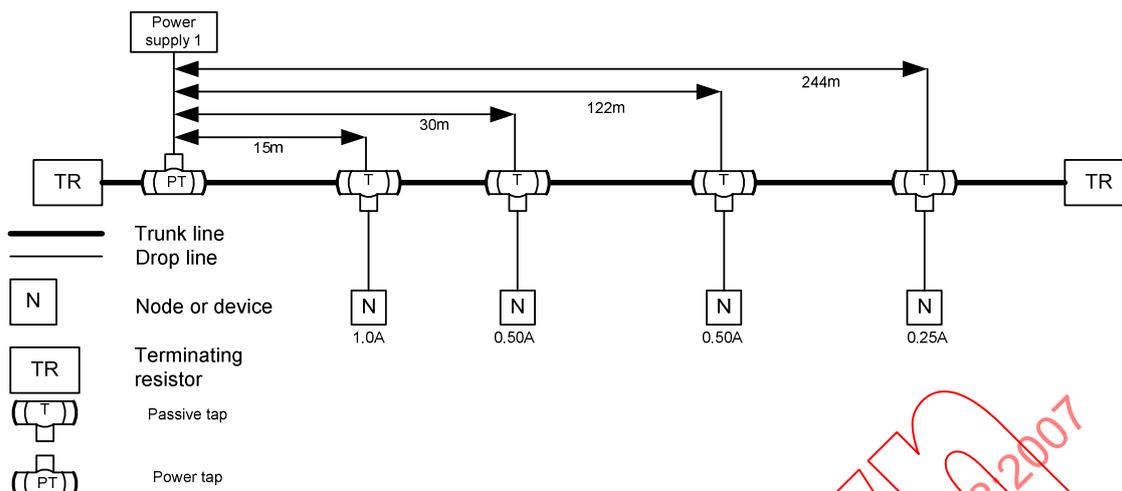
**Table C.9 – Definition of equation variables**

Term	Definition
$L_n$	L = the distance (m or ft.) between the device and the power supply, excluding the drop line distance. N = the number of a device being evaluated, starting with one for the device closest to the power supply and increasing by one for the next device. The equation sums the calculated drop for each device and compares it to 4,65 V
$R_c$	Thick cable --- 0,015 $\Omega$ /m Mid cable --- 0,023 $\Omega$ /m Thin cable --- 0,069 $\Omega$ /m Flat cable --- 0,019 $\Omega$ /m
$N_t$	The number of taps between the device being evaluated and the power supply. For example: When a device is the first one closest to the power supply, this number is 1 When a device has one device between it and the power supply, this number is 2. When 10 devices exist between the evaluated device and the power supply, this number is 11. For devices attached to a multi port tap, treat the tap as one tap. The current for all devices attached to one of these taps shall be summed and used with the equation only once. For flat cable, $N_t = 1 +$ twice the number of intermediate splice kits
0,005	The nominal contact resistance used for every connection to the trunk line.
$I_n$	I = The current drawn from the cable system by the device. For current within 90 % of the maximum, use the nominal device current. Otherwise, use the maximum rated current of the device. For multiport taps, sum the currents of all the attached devices, and count the tap as one tap. N = The number of a device being evaluated, starting with one for the device closest to the power supply and increasing by one for the next device
4,65 V	The maximum voltage drop allowed on the DeviceNet trunk line is V-. 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.4.3.2.5.6 Example of one power supply (end-connected) using thick cable

The example in Figure C.16 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.16 – One power supply end connected**

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

$$\text{SUM} \{[(L_n \times (0,0045)) + (N_t \times (0,005))] \times I_n\} < 4,65 \text{ V.}$$

$$\text{A.} [(50 \times (0,0045)) + (1 \times (0,005))] \times 1,00 = 0,23 \text{ V}$$

$$\text{B.} [(100 \times (0,0045)) + (2 \times (0,005))] \times 0,50 = 0,23 \text{ V}$$

$$\text{C.} [(400 \times (0,0045)) + (3 \times (0,005))] \times 0,50 = 0,91 \text{ V}$$

$$\text{D.} [(800 \times (0,0045)) + (4 \times (0,005))] \times 0,25 = 0,91 \text{ V}$$

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

$$0,23 \text{ V} + 0,23 \text{ V} + 0,91 \text{ V} + 0,91 \text{ V} = 2,28 \text{ V}$$

Since the total voltage does not exceed 4,65 V, the system will operate properly (2,28 V < 4,65 V).

