भारतीय मानक IS/ISO/IEC 11801-3 : 2021

Indian Standard

सूचान प्रौद्योगिकी — ग्राहक परिसर के लिए सामान्य केबलिंग

भाग 3 औद्योगिक परिसर

Information Technology — Generic Cabling for Customer Premises

Part 3 Industrial Premises

ICS 35.200

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

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NATIONAL FOREWORD

This Indian Standard (Part 3) which is identical to ISO/IEC 11801-3 : 2021 'Information technology — Generic cabling for customer premises — Part 3: Industrial premises' issued by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) jointly was adopted by the Bureau of Indian Standards on the recommendation of the Interconnection and Information exchange among IT Equipments and Systems Sectional Committee and approval of the Electronics and Information Technology Division Council.

This Indian Standard is published in three parts. The other parts in this series are:

Part 1 General requirements
Part 2 Office premises
Part 5 Data centres

The text of ISO/IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are however not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appears referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current Practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standard which is to be substituted in its respective place is listed below along with its degree of equivalence for the edition indicated. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO/IEC 11801-1 : 2017 Information technology — Generic cabling for customer premises — Part 1: General requirements	IS/ISO/IEC 11801-1 : 2017 Information technology generic cabling for customer premises Part 1: General requirements	Identical
ISO/IEC 11801-2 : 2017 Information technology — Generic cabling for customer premises — Part 2: Office premises	IS/ISO/IEC 11801-2 : 2017 Information technology generic cabling for customer premises Part 2: Office premises	Identical

The Committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

(*Continued on third cover)*

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INTRODUCTION

The importance of cabling infrastructure is similar to that of other fundamental utilities such as water and energy supply and interruptions to the services provided over that infrastructure can have a serious impact. A lack of design foresight, the use of inappropriate components, incorrect installation, poor administration or inadequate support can threaten quality of service and have commercial consequence for all types of users.

This document specifies generic cabling, which is critical for providing robust services to the automation islands in industrial premises, or industrial spaces within other types of building.

Additionally those premises can include

- office spaces for which generic cabling is specified in ISO/IEC 11801-2,
- data centre spaces for which generic cabling is specified in ISO/IEC 11801-5.

Generic cabling for distributed building services in industrial spaces is specified in ISO/IEC 11801-6, which addresses all of the above premises and spaces within them.

This document has taken into account the correlation between all parts of the ISO/IEC 11801 series and the IEC 61918 and IEC 61784-5 series.

Figure 1 shows the schematic and contextual relationships between the standards relating to information technology cabling produced by ISO/IEC JTC 1/SC 25, namely the ISO/IEC 11801 series of standards for generic cabling design, standards for the installation, operation and administration of generic cabling and for testing of installed generic cabling.

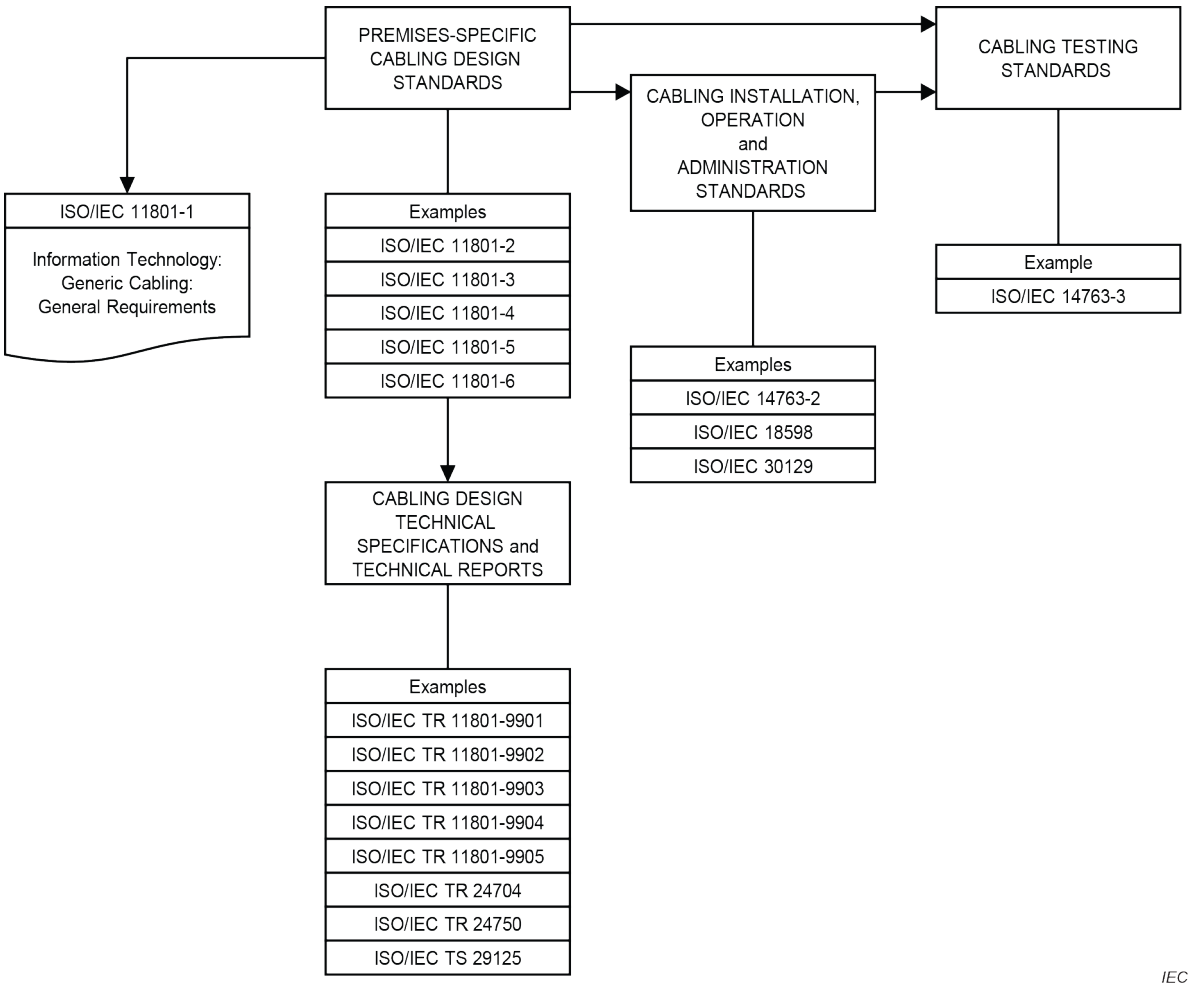


Figure 1 – Relationships between the generic cabling documents produced by ISO/IEC JTC 1/SC 25

The generic cabling specified by this document provides users with

a) an application independent system capable of supporting a wide range of applications in a range of installation and operating environments,

b) a flexible scheme such that modifications are both easy and economical,

c) a multi-vendor supply chain within an open market for cabling components.

In addition, this document provides

d) relevant industry professionals with guidance allowing the accommodation of cabling before specific requirements are known, i.e. in the initial planning either for construction or refurbishment and for further deployment as the requirements of areas are defined,

e) industry and standardization bodies with a cabling system which supports current products and provides a basis for future product development and applications standardization.

Applications addressed in this document include those developed by the technical committees of IEC (including the subcommittees of ISO/IEC JTC 1), including critical industrial process control and monitoring applications and study groups of ITU-T.

As a result, this document

1) specifies a structure for generic cabling supporting a wide variety of applications,

2) adopts balanced cabling channel and link Classes D, E, E_A, F and F_A, specified in ISO/IEC 11801-1,

3) adopts component requirements, specified in ISO/IEC 11801-1, and specifies cabling implementations that ensure performance of permanent links and of channels that meet or exceed the requirements of a specified group (e.g. Class) of applications.

Figure 2 shows the relationship between all the documents (the generic cabling standards produced by ISO/IEC JTC 1/SC 25 and the application-specific standards produced by IEC SC 65C) that apply to industrial premises.

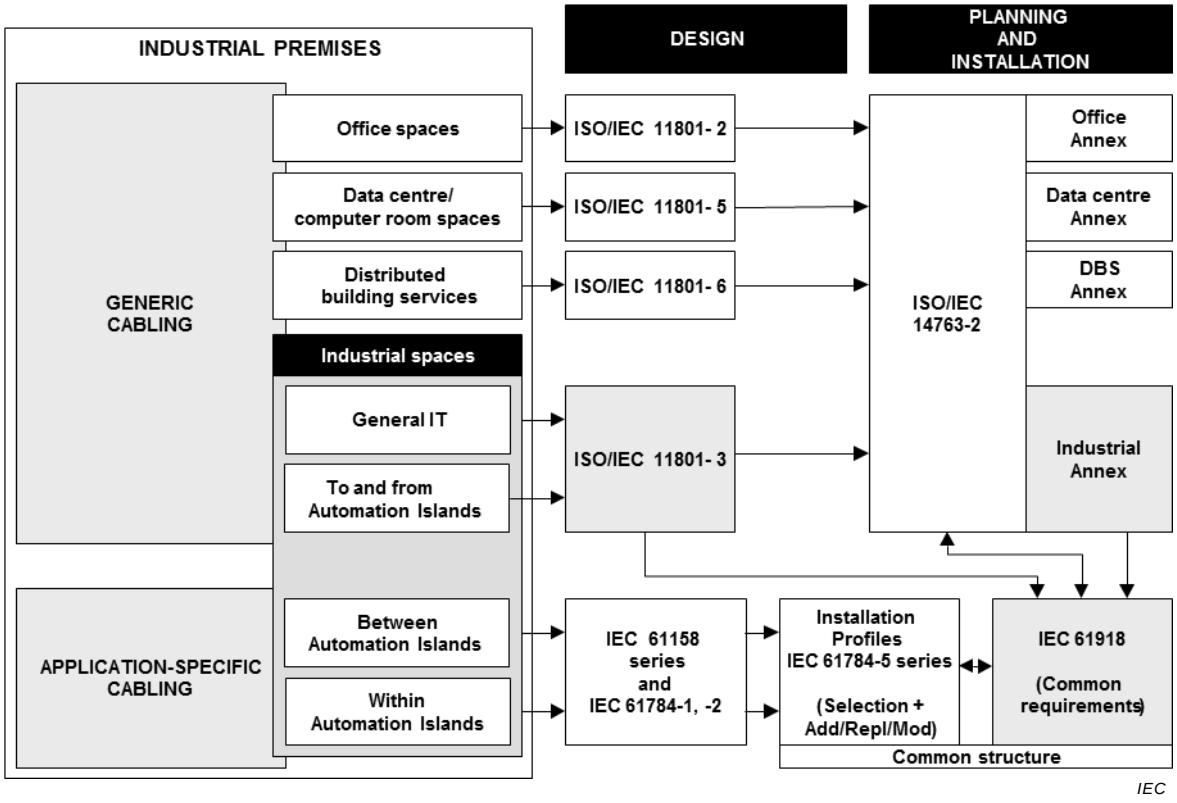


Figure 2 – Relationships between the ISO/IEC and IEC cabling documents that apply to industrial premises

It is anticipated that the generic cabling system meeting the minimum requirements of this document will have a life expectancy consistent with other infrastructures within industrial premises.

This document has taken into account requirements specified in application standards listed in ISO/IEC 11801-1:2017, Annex E. It refers to International Standards for components and test methods whenever appropriate International Standards are available.

NOTE Telecommunications infrastructure affects raw material consumption. The infrastructure design and installation methods also influence product life and sustainability of electronic equipment life cycling. These aspects of telecommunications infrastructure impact our environment. Since building life cycles are typically planned for decades, technological electronic equipment upgrades are necessary. The telecommunications infrastructure design and installation process magnifies the need for sustainable infrastructures with respect to building life, electronic equipment life cycling and considerations of effects on environmental waste. Telecommunications designers are encouraged to research local building practices for a sustainable environment and conservation of fossil fuels as part of the design process.

INTRODUCTION to Amendment 1

This document contains requirements and/or recommendations for deployment of single pair balanced cabling on the industrial cabling specified in ISO/IEC 11801-3:2017.

This document also includes end-to-end link requirements for Class D, E and E_A.

Indian Standard

INFORMATION TECHNOLOGY — GENERI CABLING FOR CUSTOMER PREMISES

PART 3 INDUSTRIAL PREMISES

1 Scope

This part of ISO/IEC 11801 specifies generic cabling for use within industrial premises, or industrial areas within other types of premises, which can comprise single or multiple buildings on a campus. It covers balanced cabling and optical fibre cabling.

This document is optimized for premises in which the maximum distance over which telecommunications services can be distributed is 10 000 m. The principles of this document can be applied to larger installations.

Cabling defined by this document supports a wide range of services, including automation, process control, and monitoring applications. That can also incorporate the supply of power.

This document specifies directly or via reference to ISO/IEC 11801-1

a) the structure and minimum configuration for generic cabling within industrial premises,

b) the interfaces at the telecommunications outlet (TO),

c) the performance requirements for cabling links and channels,

d) the implementation requirements and options,

e) the performance requirements for cabling components,

f) the conformance requirements and verification procedures.

The cabling providing critical automation, process control and monitoring applications within the automation islands is not addressed by this document. Information for this application-specific cabling is provided in the IEC 61784-5 series (design) and in IEC 61918 (installation).

Safety (electrical safety and protection, fire, etc.) and electromagnetic compatibility (EMC) requirements are outside the scope of this document, and are covered by other standards and by regulations. However, information given by this document can be of assistance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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

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

IEC 61156-12[1], *Multicore and symmetrical pair/quad cables for digital communications – Part 12: Symmetrical single pair cables with transmission characteristics up to 600 MHz – Work area wiring*

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

ISO/IEC 11801-2, *Information technology – Generic cabling for customer premises – Part 2: Office premises*

ISO/IEC 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

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

ISO/IEC 30129, *Information technology – Telecommunications bonding networks for buildings and other structures*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 11801-1 and the following apply.

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

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

3.1.1
apparatus
one or more pieces of equipment having specific and defined overall functions within industrial premises served by one or more network interfaces

3.1.2
apparatus attachment cord
cord used to connect a telecommunications outlet to a network interface

3.1.3
automation island
premises and areas where a combination of systems that control, monitor and protect process(es) of a plant are installed

3.1.4
automation outlet
fixed connecting hardware which provides an interface to the automation island (AI)

3.1.5
bulkhead
wall or barrier which maintains the ingress and climatic environmental classifications applicable on either side

[1] Under preparation. Stage at time of publication: IEC CDV 61156-12:2020.

3.1.6
equipment room
room dedicated to housing distributors and application-specific equipment

3.1.7
floor cable
cable connecting the floor distributor to the intermediate distributor

3.1.8
floor distributor
distributor used to make connections between the floor cable, other cabling subsystems and active equipment

3.1.9
intermediate cable
cable connecting the intermediate distributor to the telecommunications outlet

3.1.10
intermediate distributor
distributor used to make connections between the intermediate cable, other cabling subsystems and active equipment

3.1.11
industrial intermediate distributor
intermediate distributor used to make connections between several automation islands and transmit critical process control, monitoring and automation data (PCMA) between them

3.1.12
network interface
interface between the apparatus attachment cabling and the apparatus network

3.1.13
telecommunications room
enclosed space for housing telecommunications equipment, cable terminations, interconnect and cross-connect

3.1.14
balanced 1-pair cabling channel
transmission path between equipment constructed from balanced 1-pair cables, balanced 1-pair connectors and balanced 1-pair cable assemblies to facilitate signal and power delivery

3.1.15
edge distributor
optional additional distributor to accommodate active equipment to allow transition from balanced 4-pair cabling to balanced 1-pair cabling

3.1.16
end-to-end link
transmission path between equipment including the end connections attached to the equipment

3.1.17
bulkhead connection
connection that serves as an interconnection point located through an enclosure wall

3.1.18
segment
cabling between connectors of an end-to-end link

3.2 Abbreviated terms

AI automation island

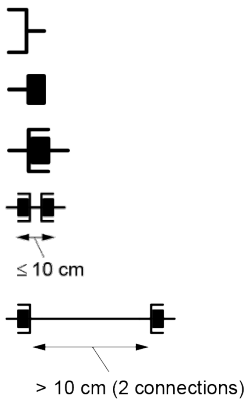
AO automation outlet

CPL CP link
E2E link end-to-end link

FD	floor distributor
ID	intermediate distributor
IID	industrial intermediate distributor
NI	network interface
PCMA	process control, monitoring and automation (data)
B	bulkhead connection
C	connection
CP	consolidation point
ED	edge distributor
ffs	for further study
L1	length of end-to-end link
SPE	Single Pair Ethernet
TI	test interface

3.3 Symbols

Symbols used identically in different parts of ISO/IEC 11801 are defined in ISO/IEC 11801-1:2017, 3.3.



fixed connector

free connector

connection

bulkhead connection with back-to-back fixed connectors acting as one connection

bulkhead connection with separated back-to-back fixed connectors acting as two connections

The symbols shown in Figure 14 define the number of connections in all end-to-end links.

Figure 14 – Symbols for bulkhead connections

NOTE Bulkhead mounted connections with fixed cable can have a variable length to accommodate the installation within the cabinet.

4 Conformance

For a cabling installation to conform to this document the following applies.

a) The configuration and structure shall conform to the requirements outlined in Clause 5.

b) Channels shall meet the requirements specified in Clause 6 when subjected to environment conditions, local to the channels (see NOTE below), as defined by the applicable environmental Class(es) of Clause 6.

This shall be achieved by one of the following:

1) a channel design and implementation ensuring that the prescribed channel performance of Clause 6 is met;

2) attachment of appropriate components to a permanent link or CP link design meeting the prescribed performance class of Clause 7. Channel performance shall be ensured where a channel is created by adding more than one cord to either end of a link meeting the requirements of Clause 7;

3) for E_1 environments, using the reference implementations of Clause 8 and compatible cabling components conforming to the requirements of Clauses 9, 10 and 11 based upon a statistical approach of performance modelling.

c) The interfaces to the cabling at the TO shall conform to the requirements of Clause 10 with respect to mating interfaces and performance when subjected to environment conditions, local to the connecting hardware (see NOTE below), as defined by the applicable environmental Class(es) of Clause 6.

d) Connecting hardware at other places in the cabling structure shall meet the performance requirements specified in Clause 10 when subjected to environment conditions, local to the connecting hardware (see NOTE below), as defined by the applicable environmental Class(es) of Clause 6.

e) The requirements of ISO/IEC 14763-2 and ISO/IEC 30129 shall be met.

f) In case balanced 1-pair cabling channels are installed between the IID or ED and the NI of an Automation Island, between the IID or ED and the TO or AO, or between the IID and ED, channels shall conform to the requirements of Annex A;

g) In case balanced 1-pair cabling channels are installed between the ID and the NI of an Automation Island, channels shall conform to the requirements of Annex E.

This document does not specify which tests and sampling levels should be adopted. Test methods to assess conformance with the channel and link requirements of Clause 6 and Clause 7, respectively, are specified in ISO/IEC 11801-1. The test parameters to be measured, the sampling levels and the treatment of measured results to be applied for particular installation shall be defined in the installation specification and quality plan for that installation prepared in accordance with ISO/IEC 14763-2.

For installations beyond the IID, IEC 61918 and IEC 61784-5 series shall be met (see Annex A).

In the absence of the channel, the conformance of the link shall be used to verify conformance with this document.

Specifications marked "ffs" are preliminary specifications, and are not required for conformance to this document.

NOTE The applicable environment of ISO/IEC 11801-1:2017, 6.2.2, local to the cabling or cabling component(s), is that of the external environment or that modified environment created by use of mitigating installation techniques.

5 Structure of the generic cabling system

5.1 General

Clause 5 identifies the functional elements of generic cabling for industrial premises, describes how they are connected together to form subsystems and identifies the interfaces at which application-specific components are connected. Applications listed in ISO/IEC 11801-1:2017, Annex E, are supported by connecting active equipment at the TOs and the distributors.

In general, all functional elements, subsystems and interfaces from the campus distributor to the floor distributor as described in ISO/IEC 11801-1 are applicable.

5.2 Functional elements

In addition to the functional elements of ISO/IEC 11801-1, cabling in accordance with this document specifies the following functional elements:

a) floor distributor (FD),

b) floor cable,

c) intermediate distributor (ID),

d) intermediate cable,

e) consolidation point (CP) – optional,

f) consolidation cable (CP cable),

g) telecommunications outlet (TO).

As shown in Figure 3, an ID is able to serve TOs on separate pieces of apparatus or multiple TOs on a single piece of apparatus. The type and nature of the apparatus cabling are beyond the scope of this document.

Groups of the functional elements are connected together to form cabling subsystems.

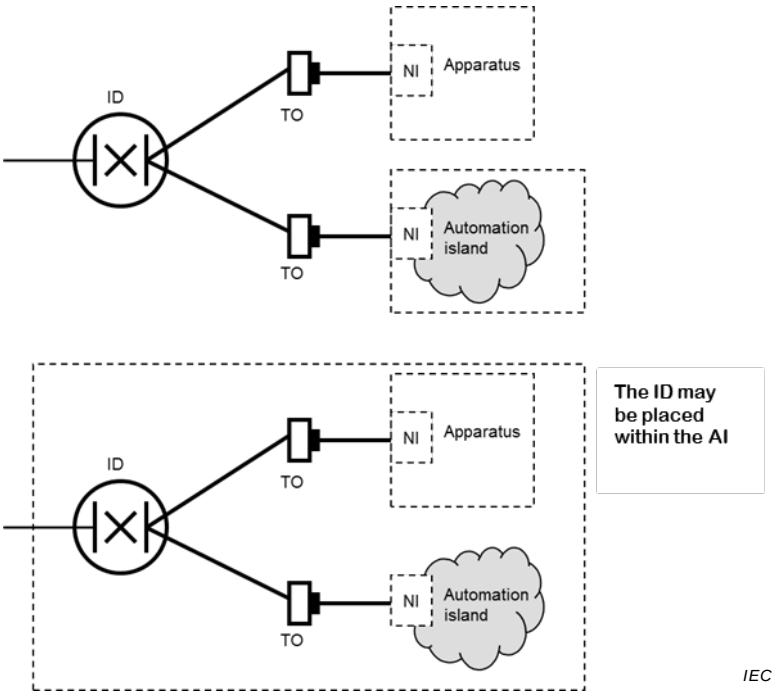


Figure 3 – Configuration of apparatus-based functional elements within industrial premises

5.3 Cabling subsystem

5.3.1 General structure

Generic cabling schemes for industrial premises contain up to four cabling subsystems: campus backbone, building backbone, floor and intermediate. In addition, cabling is necessary to connect telecommunication, process control and monitoring equipment to the generic cabling. This apparatus attachment cabling is application-specific and therefore not specified by this document. The composition of the subsystems is described in 5.3.2, 5.3.3 and 5.3.4. The cabling subsystems are connected together to create a generic cabling structure as shown in Figure 4.

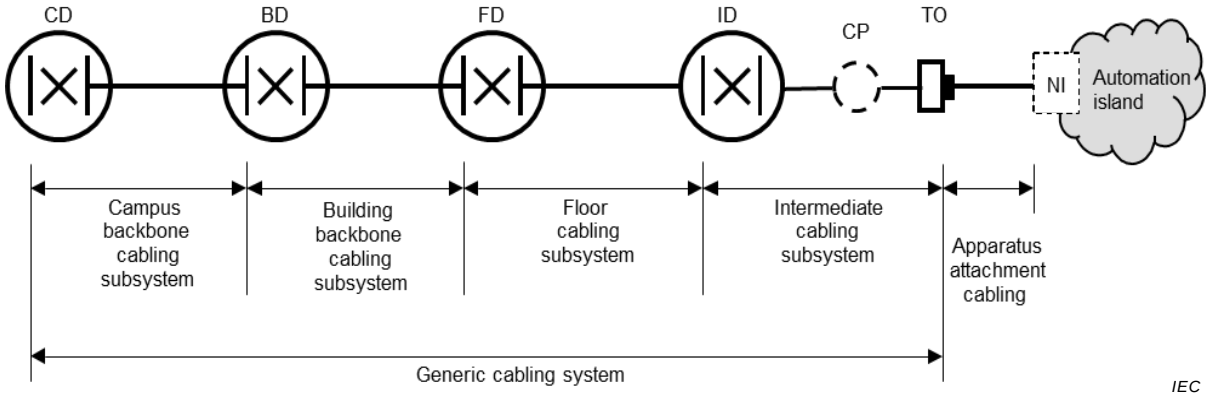


Figure 4 – Structure of generic cabling for industrial environment

Connections between cabling subsystems are either active, requiring application-specific equipment, or passive. Connection to application-specific equipment adopts either an interconnect or a cross-connect approach (see ISO/IEC 11801-1). Passive connections between cabling subsystems shall be achieved using cross-connections generally by way of either patch cords or jumpers.

Examples of more complex equipment connection systems that are not in accordance with Clause 5 are described in Annex A, Annex B and Annex C as follows.

a) Annex A describes the combined cabling structure of generic and industrial cabling system to connect several AIs via an ID to support critical process control, monitoring and automation data (PCMA).

b) Annex B describes reference implementations, using the components of Clauses 9, 10 and 11, which deliver transmission performance in accordance with the Classes of Clause 6.

c) Annex C describes reference implementations, using the components of Clauses 9, 10 and 11, that are capable of delivering transmission performance in accordance with the Classes of Clause 6 but are not able to be supported in a normative manner by this document.

5.3.2 Campus and building backbone cabling subsystem

See ISO/IEC 11801-1:2017, 5.3.2.

5.3.3 Floor cabling subsystem

The floor cabling subsystem extends from a floor distributor (FD) to the ID connected to it. The subsystem includes

a) the floor cables,

b) the mechanical termination of the floor cables including the connecting hardware (e.g. of interconnect or cross-connect) at the FD together with associated patch cords and/or jumpers, and any passive connections to the IDs,

c) any passive connections to the building backbone cabling.