The percent loading is found by dividing the total voltage by 4,65 V.

$$\% \text{Loading} = 2,28 / 4,65 = 49 \%$$

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.

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 for single power supplies.

#### **C.4.3.2.5.7 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 later in this chapter for the non-operational section;

- add a second power supply to the cable system as shown in the following example. Figure C.17 and Figure C.18 show how to segment the power bus to add an additional power supply. This example has the two power supplies in the center of the network which is convenient for power mains connection and reducing the number of enclosures needed.

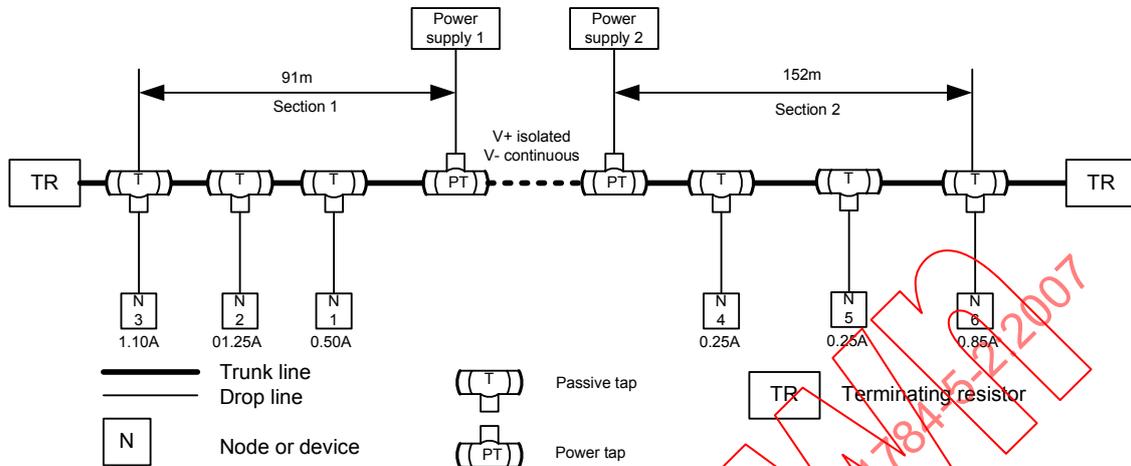


Figure C.17 – Segmenting power in the power bus

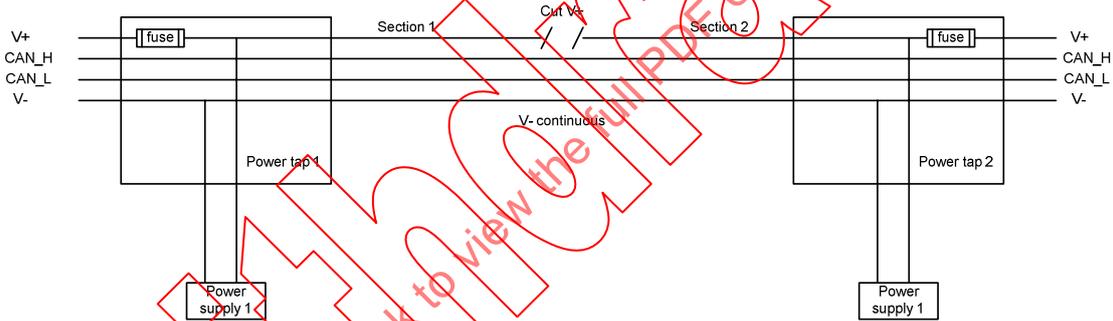


Figure C.18 – Segmenting the power bus using power taps

#### C.4.3.2.6 Specific requirements for generic cabling in accordance with ISO/IEC 24702

Not applicable.