Although equipment cords are included in a channel, they are not considered part of the cabling subsystem because they can be application-specific.

5.3.4 Intermediate cabling subsystem

The intermediate cabling subsystem extends from an ID to the TOs connected to it. The subsystem includes

a) the intermediate cables,

b) an optional CP,

c) the mechanical termination of the intermediate cables including the connections at the TO and the ID together with associated patch cords and/or jumpers at the ID,

d) the TO.

Although equipment cords and apparatus attachment cords are included in a channel, they are not considered part of the cabling subsystem because they can be application-specific.

Intermediate cables should be continuous from the ID to the TOs. The installation of a consolidation point in the intermediate cabling between the ID and the TO can useful in an open industrial space where the flexibility of relocating TOs is desired.

It is expected that the industrial environment is harsh and that the cabling is used to carry control and measurement data and therefore requires additional specifications, for example based on environmental performance requirements specified by MICE in ISO/IEC 11801-1.

The cabling within and between IDs and the automation islands shall meet the requirements of ISO/IEC 11801-1.

In the case where several AIs transmit critical process control, monitoring and automation data (PCMA) via an ID, an additional performance specification may be needed (see Annex A).

5.3.5 Centralized cabling architecture

Centralized cabling structures as shown in Figure 5 create combined backbone/horizontal channels. The channels are provided by passive connections in the distributors. The connections are achieved by using either cross-connections or interconnections. In addition, for centralized optical fibre cabling, it is possible to create connections at the distributors using splices although this reduces the ability of the cabling to support re-configuration.

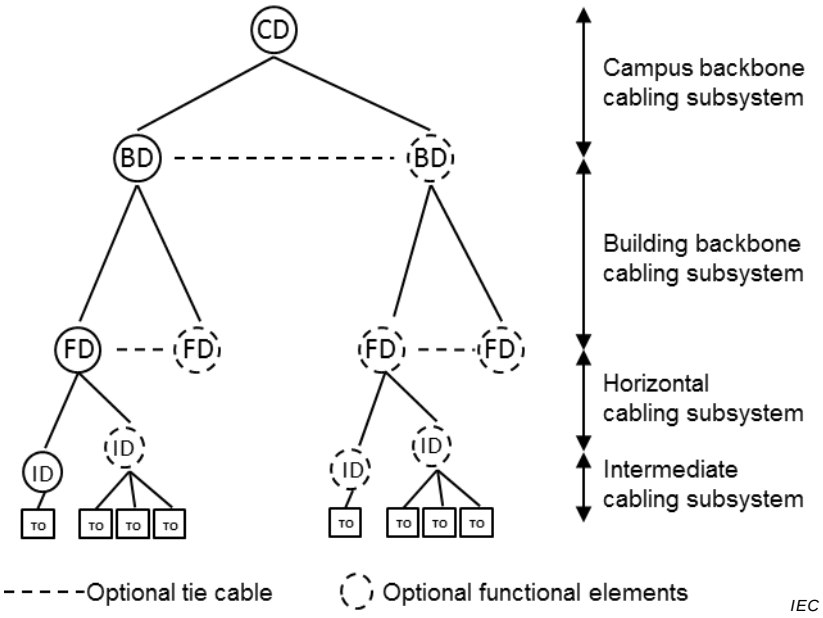


Figure 5 – Centralized structure of generic cabling for industrial premises

5.3.6 Design objectives

Intermediate cabling can be designed to support the broadest set of existing and emerging applications and therefore provide the longest operational life. This will minimize disruption and the high cost of re-cabling in the work area.

Floor and building backbone cabling can be designed for the entire life of the generic cabling system. However, it is common to adopt short-term approaches that support current and foreseeable application requirements, particularly where there is good physical access to

pathways. The selection of campus backbone cabling may require a longer-term approach than that adopted for the building backbone, particularly if access to pathways is more limited.

5.4 Interconnection of subsystems

In cabling for industrial premises, the functional elements of the cabling subsystems are interconnected to form a hierarchical structure as shown in Figure 6.

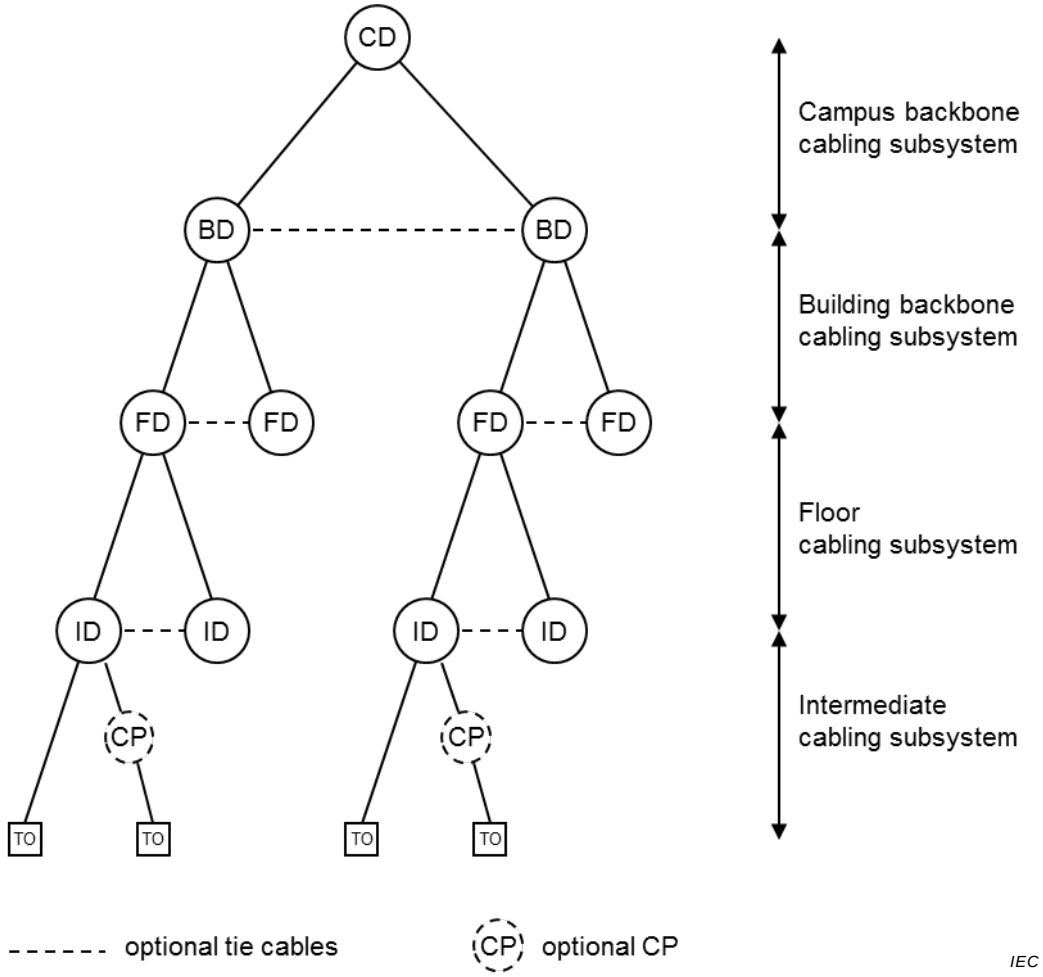


Figure 6 – Hierarchical structure of generic cabling for industrial premises

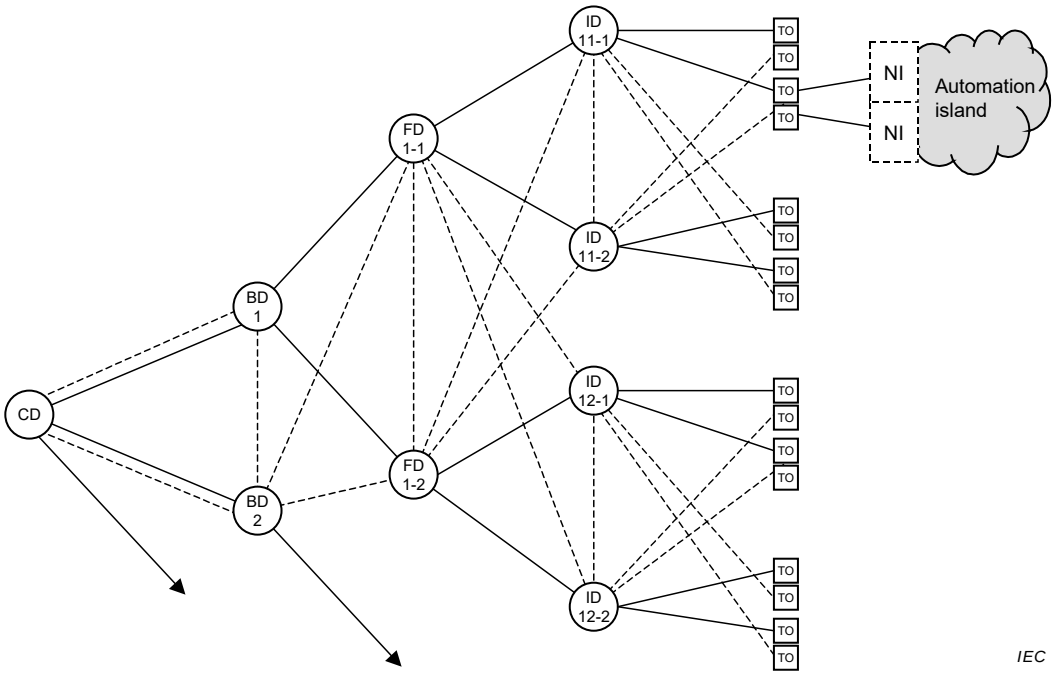


Figure 7 – Inter-relationship of functional elements in an installation with diversity for protection against failure (CPs optional between IDs and TOs)

In certain circumstances, for example for security or reliability reasons, redundancy can be built into a cabling design. Figure 7 is a schematic showing one of many possible examples of the connection of functional elements within the structured framework to provide such redundancy. This might form the basis for the design of generic cabling for a building, providing some protection against such hazards as fire damage or the failure of the cables providing connection to external service provision.

5.5 Accommodation of functional elements

Figure 8 shows an example of how the functional elements are accommodated in a building.

FDs and IDs are typically located in industrial enclosures, equipment rooms, telecommunications rooms or adjacent to, on or within apparatus. Other distributors are typically located in equipment rooms or telecommunications rooms as detailed in ISO/IEC 14763-2.

Cables are routed using pathways. A variety of cable management systems can be used to support the cables within the pathways including ducts, conduits and tray. Requirements for the pathways and the cable management systems within them are provided in ISO/IEC 14763-2 and IEC 61918.

TOs are normally located on the fixed building structure. If necessary, the TO can be placed within or on an apparatus.

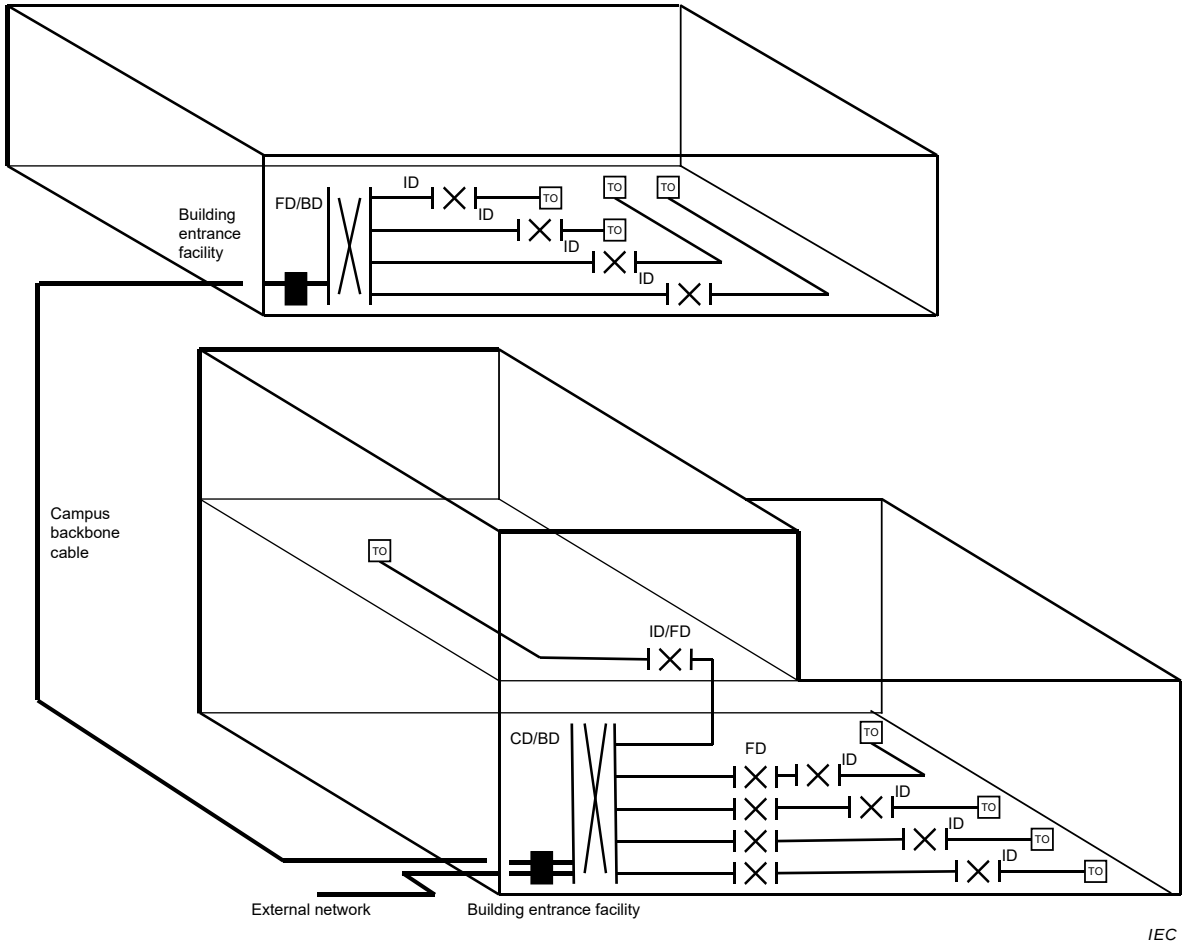


Figure 8 – Accommodation of functional elements (CPs optional between IDs and TOs)

5.6 Interfaces

5.6.1 Equipment interfaces and test interfaces

Equipment interfaces to generic cabling are located at the ends of each subsystem. Any distributor may have an equipment interface to an external service at any port.

Test interfaces to generic cabling are located at the ends of each subsystem.

Figure 9 shows the potential equipment and test interfaces.

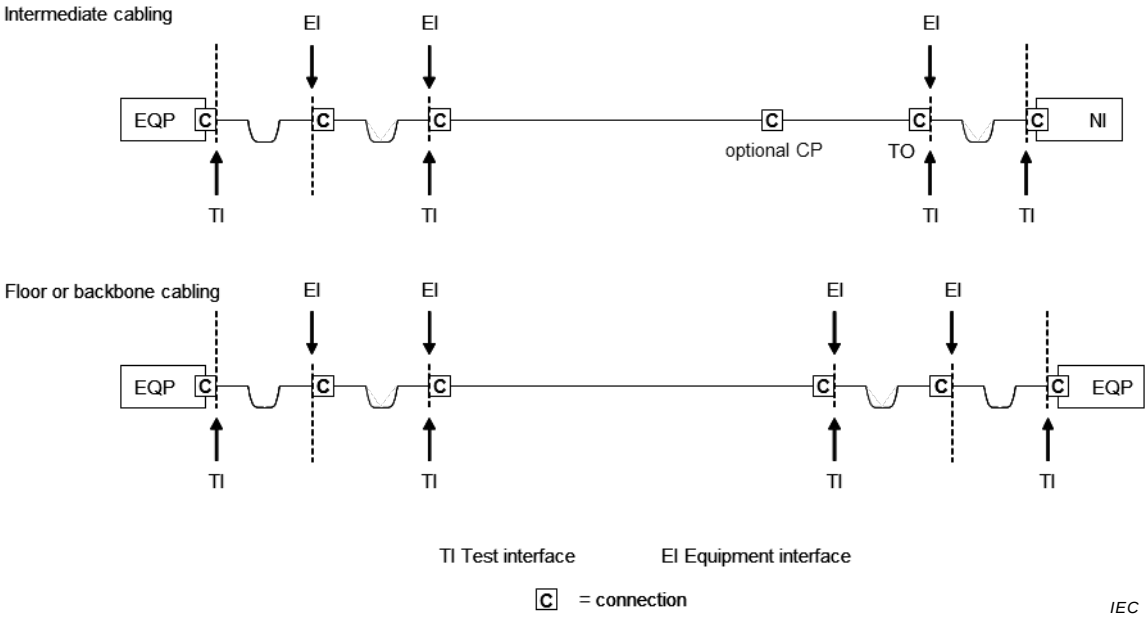


Figure 9 – Equipment and test interfaces

5.6.2 Channels and permanent links

The transmission performance of generic cabling between specific test interfaces is detailed in Clause 6 for channels and Clause 7 for permanent links.

The transmission performance of balanced 1-pair cabling between specific test interfaces is detailed in Annex E for channels.

The channel is the transmission path between active equipment interfaces. A typical channel would consist of the intermediate cabling subsystem together with apparatus attachment and equipment cords. For longer reach services the channel would be formed by the connection of two or more subsystems (again with apparatus attachment and equipment cords). It is important that the generic cabling channel is designed to meet the required performance for the applications that are to be supported. The channel excludes the mated connection at the active equipment.

5.7 Dimensioning and configuring

5.7.1 General

ISO/IEC 11801-1 specifies requirements for generic cabling. Subclauses 5.7.2 to 5.7.8 specify additional and/or modified requirements for generic cabling for industrial premises.

5.7.2 Distributors

The number and type of subsystems that are included in a generic cabling implementation depend upon the size and geography of the campus, building and the strategy of the user.

Usually there would be one campus distributor per campus. However, the number of BDs, FDs and IDs shall be determined by the size of the building, the floor space and the disposition of apparatus.

If the premises comprise only a single building that is small enough to be served by a single BD, there is no need for a campus backbone cabling subsystem.

The design of distributors shall ensure that the lengths of patch cords, jumpers and equipment cords are minimized and administration should ensure that the design lengths are maintained during operation. Distributors should be located such that the resulting cable lengths are consistent with the channel performance requirements of Clause 6

In the case of the reference implementations described in Clause 8, distributors shall be located to ensure that the channel lengths in Table 1 are not exceeded. However not all applications are supported over the maximum lengths shown in Table 1 using a single cable type.

Table 1 – Maximum channel lengths

Channel	Length m
Intermediate [a]	40
Intermediate	100
Intermediate [b]	1 000
Intermediate + horizontal + building backbone + campus backbone	10 000
NOTE In some implementations of the intermediate cabling subsystem in Clause 8, the ID might not support TOs up to the maximum distance shown. [a] for 40 m balanced 1-pair cabling [b] for 1 000 m balanced 1-pair cabling	

It is possible to combine multiple functional elements into a single element.

5.7.3 Connecting hardware

Connecting hardware shall provide only direct onward attachment for each conductor and shall not provide any contact between more than one incoming or outgoing conductor (e.g. bridge taps shall not be used).

5.7.4 Apparatus attachment and equipment cords

The apparatus attachment cord connects the TO to the network interface. Equipment cords connect active equipment to the generic cabling at distributors. Both are non-permanent and application-specific. The performance contribution of these cords shall be taken into account in the design of the channel.

Clause 8 provides guidance on cord lengths for reference implementations of generic cabling.

5.7.5 Patch cords and jumpers

Patch cords and jumpers are used within cross-connect implementations at distributors. The performance contribution of these cords shall be taken into account in the design of the channel. Clause 8 provides guidance on cord/jumper lengths for reference implementations of generic cabling.

5.7.6 Telecommunications outlet

The design of generic cabling for industrial premises should provide for TOs to be installed and located according to the requirements of the apparatus as follows.

a) Each apparatus network shall be served by a minimum of one TO.

b) The TO shall be configured with either balanced cable terminated in accordance with 10.2.2 or optical fibres terminated in accordance with 10.3.2.

c) The TO should terminate

- all pairs of four-pair balanced cable in accordance with 10.2.2.1

or the TO should terminate

- two pairs of a two-pair balanced cable in accordance with 10.2.2.2 may be used as an alternative to four pairs. However, four pairs per TO is recommended to support common applications. In the case of using two pairs per TO, pair reassignment might be required.

or

- 1-pair of a 1-pair balanced cable;

There shall be provision for identification, visible to the user, at the location of each TO.

d) Application-specific devices, if used, shall be external to the TO.

Care should be taken that the initial pair assignment and all subsequent changes are recorded (see ISO/IEC 14763-2 for details of recommended administration schemes). Pair reassignment by means of inserts is allowed.

5.7.7 Telecommunications rooms and equipment rooms

See ISO/IEC 11801-1.

5.7.8 Industrial enclosures

Industrial enclosures shall provide all the facilities (space, power), in accordance with national and local regulations, for industrial control equipment, ID and power distribution equipment. The equipment within the industrial enclosure will conform to the appropriate environmental classes outlined in Clause 6. The industrial enclosures can or cannot provide incremental environmental protection for their contents.

6 Channel performance requirements

6.1 General

Clause 6 specifies the minimum channel performance of generic cabling at and between the connections to active equipment as shown in Figure 10 and comprises only passive sections of cable, connecting hardware, cords and jumpers.

The channel performance is specified as a combination of environmental performance and transmission performance.

The minimum requirements for the transmission performance of cabling channels are specified in 6.3. The required transmission performance Class shall be met for all environmental performance Classes specified for the channel.

Compatibility between the structures and materials at the interfaces between these components and assemblies shall ensure that the required mechanical, environmental and transmission performance is maintained for the intended life of the cabling.

Where applications listed in ISO/IEC 11801-1:2017, Annex E, are to be supported, the performance of the connections at the active equipment are the responsibility of the equipment supplier.

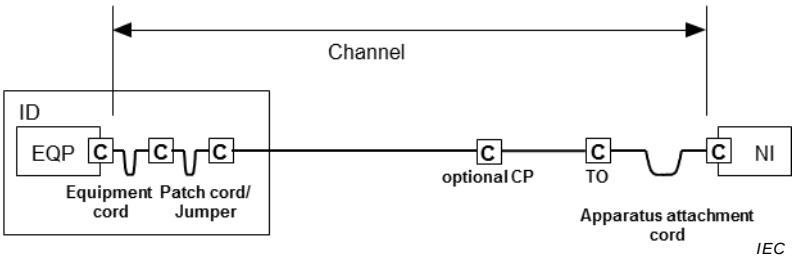


Figure 10 – Transmission performance of a channel

Application support depends on channel transmission performance, which in turn depends on cable length, the number of connections and the performance of the components within the environments to which the channel is subjected.

The required transmission performance Class shall be met for all environmental performance Classes specified for the channel.

Transmission and environmental performance shall be assured by the selection of cabling components suitable for the environmental Class(es) or by the use of pathway systems and installation practices that provide the required protection to the installed cabling.

Channels are implemented using

a) intermediate cabling only,

b) floor cabling only,

c) building backbone cabling only,

d) campus backbone cabling only,

e) combinations of the above.

Figure 11 shows an example of an NI connected to a host using two channels: an optical fibre channel and a balanced cabling channel. The optical fibre and balanced cabling channels are connected together using an optical fibre to balanced cable converter. There are four channel interfaces: one at each end of the balanced cabling channel, and one at each end of the optical fibre cabling channel.

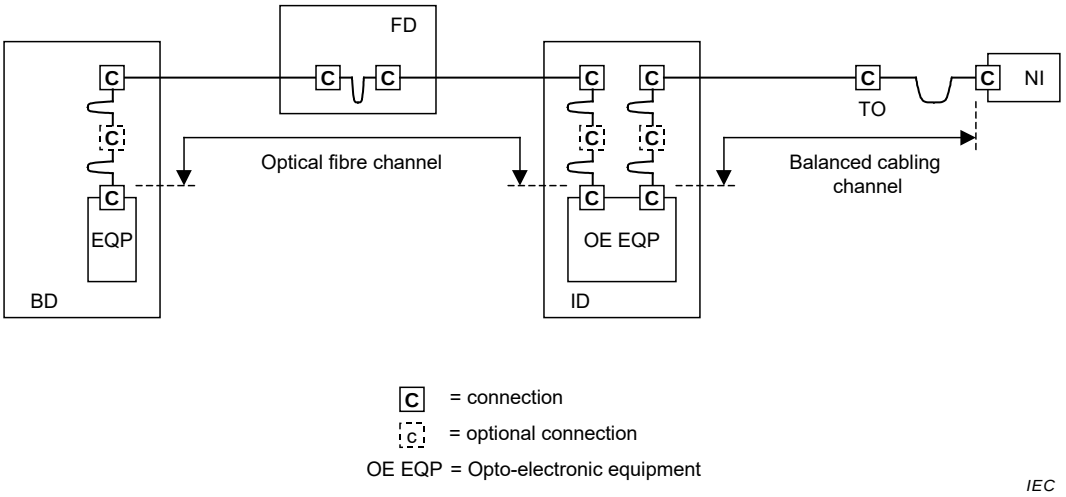


Figure 11 – Example of a system showing the location of cabling interfaces and extent of associated channels

6.2 Environmental performance

See ISO/IEC 11801-1:2017, 6.2.

6.3 Transmission performance

6.3.1 General

The channel performance requirements described in 6.3 shall be used for the design and may be used for verification of any implementation of this document, using the test methods defined, or referred to, by 6.3. In addition, these requirements can be used for application development and troubleshooting.