### 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 provides values based on the template given in IEC 61918:2007, 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 dependant
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 dependant
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 geometry	Round	Round	Flat	Flat	Round	Round	Round	Round	Round
Number of conductors	4+1	4+1	4	4	4+1	4+1	4+1	4	4+1
Shielded	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes

Parameter	Cable profiles								
	Thick	Thin	Flat	Flat II	Cable I	Cable II	Cable III	Cable IV	Cable V
<b>Max. trunk length (m)</b>									
125 kbit/s	500	100	420	265	100	500	300	0	420
250 kbit/s	250	100	200	150	100	250	250	0	200
500 kbit/s	100	100	75	75	100	100	100	0	75
Maximum current	8	3	8	5	3	8	1,5	8	8
<b>Connector support</b>									
Micro	No	Yes	No	No	No	Yes	Yes	See NOTE	No
Mini	Yes	Yes	No	No	No	Yes	Yes	See NOTE	Yes
Open style CombiCon	Yes	Yes	No	No	No	Yes	Yes	See NOTE	Yes
Flat IDC	No	No	Yes	No	No	No	No	See NOTE	No
Flat IDC Type II	No	No	No	Yes	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 ([6]) for other cable specifications.

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

	Cable profile		
	Thick	Thin	Flat
<b>Data pair</b>			
<b>Physical characteristics</b>	<b>Specification</b>		
Conductor pair size	18 AWG or 0,82 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	24 AWG or 0,204 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	16 AWG or 1,3 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)
Insulation diameter	3,8 mm (nominal)	1,96 mm (nominal)	2,794 mm (nominal)
Colours	Lt BU and WH	Lt BU WH	Lt BU WH
Pair twist/m	9,8/m (approx.)	16,5/m (approximately)	n/a
Tape shield over pair	0,05 mm/0,025 4 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	0,025 4 mm/0,025 4 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	n/a
<b>Electrical characteristics</b>	<b>Specification</b>		
Impedance	(120 ± 10 %) Ω (at 1 MHz)	(120 ± 10 %) Ω (at 1 MHz)	(120 ± 10 %) Ω (at 500 kHz)
Propagation delay	4,46 ns/m (maximum)	4,46 ns/m (maximum)	5,25 ns/m (maximum)

	Cable profile		
	Thick	Thin	Flat
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)	n/a
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 D4566-94
DCR at 20 °C	22,60 Ω /1 000 m (maximum)	91,9 Ω /1 000 m (maximum)	16,1 Ω /1 000 m (maximum)
Attenuation	0,43 dB/100 m at 125 kHz (maximum) 0,82 dB/100 m at 500 kHz (maximum) 1,312 dB/100 m at 1,00 MHz (maximum)	0,95 dB/100 m at 125 kHz (maximum) 1,64 dB/100 m at 500 kHz (maximum) 2,3 dB/100 m at 1,00 MHz (maximum)	0,43 dB/100 m at 125 kHz (maximum) 0,82 dB/100 m at 250 kHz (maximum) 1,31 dB/100 m at 500 kHz (maximum)
Power pair			
Physical characteristics	Specification		
Conductor pair size	15 AWG or 1,65 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	22 AWG or 0,33 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	16 AWG or 1,3 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)
Insulation diameter	2,49 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	n/a
Tape shield over pair	0,025 4 mm/0,025 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	0,025 4 mm/0,025 mm, Al/Mylar, Al side out w/shorting fold (pullon applied)	n/a
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)
General specifications			
Physical characteristics	Specification		
Geometry	Two shielded pairs, common axis with drain wire in center	Two shielded pairs, common axis with drain wire in center	n/a
Overall braid shield	65 % coverage 36 AWG or 0,012 mm <sup>2</sup> tinned Cu braid minimum (individually tinned)	65 % coverage 36 AWG or 0,12 mm tinned Cu braid minimum (individually tinned)	n/a
Drain wire	18 AWG or 0,82 mm <sup>2</sup> copper minimum; 19 strands minimum (individually tinned)	22 AWG or 0,33 mm <sup>2</sup> copper 19 strands minimum (individually tinned)	n/a
Outside diameter	10,41 mm (minimum) to 12,45 mm (maximum)	6,1 mm (minimum) to 7,11 mm (maximum)	See Figure C.22
Roundness	Radius delta to be within 15 % of 0,5 outer diameter	Radius delta to be within 20 % of 0,5 outer diameter	n/a
Jacket marking	Vendor name & part #, and additional markings	Vendor name and part # and additional markings	Vendor name and part # and additional markings