6.3.2 Balanced cabling

6.3.2.1 Backbone cabling

Backbone balanced cabling shall provide channel performance as required from Classes A to F_A as specified in ISO/IEC 11801-1:2017, 6.3.

6.3.2.2 Floor cabling

Floor balanced cabling shall comply with the channel performance as required from Classes D to F_A as specified in ISO/IEC 11801-1:2017, 6.3.

The implementation of channels of a lower Class, incorporating intermediate cabling, is discussed in Annex B and Annex C.

6.3.2.3 Intermediate cabling

Intermediate balanced cabling shall comply with the channel performance as required from Classes D to F_A as specified in ISO/IEC 11801-1:2017, 6.3.

Generic balanced 1-pair cabling shall comply with the channel performance as required by Annex C and ISO/IEC 11801-1.

For the applications specified in Annex E, 1-pair cabling shall comply with the channel performance as required by Annex C and Annex E.

6.3.2.4 Cable sharing

In the case of cable sharing, additional requirements shall be taken into account for balanced cabling. The additional crosstalk requirements are specified in ISO/IEC 11801-1:2017, 9.3.2.5.1.

In the case of cable sharing by using balanced 1-pair cabling channels, additional requirements shall be taken into account for balanced cabling in accordance with ISO/IEC 11801-1 and ISO/IEC TR 11801-9906:2020, Annex D.

6.3.3 Optical fibre cabling

The selection of optical fibre components shall take into account the applications to be supported, and the required channel lengths, and should take into account any predicted changes to the applications to be supported during the expected life of the cabling.

Cabling shall be designed using the cabled optical fibres referenced in 9.3 to provide channel performance as required to support the relevant applications of ISO/IEC 11801-1:2017, Annex E for the following parameters:

a) channel attenuation,

b) channel length.

Channel performance shall meet the requirements of ISO/IEC 11801-1:2017, 6.5.

7 Link performance requirements

7.1 General

A link comprises only passive sections of cable and connections. Compatibility between the structures and materials at the interfaces between these components shall ensure that the required mechanical, environmental and transmission performance is maintained for the intended life of the cabling.

7.2 Balanced cabling

Link performance shall meet the requirements of ISO/IEC 11801-1:2017, 7.2.

Generic balanced 1-pair cabling shall comply with the link performance as required by Annex C and ISO/IEC 11801-1.

For the applications specified in Annex E, 1-pair cabling shall comply with the link performance as required by Annex C and Annex E.

7.3 Optical fibre cabling

Link performance shall meet the requirements of ISO/IEC 11801-1:2017, 7.4.

8 Reference implementations

8.1 General

Clause 8 describes implementations of generic cabling that utilize components referenced in Clauses 9, 10 and 11. These reference implementations meet the requirements of Clause 5 and, when installed in accordance with ISO/IEC 14763-2 or IEC 61918, comply with the

channel transmission performance requirements of Clause 6 or performance requirements of Annex E in case balanced 1-pair cabling is installed.

8.2 Balanced cabling

8.2.1 General

Balanced components are referenced in Clauses 9, 10 and 11. In the case of already installed balanced 1-pair cabling channels for up to 1 000 m the performance shall be ensured. In the reference implementations of Clause 8, the components used in each cabling channel shall have the same nominal impedance.

The implementations are based on component performance at 20 °C. The effect of temperature on the performance of cables shall be accommodated by de-rating length as shown in Table 3 and Table 4. Where the temperature range exceeds that defined in ISO/IEC 11801-1 then manufacturers' information shall be consulted regarding required reductions in cable length.

Cables and connecting hardware of different Categories may be mixed within a channel. However, the resultant cabling performance will be determined by the Category of the lowest performing component.

8.2.2 Intermediate cabling subsystem

8.2.2.1 Component choice

The following reference implementations are applicable to intermediate cabling subject to the condition that components used shall meet the environmental requirements of Clauses 9, 10 and 11.

The selection of balanced cabling components will be determined by the Class to be met. Refer to ISO/IEC 11801-1:2017, Annex E, for applications supported by cabling Classes.

In order to maintain specific channel lengths under such conditions (due to the effect of ambient temperature and/or the impact of applications supported by the cabling),

a) Cables can be specified with lower insertion loss specifications than those detailed in 8.3.2 and 8.3.3, or

b) appropriate protection can be provided to reduce the operating temperature of the channel.

Using the configurations of 8.2.2.2,

1) Category 5 components provide Class D balanced cabling performance,

2) Category 6 components provide Class E balanced cabling performance,

3) Category 6_A or 8.1 components provide Class E_A balanced cabling performance,

4) Category 7 components provide Class F balanced cabling performance,

5) Category 7_A or 8.2 components provide Class F_A balanced cabling performance.

Using the configurations of 8.2.2.3,

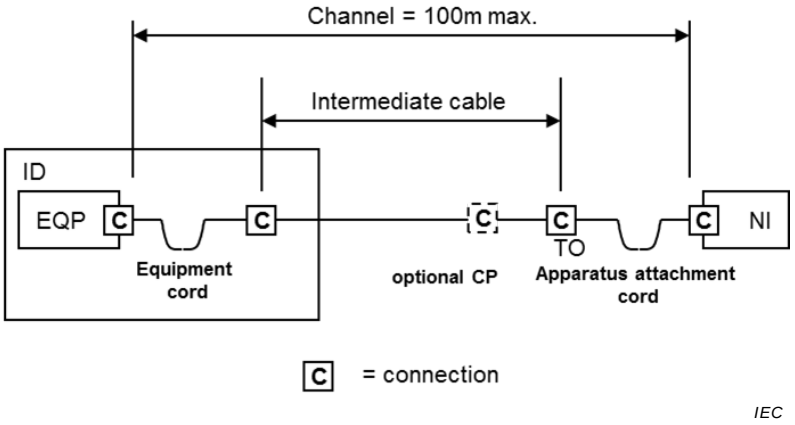
– cables in accordance with IEC 61156-11 and IEC 61156-12 and connectors in accordance with IEC 63171-6 provide cabling performance to the 600 MHz 40 m balanced 1-pair channel of Annex E;

NOTE Cables in accordance with two future parts of IEC 61156 (IEC 61156-13 and IEC 61156-14) and connectors in accordance with IEC 63171-6 will provide cabling performance to the 20 MHz 1 000 m balanced 1-pair channel of Annex E.

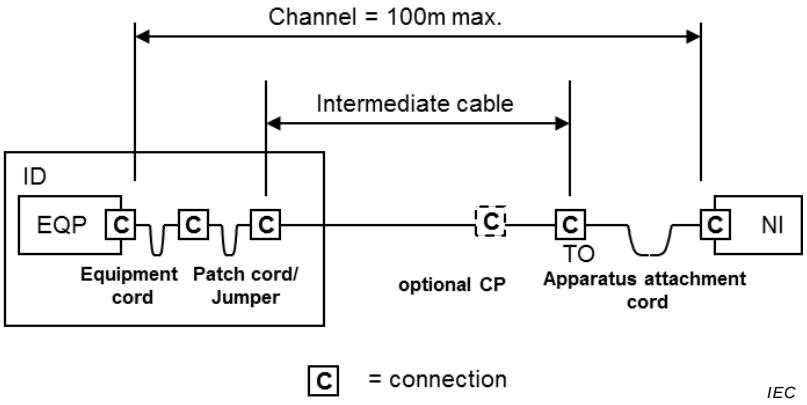
8.2.2.2 Dimensions

Figure 12 shows the models used to correlate intermediate cabling dimensions specified in Clause 8 with the channel specifications in Clause 6.

Figure 12a) shows a channel containing only an interconnect and a TO. Figure 12b) contains an additional connection as a cross-connect. In both cases the fixed horizontal cable connects the ID to the TO. The channel includes cords comprising patch cords/jumpers, equipment and apparatus attachment cords.



a) Interconnect – TO model



b) Cross-connect – TO model

Figure 12 – Intermediate cabling models

Table 2 contains the length assumptions of the mathematical model used to validate channel performance using components of Clauses 9, 10 and 11. They do not represent absolute restrictions on the implementation of channels and permanent links, but may be used for guidance in reference implementations.

Table 2 – Length assumptions used in the mathematical modelling of balanced intermediate cabling

Segment	Length m	
	Minimum	Maximum
ID-CP	15	85
CP-TO	5	-
ID-TO (no CP)	15	90
Apparatus attachment cord [a]	2	5
Patch cord	2	-
Equipment cord [b]	2	5
All cords	-	10

[a] If there is no CP, the minimum length of the apparatus attachment cord is 1 m.

[b] If there is no cross-connect, the minimum length of the equipment cord is 1 m.

In order to accommodate cables used for apparatus attachment cords, patch cords, jumpers and equipment cords with different insertion loss, the length of the cables used within a channel shall be determined by the equations shown in Table 3.

Table 3 – Intermediate link length equations

Model	Figure	Implementation equation		
		Class D	Class E and E_A	Class F and F_A
Interconnect – TO	12a)	$l_i = 109 - l_a \times X$	$l_i = 104 - l_a \times X$	$l_i = 105 - l_a \times X$
Cross-connect – TO	12b)	$l_i = 107 - l_a \times X$	$l_i = 103 - l_a \times X$	$l_i = 103 - l_a \times X$

l_i maximum length of the intermediate cable (m)

l_a combined length of patch cords/jumpers, equipment and apparatus attachment cords (m)

X ratio of cord cable insertion loss (dB/m) to fixed horizontal cable insertion loss (dB/m)

For operating temperatures above 20 °C, l_i should be reduced by 0,2 % per °C for screened cables; 0,4 % per °C (20 °C to 40 °C) and 0,6 % per °C (> 40 °C to 60 °C) for unscreened cables.

For the purpose of calculation in Table 3 it is assumed that

a) the flexible cable within these cords has a higher insertion loss than that used in the intermediate cable (see 11.2),

b) all the cords in the channel have a common insertion loss specification.

The following general restrictions apply.

1) The physical length of the channel shall not exceed 100 m.

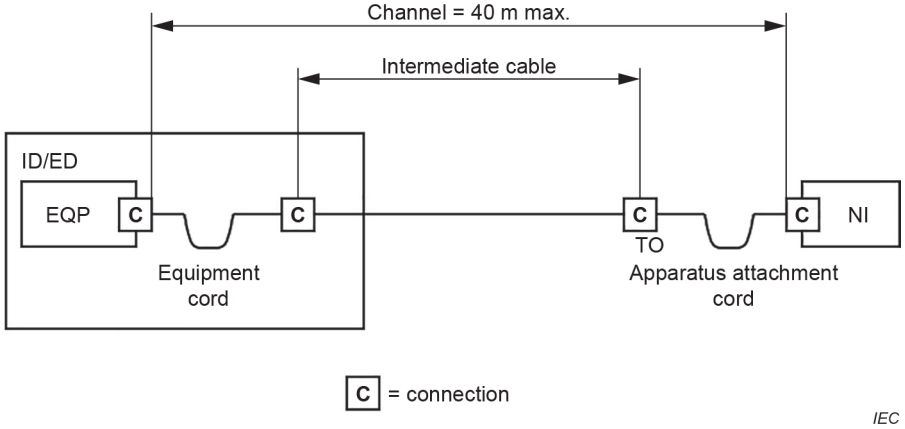
2) The physical length of the intermediate cable shall not exceed 90 m. When the total length of patch, equipment and apparatus attachment cords exceeds 10 m, the allowed physical length of the intermediate cable shall be reduced according to Table 3.

3) The length of patch cords/jumper cables should not exceed 5 m.

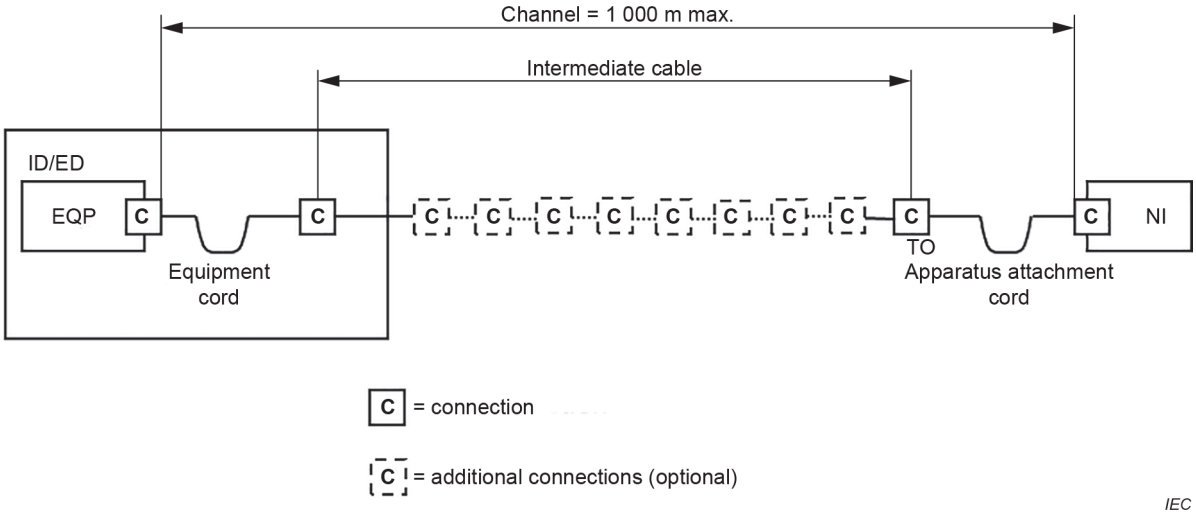
The maximum length of the intermediate cable will depend on the total length of cords to be supported within a channel. During the operation of the installed cabling, a management system should be implemented to ensure that the cords and jumper cables used to create the channel conform to the design rules for the floor, building or installation.

8.2.2.3 Balanced 1-pair cabling dimensions

Figure 15a) shows a 40 m balanced 1-pair channel (40 m interconnect – TO model). Figure 15b) shows a 1 000 m balanced 1-pair channel (1 000 m interconnect – TO model).



a) Interconnect – TO model balanced 1-pair cabling channel 40 m



b) Interconnect – TO model balanced 1-pair cabling channel 1 000 m with up to 10 connections

Figure 15 – Balanced 1-pair intermediate cabling models

Table 5 and Table 6 contain the length assumptions of the 40 m and the 1 000 m, respectively, balanced 1-pair intermediate cabling.

Table 5 – Length assumptions used in mathematical modelling of the 40 m balanced 1-pair intermediate cabling

Segment	Length m	
	minimum	maximum
ID – TO (no CP) [a]	5	34
Apparatus attachment cord	1	3
Equipment cord	1	3
All cords	–	6

[a] Either consists of 34 m cabling and two 3 m cords or can be an end-to-end link configuration (but end-to-end links do not include a TO).

–

Table 6 – Length assumptions used in mathematical modelling of the 1 000 m balanced 1-pair intermediate cabling

Segment	Length m	
	minimum	maximum
ID – TO (no CP) [a]	15	990
Apparatus attachment cord	1	5
Equipment cord	1	5
All cords	–	10
[a] Allows up to two 5 m cords.		

In order to accommodate cables used for apparatus attachment cords, patch cords, jumpers and equipment cords with different insertion loss, the length of the cables used within a channel shall be determined by the equations shown in Table 7.

Table 7 – Balanced 1-pair intermediate link length equations

Model	Figure	Implementation equation	
		new T1 class for 600 MHz 40 m channel	new T1 class for 20 MHz 1 000 m channel
Interconnect – TO (1-pair, 40 m)	15a	ffs	not applicable
Interconnect – TO (1-pair, 1 000 m)	15b	not applicable	ffs
l_i maximum length of the intermediate cable (m) l_a combined length of patch cords/jumpers, equipment and apparatus attachment cords (m) X ratio of cord cable insertion loss (dB/m) to fixed horizontal cable insertion loss (dB/m)			
For operating temperatures above 20 °C, l_i should be reduced by 0,2 % per °C for screened cables; 0,4 % per °C (20 °C to 40 °C) and 0,6 % per °C (> 40 °C to 60 °C) for unscreened cables.			

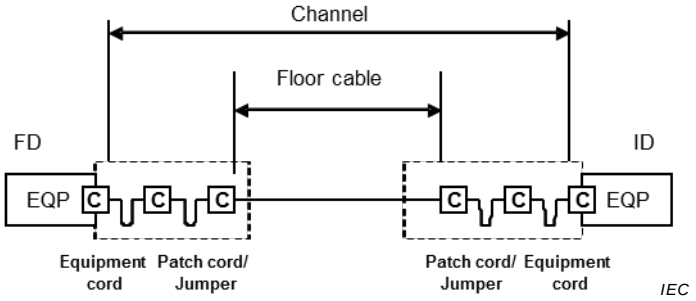
8.2.3 Floor cabling subsystem

8.2.3.1 Component choice

The selection of balanced components will be determined by the channel lengths required and the class of applications to be supported. Refer to ISO/IEC 11801-1:2017, Annex E, for guidance.

8.2.3.2 Dimensions

Figure 13 shows the model used to correlate cabling dimensions specified in Clause 8 with the channel specifications in Clause 6. The channel shown contains a cross-connect at each end. This represents the maximum configuration for a Class D, E, E_A, F or F_A floor channel. The channel includes additional cords comprising patch cords/jumpers and equipment cords.



EQP = equipment; C = connection (mated pair)

Figure 13 – Floor cabling model

In order to accommodate the higher insertion loss of cables used for patch cords, jumpers and equipment cords, the length of the cables used within a channel of a given Class shall be determined by the equations shown in Table 4.

In Table 4 it is assumed that

a) the flexible cable within these cords can have a higher insertion loss than that used in the floor cable,

b) all the cords in the channel have a common insertion loss specification.

The following general restrictions apply for Classes D, E, E_A, F and F_A.

1) The physical length of channels shall not exceed 100 m.

2) When four connections are used in a channel, the physical length of the floor cable should be at least 15 m.

The maximum length of the floor cable will depend on the total length of cords to be supported within a channel. The maximum lengths of cords shall be set during the design phase and a management system is required to ensure that these lengths are not exceeded during the operation of the cabling system.

Table 4 – Floor link length equations

Component Category	Floor implementation equations				
	Class D	Class E	Class E_A	Class F	Class F_A
5	$l_{fb} = 105 - l_a \times X$	–	–	–	–
6	$l_{fb} = 111 - l_a \times X$	$l_{fb} = 102 - l_a \times X$	–	–	–
6_A or 8.1	$l_{fb} = 114 - l_a \times X$	$l_{fb} = 105 - l_a \times X$	$l_{fb} = 102 - l_a \times X$	–	–
7	$l_{fb} = 115 - l_a \times X$	$l_{fb} = 106 - l_a \times X$	$l_{fb} = 104 - l_a \times X$	$l_{fb} = 102 - l_a \times X$	–
7_A or 8.2	$l_{fb} = 117 - l_a \times X$	$l_{fb} = 108 - l_a \times X$	$l_{fb} = 102 - l_a \times X$	$l_{fb} = 102 - l_a \times X$	$l_{fb} = 102 - l_a \times X$

l_{fb} maximum length of the floor or backbone cable (m)

l_a combined length of patch cords/jumpers and equipment cords (m)

X ratio of cord cable insertion loss (dB/m) to backbone cable insertion loss (dB/m)

Where channels contain a different number of connections than in the model shown in Figure 13, the fixed cable length is reduced (where more connections exist) or increased (where fewer connections exist) by 2 m per connection for Category 5 cables and 1 m per connection for Category 6, 6_A, 7 and 7_A cables. Additionally, the NEXT, return loss (RL) and ACR-F performance should be verified.

For operating temperatures above 20 °C, l_{fb} should be reduced by 0,2 % per °C for screened cables; 0,4 % per °C (20 °C to 40 °C) and 0,6 % per °C (> 40 °C to 60 °C) for unscreened cables.

8.2.4 Campus and building backbone cabling subsystem

See ISO/IEC 11801-1:2017, 8.2.

8.3 Optical fibre cabling

See ISO/IEC 11801-1:2017, 8.3.

In order to accommodate increased quantities of mated connections and splices used within a channel, the total length of the channels is typically reduced to accommodate the additional attenuation.

Additional connections may be used if the maximum channel insertion loss (or optical power budget, as applicable) of the application allows (see ISO/IEC 11801-1:2017, Annex E).

9 Cable requirements

9.1 General

Clause 9 defines the minimum requirements for

a) cables installed in the intermediate, floor and backbone cabling subsystems specified in Clause 5 and used in the reference implementations of Clause 8,

b) flexible balanced cables to be assembled as cords as specified in Clause 11 and used in the reference implementations of Clause 8,

c) balanced cables or cable elements to be used as jumpers.

9.2 Balanced cables

See ISO/IEC 11801-1:2017, 9.3.1 and 9.3.2. For balanced 1-pair cables with transmission characteristics up to 600 MHz, see IEC 61156-11 and IEC 61156-12.

NOTE Future parts of IEC 61156 (IEC 61156-13 and IEC 61156-14) will specify requirements for balanced 1-pair cables with transmission characteristics up to 20 MHz.

9.3 Optical fibre cables

Cabled optical fibres shall meet the requirements of ISO/IEC 11801-1:2017, 9.5.

10 Connecting hardware requirements

10.1 General requirements

Connecting hardware is installed:

a) in a campus distributor permitting connections to building backbone and campus backbone cabling and equipment (if provided);

b) in a building distributor permitting connections to the backbone cabling and equipment (if provided);

c) in a floor distributor providing the cross-connections between backbone and floor cabling and permitting connections to equipment (if provided);

d) in an intermediate distributor providing the cross-connections between floor and intermediate cabling and permitting connections to equipment (if provided);

e) at the TO;

f) at bulkheads.

10.2 Connecting hardware for balanced cabling

10.2.1 General requirements

See ISO/IEC 11801-1:2017, 10.1.

10.2.2 Electrical, mechanical and environmental performance

10.2.2.1 Connecting hardware at the TO using four pairs at the TO

See ISO/IEC 11801-1:2017, 10.2, 10.6 and 10.9.

Where space is a consideration and a smaller interface is needed, connecting hardware meeting the mechanical and physical requirements of IEC 61076-2-109 X-coding may also be used.

Pair rearrangement at the TO should not involve modification of the intermediate cable terminations. If pair rearrangement is used at the TO, the configuration of the outlet terminations shall be clearly identified.

10.2.2.2 Connecting hardware at the TO using two pairs at the TO

Where a smaller housing is required and where the provision of only two balanced pairs is acceptable, connecting hardware meeting the mechanical and physical requirements of IEC 61076-2-101 D-coding may also be used as an alternative to that specified in 10.2.2.1. See ISO/IEC 11801-1:2017, 10.2 and 10.8.

If four pair cables are used with two pair connectors, the unused pairs shall be terminated to match the nominal impedance of the cable pairs. The same pair count shall be used throughout the link or channel.

When two physically similar cabling links are used in the same installation (for example, different performance categories and cables with different nominal impedance) special precautions are required to ensure that they are properly identified.

10.2.2.3 Connecting hardware at other locations

The requirements of 10.2.2.1 and 10.2.2.2 are based upon the categories of connecting hardware specified in the reference implementations of Clause 8. For channel, permanent link, and CP link design routes to conformance, as specified in Clause 4, other connecting hardware can be used at places other than the TO.

10.2.2.4 Connecting hardware at the TO using balanced 1-pair cable at the TO

Where balanced 1-pair cabling is installed, connecting hardware meeting the mechanical and physical requirements of IEC 63171-6 shall be used.

For connecting hardware in $M_1I_1C_1E_1$ installation environments within industrial premises, refer to ISO/IEC 11801-1.

10.3 Connecting hardware for optical fibre cabling

10.3.1 General requirements

See ISO/IEC 11801-1:2017, 10.1.

10.3.2 Optical, mechanical and environmental performance

10.3.2.1 Connecting hardware at the TO

See ISO/IEC 11801-1:2017, 10.5.

The connecting hardware shall be as specified in IEC 61754-20 (LC connector family).

10.3.2.2 Connecting hardware at other locations

See ISO/IEC 11801-1:2017, 10.5.

11 Cords

11.1 Jumpers

See Clause 9.

11.2 Balanced cords

11.2.1 General

See ISO/IEC 11801-1:2017, 11.1, 11.2 and 11.3.

NOTE Requirements for balanced 1-pair cabling will be given in a future Amendment 1 to ISO/IEC 11801-1:2017.

Cords shall be assembled using flexible cables in accordance with ISO/IEC 11801-1:2017, 9.3 and connectors in accordance with Clause 10 with the exception of the equipment connectors used on apparatus attachment and equipment cords that lie outside the scope of this document.

11.2.2 Additional requirements for apparatus attachment cords

Apparatus attachment cords shall only be assembled using flexible cables as defined in ISO/IEC 11801-1:2017, 9.3.2.6.

11.3 Optical fibre cords

See ISO/IEC 11801-1, 11.1, 11.2 and 11.5.

Annex A
(normative)

Industrial cabling system

A.1 General

An automation island (AI) can be connected to the generic cabling by the intermediate cabling subsystem as described in 5.3.4 and shown in Figure 4.

In the case where several AIs transmit critical process control, monitoring and automation data (PCMA) via a distributor additional performance specifications may be needed defined by IEC 61918 and the intermediate distributor (ID) of Clause 5 is replaced by an industrial intermediate distributor (IID) which serves an industrial cabling system.

An IID may also serve TOs in accordance with Clause 5 with intermediate cabling subsystem channels in accordance with Clause 6.