	Cable profile		
	Thick	Thin	Flat
<b>Electrical characteristics</b>	<b>Specification</b>		
DCR (braid+tape+drain)	5,74 $\Omega$ /1 000 m (nom. at 20 °C)	10,5 $\Omega$ /1 000 m (nom. at 20 °C)	n/a
<b>Applicable environmental characteristics</b>	<b>Specification</b>		
Agency Certifications (U.S. and Canada)	NEC (UL) type, CL2/CL3 (minimum)	NEC (UL) type CL2 (minimum)	NEC (UL) type CL2 (minimum)
Flexure	2 000 cycles at bend radius, 90 °, 8,9 N pull force, 15 cycles per minute, tic-toc or rolling "C" track method	2 000 cycles at bend radius, 90 °, 8,9 N pull force, 15 cycles per minute, tic-toc or rolling "C" track method	1,0 Mcycles at bend radius, 15,24 cm minimum length, 15 cycles per minute, rolling "C" track method
Bend radius	20 x diameter (installation) / 7 x diameter (fixed)	20 x diameter (installation) / 7 x diameter (fixed)	10 x thickness (installation and 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 to +75 °C at 1,5 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	400 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

Not applicable.

#### C.4.4.1.4 Optical fibre cables

Not applicable.

#### C.4.4.1.5 Special purpose 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 hyflex 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 24702

Not applicable.

#### 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 61918:2007, Table 8.

**Table C.14 – Copper connectors for non-Ethernet based fieldbus**

	IEC 60807-2 or IEC 60807-3	IEC 60947-5-2 or IEC 61076-2-101			EN 122120	ANSI/NFPA T3.5.29 R1-2003		Others		
	Sub-D	M12-5 with A-coding	M12-5 with B-coding	M12-n with X-coding	Coaxial (BNC)	M18	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 may cause damage to the applications.

*Addition:*

Table C.15 provides a list of available connectors for DeviceNet networks. This table is an extension of Table C.14.

**Table C.15 – Additional connectors for CP 2/3 (DeviceNet)**

Connector	M12-5 A-coding	Mini 7/8-16 UN-2A THD / M18	Open	Flat
Standard	IEC 60947-5-2 Figure D.2	ANSI/B93.55M-1981	ODVA (see [6])	ODVA (see [6])
Contacts	5	5	5	4
Current (A)	3	8	8	8
Sealed	Yes	Yes	No	Yes

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

Not applicable.

**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 24702**

Not applicable.

**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 for CPs based on Ethernet**

Not applicable.

**C.4.4.3.3 Copper cabling connections 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 fiber cabling connections for CPs based on Ethernet**

Not applicable.

**C.4.4.3.5 Optical fibre cabling connections for CPs not based on Ethernet**

Not applicable.

**C.4.4.3.6 Specification requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**C.4.4.4 Terminators****C.4.4.4.1 Common description****C.4.4.4.2 Specific requirements for CPs**

*Addition:*

The trunk line shall be terminated at each end of the network into its characteristic impedance of 121  $\Omega$ . The terminator can be in integral part of a plug or a resistor. The terminator shall conform to the values below:

- Value: 121  $\Omega$ ;
- Tolerance: +/-1 %;
- Wattage: ¼ W.

Physical: recommend 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.

Bulkheads may be used as needed. For modularity, see C.4.4.3.2.

**C.4.4.4.3 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**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 24702**

Not applicable.

**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 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 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 61918:2007, Table 15.

**C.4.4.7.3 Earthing methods****C.4.4.7.3.1 Mesh, equipotential**

*Addition:*

If the building does not have an adequate or has an unknown equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets in the communications coverage area. There shall be no noise currents in the communications shields as a result of earth potential offsets in the communications coverage area. An alternate media such as fibre may be considered as part of a mitigation technique.

One of the two methods shall be used to mitigate potential offsets within the communications coverage area. Some devices are enclosed in isolated enclosures. These devices may not require earthing. If earthing is required then they shall be earthed in accordance with local regulations and the manufacturers instructions.

If equipotential equalization cannot be guaranteed or is unknown, then the star earthing system shall be specified.

**C.4.4.7.3.2 Star**

*Addition:*

If the building does not have an adequate or has an unknown equipotential earthing system, then star earthing method shall be used to mitigate earth potential offsets in the communications coverage area. There shall be no noise currents in the communications shields as a result of earth potential offsets in the communications coverage area. An alternate media such as fibre may be considered as part of a mitigation technique.