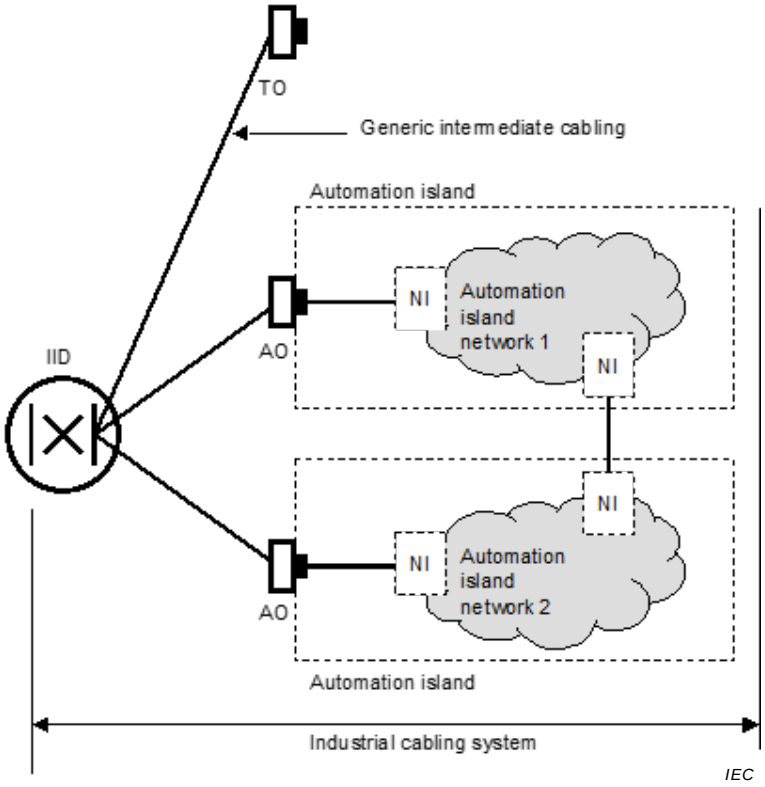


Figure A.1 – Industrial cabling system supporting several AIs via an IID

In the case where an industrial intermediate distributor is installed, TOs can become AOs. For connecting hardware requirements at the TO(s) see ISO/IEC 11801-1:2017, 10.6, 10.8, 10.9 and 10.11. Where connections provide dedicated support for applications specified by the IEC 61784-5 series, the TO becomes an AO and the AI interfaces of IEC 61918 should be used.

For operating requirements according to the environmental classes of MICE specification, see ISO/IEC 11801-1:2017, 10.1.4.

A.2 Industrial intermediate cabling subsystem

The industrial intermediate cabling subsystem starts with and extends from an IID to the TO(s) or AO(s) connected to it or it extends directly from the IID to the NI of AIs and/or apparatus (see Figure A.2). The subsystem includes

a) the IID,

b) the industrial intermediate cables,

c) the mechanical termination of the industrial intermediate cables including the connections at the TO or AO and the IID together with associated patch cords and/or jumpers at the IID,

d) the TO or AO – optional.

e) the ED – optional.

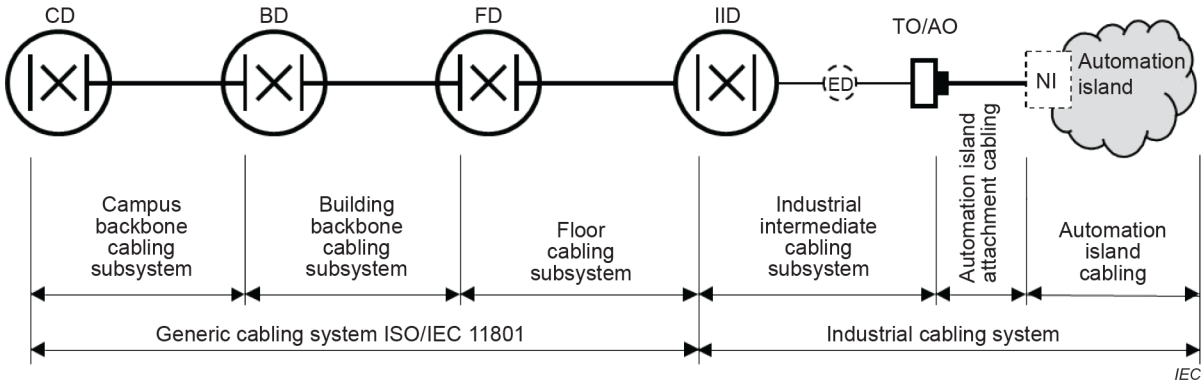


Figure A.2 – Combined structure of generic and industrial cabling system using an IID with optional ED

The industrial intermediate cabling subsystem supports one or more applications defined by IEC 61784-5 series but not necessarily all applications defined by ISO/IEC 11801. The industrial intermediate cabling subsystem delivers connections between AI(s) and/or industrial apparatus going through the IID and directly between AI(s) and/or industrial apparatus (see Figure A.1). The industrial intermediate cabling may include an edge distributor (ED) to accommodate active equipment to allow transition from balanced 4-pair cabling to balanced 1-pair cabling.

Industrial intermediate cabling subsystems shall conform at a minimum to the requirements of ISO/IEC 11801-1 and ISO/IEC 11801-2 and the TCL, ELTCTL and coupling attenuation shall be as defined in IEC 61918.

Annex B
(normative)

Additional reference implementations

B.1 General

Annex B describes implementations of generic cabling that utilize components referenced in Clauses 9, 10 and 11. These additional reference implementations do not meet the requirements of Clause 5 and thus are non-conformant. When installed in accordance with ISO/IEC 14763-2 and IEC 61918, they comply with the channel transmission performance requirements of Clause 6 based on a statistical approach of performance modelling.

B.2 Channel configurations

B.2.1 General

B.2.2 discusses channels with no intermediate connections. B.2.3 discusses inter-connections only. Both consider the channel according to the definition in ISO/IEC 11801-1.

In addition, B.2.4 describes a cabling definition called end-to-end link (E2E link), which is defined and explained in ISO/IEC TR 11801-9902.

B.2.2 Channels with no connections

Figure B.1 shows

a) an intermediate cabling channel created without intermediate connections,

b) a floor distribution channel created without intermediate connections,

c) a combined intermediate and floor distribution channel created without intermediate connections.

For balanced cabling, the length of the channel shall be determined by using N = 0 and l_a = 0 within the equations shown in Table B.1.

It should be noted that although reassignment of cable elements is possible at one or other of the ends of the cable as required by the application-specific equipment, this will create difficulties for the testing of such installed cabling.

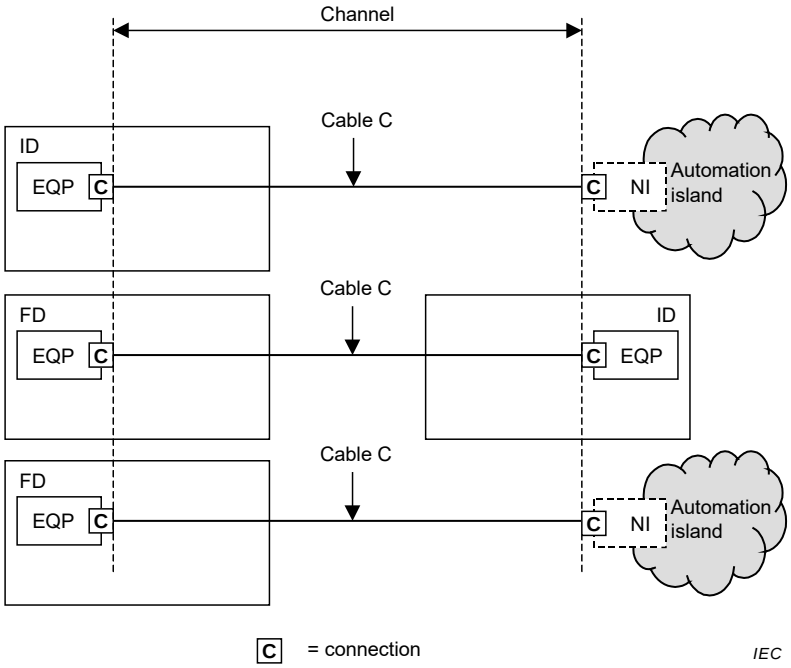


Figure B.1 – Channel configurations without intermediate connections

B.2.3 Channels with inter-connections

Figure B.2 shows the channels of Figure B.1 with the addition of an interconnect panel and an equipment cord at the distributor(s).

For balanced cabling, the length of the channel shall be determined by the equations shown in Table B.1.

In Table B.1 it is assumed that

a) the flexible cable within the equipment cord(s) has a higher insertion loss specification than that used in the fixed cable (see 9.2),

b) the cables within these cords in the channel have a common insertion loss specification.

The maximum length of the fixed cable will depend on the total length of cords to be supported within a channel. During the operation of the installed cabling, a management system should be implemented to ensure that the cords used to create the channel conform with the design rules for the floor, building or installation.

It should be noted that although reassignment of cable elements is possible at one or other of the ends of the cords as required by the application-specific equipment, this will create difficulties for the testing of such a channel.

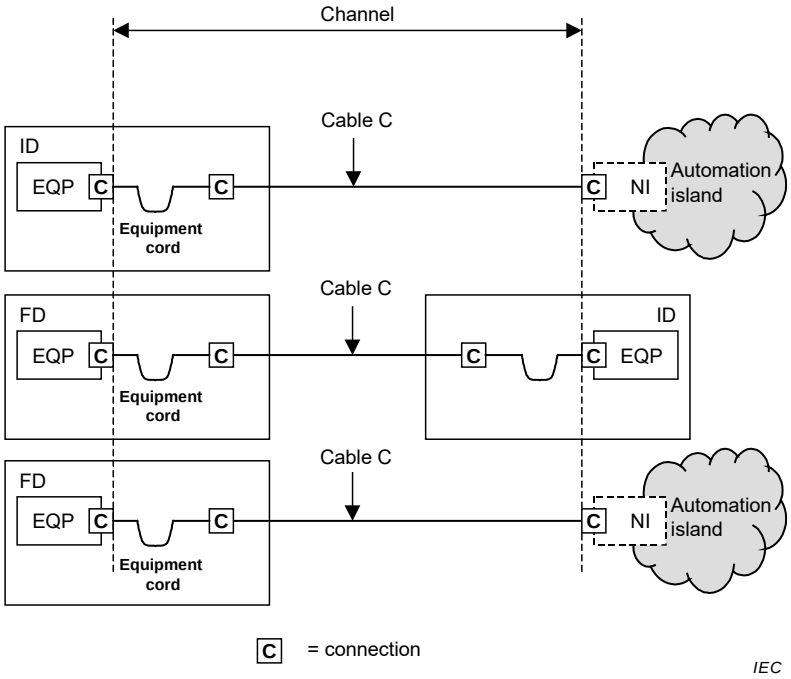


Figure B.2 – Channel configurations with inter-connections

Table B.1 – Channel length equations for balanced cabling with inter-connections

Component Category	Channel length equations							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
5	2 000	$(258 - 2N - l_a \times Y)/X$	$(178 - 2N - l_a \times Y)/X$	$(113 - 2N - l_a \times Y)/X$	–	–	–	–
6	2 000	$(268 - N - l_a \times Y)/X$	$(193 - N - l_a \times Y)/X$	$(115 - N - l_a \times Y)/X$	$(106 - N - l_a \times Y)/X$	–	–	–
6_A or 8.1	2 000	$(268 - N - l_a \times Y)/X$	$(197 - N - l_a \times Y)/X$	$(118 - N - l_a \times Y)/X$	$(109 - N - l_a \times Y)/X$	$(106 - N - l_a \times Y)/X$	–	–
7	2 000	$(268 - N - l_a \times Y)/X$	$(198 - N - l_a \times Y)/X$	$(119 - N - l_a \times Y)/X$	$(110 - N - l_a \times Y)/X$	$(108 - N - l_a \times Y)/X$	$(106 - N - l_a \times Y)/X$	–
7_A or 8.2	2 000	$(268 - N - l_a \times Y)/X$	$(200 - N - l_a \times Y)/X$	$(121 - N - l_a \times Y)/X$	$(112 - N - l_a \times Y)/X$	$(106 - N - l_a \times Y)/X$	$(106 - N - l_a \times Y)/X$	$(106 - N - l_a \times Y)/X$

N number of inter-connections in the channel

l_a combined length of the equipment cords (m)

X ratio of the insertion loss of the cable C (dB/m) to fixed cable attenuation (dB/m) – see Clause 9

Y ratio of the equipment cord cable insertion loss (dB/m) to fixed cable attenuation (dB/m) – see Clause 9

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

B.2.4 End-to-end link (E2E link)

In addition to the channels discussed in B.2.2 and B.2.3 there is a cabling definition called end-to-end link (E2E link). This implementation is defined and specified in ISO/IEC TR 11801-9902.

ISO/IEC 14763-4 describes the measurement of E2E links of two- and four-pair balanced cabling up to 250 MHz using field testing and laboratory equipment.

B.3 Channels using balanced cabling bulkhead connections

Bulkhead connector assemblies can consist of one free and one fixed connector (jack-plug) assembly with a cable attached or two back-to-back jacks meeting the distance specifications defined by IEC 61918 for a specific transmission class.

Figure B.3 shows an intermediate cabling channel and a floor distribution channel created using a fixed cable terminated at a closure bulkhead.

The length of the fixed cable used within a channel shall be determined by the equations shown in Table B.2.