One of the two methods shall be used to mitigate potential offsets within the communications coverage area. Some devices are enclosed in isolated enclosures. These devices may not require earthing. If earthing is required then they shall be earthed in accordance with local regulations and the manufacturers instructions.

Star earthing of enclosures, equipment and pathways shall be star earthed in accordance with the planner's documentation.

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

*Replacement:*

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

**C.4.4.7.3.4 Installing copper bus bars**

*Addition:*

In some cases it may be necessary to install copper bus bars in accordance with the star earthing system. When doing so insulators may be required to isolate the bus bar from the enclosure or building earth reference. When it is necessary to isolate the copper bus bar, the d.c. resistance to the local earth shall be a minimum of 2 M $\Omega$ . If the bus bar is plated, it shall be in accordance with IEC 61918:2007, Table 15.

The bus bar surface shall be prepared in accordance with IEC 61918:2007, 5.7.2.3. The conductor sizing shall be in accordance with IEC 61918:2007, 4.4.7.2.1, Table 13.

**C.4.4.7.4 Shield earthing****C.4.4.7.4.1 Non-earthing or parallel RC****C.4.4.7.4.2 Direct**

Not applicable.

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

*Addition:*

DeviceNet shall be earthed at one location in the network only. This location is recommended to be at the power supply or power tap where the power supply connects to the trunk. In addition the V- is earthed at this location. This location shall provide an earth connection for the communications cable shield. Devices shall not connect V-, or the shield directly to earth. Devices may connect the shield to earth through a 1 M $\Omega$  resistor in parallel 0,01  $\mu$ F capacitor or float the shield. The flat trunk cabling system has no shield, therefore provides no earthing for devices.

**C.4.4.7.5 Specific requirements for CPs**

*Addition:*

DeviceNet V- and the communications shield may be earthed. Earthing shall be only at one location in the network to prevent ground loops. 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 61918:2007, 4.4.7.2.1, or a suitable star earthing system be installed as described in IEC 61918:2007, 4.4.7.2.2.

**C.4.4.7.6 Specific requirements for generic cabling in accordance with ISO/IEC 24702**

Not applicable.

**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 Detailed requirements for cable routing inside enclosures**

**C.4.4.9.4 Cable routing inside buildings**

**C.4.4.9.5 Cable routing outside buildings**

**C.4.4.9.6 Installing redundant communication cables**

**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 24702**

Not applicable.

**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 for 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 24702**

Not applicable.

**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 for Table 17:

Table C.16 values based on the template given in IEC 61918:2007, Table 17.

**Table C.16 – Parameters for balanced cables**

	Characteristic	Value
<b>Mechanical force</b>	Minimum bending radius, single bending (mm)	10 x diameter
	Bending radius, multiple bending (mm)	7 x diameter
	Pull forces (N)	840
	Permanent tensile forces (N)	n/a
	Maximum lateral forces (N)	n/a
	Temperature range during installation (°C)	20 °C to 60 °C

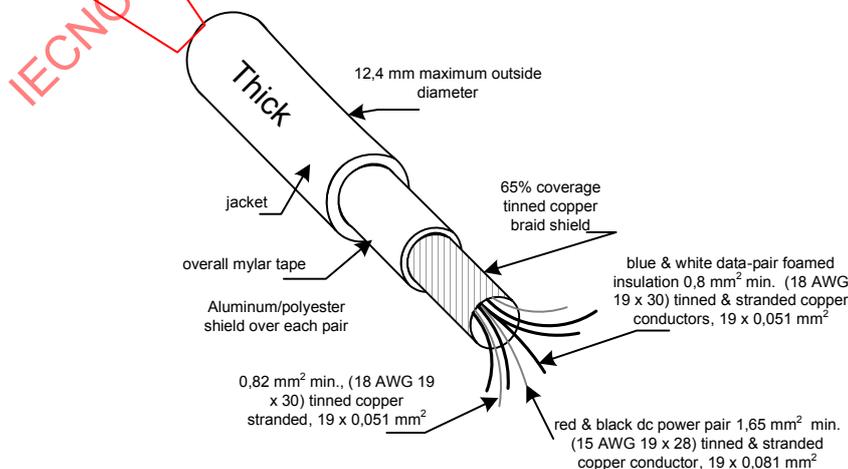
Tables 18 to 20 of IEC 61918:2007 are not applicable.

#### C.5.2.2 Installation and routing

#### C.5.2.3 Specific requirements for CPs

Addition:

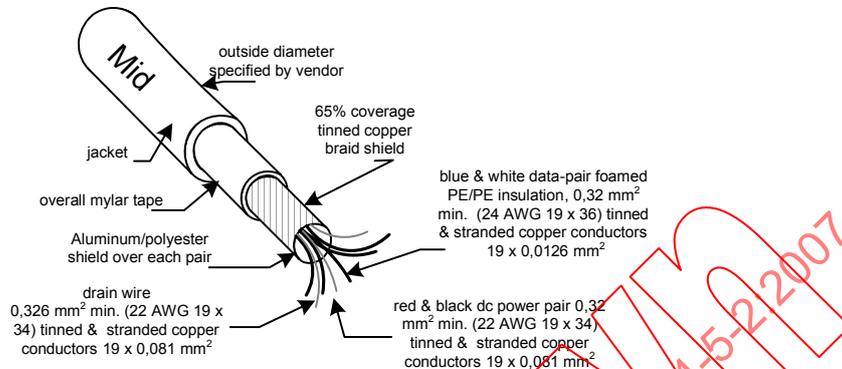
Thick cable, with an outside diameter of 12,2 mm, is generally used as the trunk line on the DeviceNet network. Thick cable can also be used for drop lines. The cable construction is detailed in Figure C.19.



**Figure C.19 – Thick cable construction**

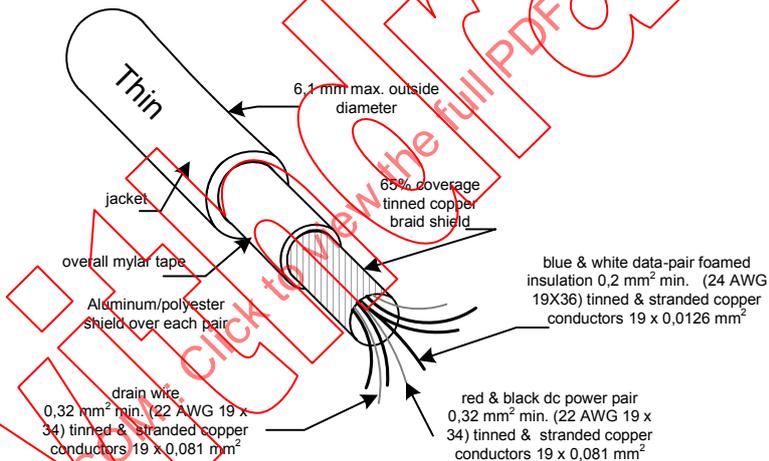
NOTE The mm<sup>2</sup> wire sizes in this and similar drawing are for information only. The wires are specified in AWG sizes.

Mid cable, with an outside diameter specified by the vendor, connects devices to the DeviceNet trunk line via taps. Mid cable can be used for trunk lines and drop lines. The construction of the mid cable is detailed in Figure C.20.



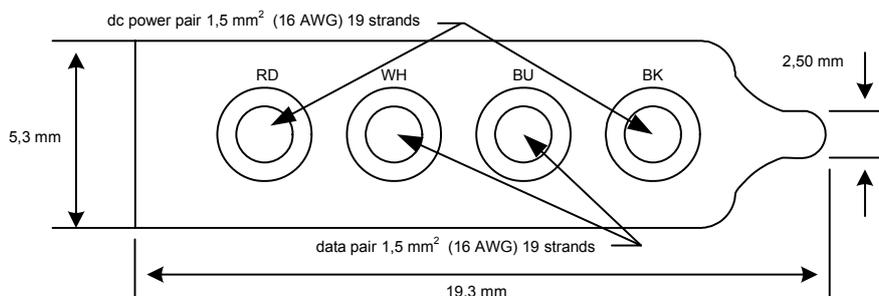
**Figure C.20 – Mid cable construction**

Thin cable, with an outside diameter of 6,9 mm, connect 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.21.



**Figure C.21 – 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.22.



**Figure C.22 – 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