In Table B.2 it is assumed that

a) the flexible cable within these cords has a higher insertion loss specification than that used in the fixed cable (see Clause 9),

b) the cables within these cords in the channel have a common insertion loss specification.

The maximum length of the fixed cable will depend on the total length of cords to be supported within a channel. During the operation of the installed cabling, a management system should be implemented to ensure that the cords used to create the channel conform to the design rules for the floor, building or installation.

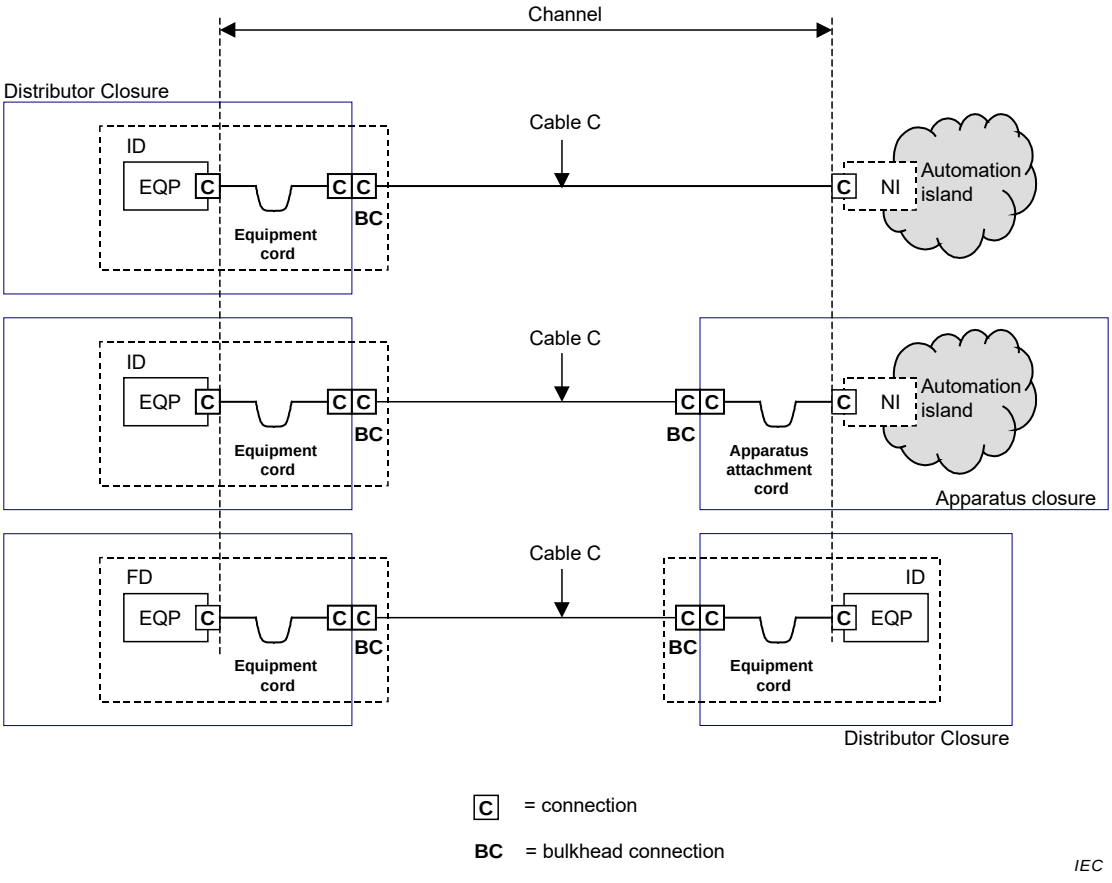


Figure B.3 – Channel configurations with bulkhead connections

Table B.2 – Channel length equations with bulkhead connections

Component Category	Channel length equations for balanced cabling							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
5	2 000	$(258 - 5M - 2N - l_a \times Y)/X$	$(178 - 5M - 2N - l_a \times Y)/X$	–	–	–	–	–
6	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(193 - 5M - N - l_a \times Y)/X$	$(115 - 5M - N - l_a \times Y)/X$	–	–	–	–
6_A	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(197 - 5M - N - l_a \times Y)/X$	$(118 - 5M - N - l_a \times Y)/X$	$(109 - 5M - N - l_a \times Y)/X$	–	–	–
7	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(198 - 5M - N - l_a \times Y)/X$	$(119 - 5M - N - l_a \times Y)/X$	$(110 - 5M - N - l_a \times Y)/X$	$(108 - 5M - N - l_a \times Y)/X$	–	–
7_A	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(200 - 5M - N - l_a \times Y)/X$	$(121 - 5M - N - l_a \times Y)/X$	$(112 - 5M - N - l_a \times Y)/X$	$(106 - 5M - N - l_a \times Y)/X$	$(106 - 5M - N - l_a \times Y)/X$	–

M number of bulkhead connections in the channel

N number of connections in the channel

l_a combined length of the equipment cords (m)

X ratio of the insertion loss of the cable C (dB/m) to fixed cable attenuation (dB/m) – see Clause 9

Y ratio of the equipment cord cable insertion loss (dB/m) to fixed cable attenuation (dB/m) – see Clause 9

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

The bulkhead connection is considered to comprise a "back-to-back" connection as described in ISO/IEC 11801-1:2017, 10.2.5.2., as follows:

However, the physical implementation of bulkhead connections typically features a very short cable length and the connection transmission performance may fall below that defined above.

It should be noted that the following reference implementations may not be supported if multiple bulkhead connections are used:

a) Class D channels using Category 5 components;

b) Class E channels using Category 6 components;

c) Class E_A channels using Category 6_A components;

d) Class F channels using Category 7 components;

e) Class F_A channels using Category 7_A components.

If any of the above implementations are desired then a single connection at a bulkhead is recommended.

Annex C
(informative)

Other implementations

C.1 General

Annex C describes implementations, using the components of Clauses 9, 10 and 11, that are capable of delivering transmission performance in accordance with the Classes of Clause 6 for cabling structures that are not supported by Clause 5. These implementations cannot be supported in a normative manner by this document.

C.2 Channels using balanced cabling bulkhead connections with additional connections

Figure C.1 shows intermediate and floor distribution channels created using a fixed cable terminated at one or more closure bulkheads with additional connections associated with those bulkhead connections.

The length of the fixed cable used within a channel shall be determined by the equations shown in Table C.1.

In Table C.1 it is assumed that

a) the flexible cable within these cords has a higher insertion loss specification than that used in the fixed cable (see Clause 9),

b) the cables within these cords in the channel have a common insertion loss specification.

The maximum length of the fixed cable will depend on the total length of cords to be supported within a channel. During the operation of the installed cabling, a management system should be implemented to ensure that the cords used to create the channel conform with the design rules for the floor, building or installation.

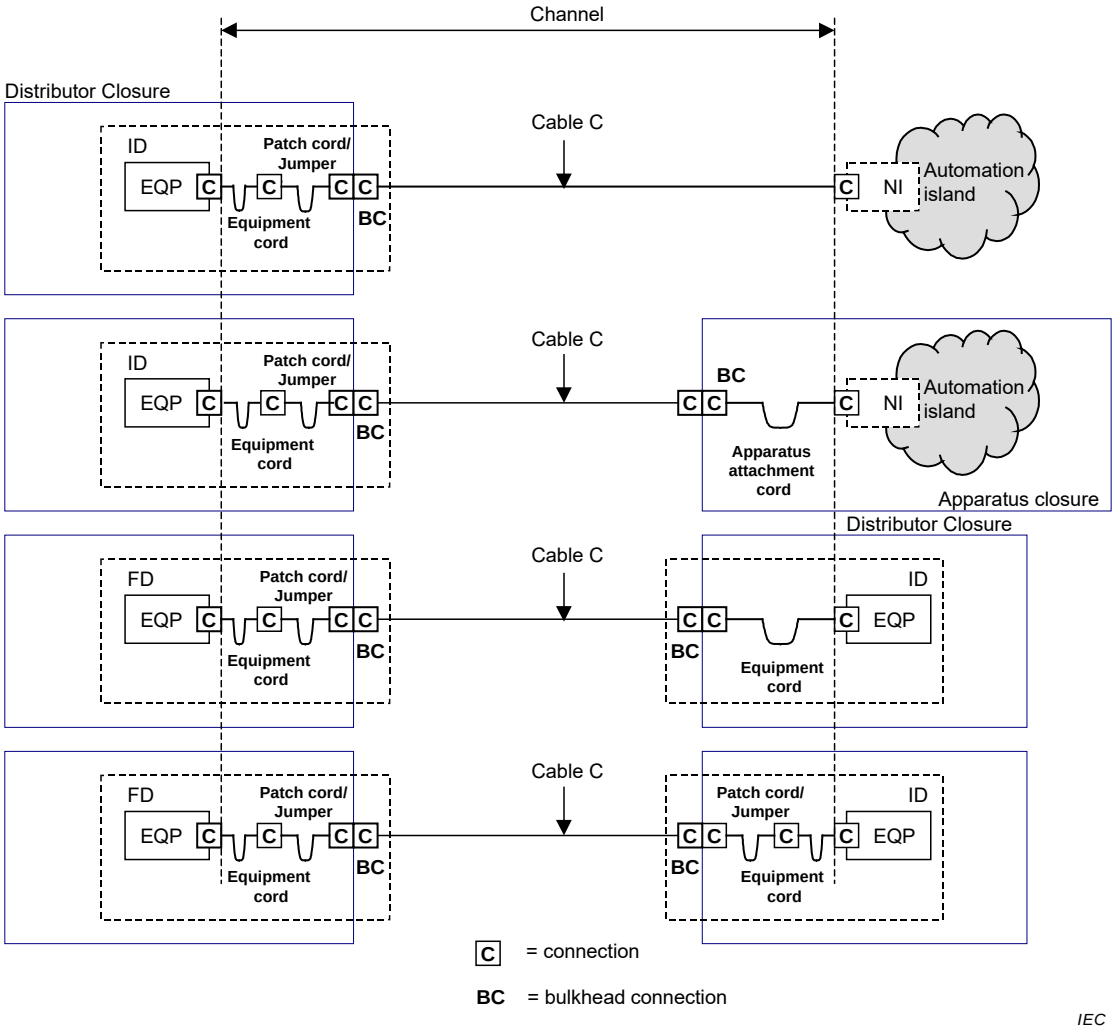


Figure C.1 – Channel configurations with bulkhead and additional connections

Table C.1 – Channel equations with bulkhead and additional connections

Component Category	Channel length equations for balanced cabling							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
5	2 000	$(258 - 5M - 2N - l_a \times Y)/X$	$(178 - 5M - 2N - l_a \times Y)/X$	–	–	–	–	–
6	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(193 - 5M - N - l_a \times Y)/X$	$(115 - 5M - N - l_a \times Y)/X$	–	–	–	–
6_A	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(197 - 5M - N - l_a \times Y)/X$	$(118 - 5M - N - l_a \times Y)/X$	$(109 - 5M - N - l_a \times Y)/X$	–	–	–
7	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(198 - 5M - N - l_a \times Y)/X$	$(119 - 5M - N - l_a \times Y)/X$	$(110 - 5M - N - l_a \times Y)/X$	$(108 - 5M - N - l_a \times Y)/X$	–	–
7_A	2 000	$(268 - 5M - N - l_a \times Y)/X$	$(200 - 5M - N - l_a \times Y)/X$	$(121 - 5M - N - l_a \times Y)/X$	$(112 - 5M - N - l_a \times Y)/X$	$(106 - 5M - N - l_a \times Y)/X$	$(106 - 5M - N - l_a \times Y)/X$	–

M number of bulkhead connections in the channel

N number of connections in the channel

l_a combined length of the equipment cords (m)

X ratio of the insertion loss of the cable C (dB/m) to fixed cable attenuation (dB/m) – see Clause 9

Y ratio of the equipment cord cable insertion loss (dB/m) to fixed cable attenuation (dB/m) – see Clause 9

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

The bulkhead connection is considered to comprise a "back-to-back" connection as described in ISO/IEC 11801-1:2017, 10.2.5.2., as follows:

However, the physical implementations of bulkhead connections typically feature a very short cable length and the connection transmission performance may fall below that defined above.

It should be noted that the following implementations cannot be supported if bulkhead connections are used:

1) Class D channels using Category 5 components;
2) Class E channels using Category 6 components;
3) Class E_A channels using Category 6_A components;
4) Class F channels using Category 7 components;
5) Class F_A channels using Category 7_A components.

If any of the above implementations are desired then a single connection at a bulkhead is recommended.

Annex D
(normative)

Requirements for end-to-end link configurations

D.1 General

Annex D provides definitions and requirements for end-to-end links.

In addition, this document provides performance specifications to support Class D, Class E and Class E_A balanced cabling channels of ISO/IEC 11801-1. These specifications amend those channel specifications of ISO/IEC 11801-1 by including the impact of the free connectors in accordance with the interfaces specified in ISO/IEC 11801-3 used to terminate the end-to-end link.

Tests shall be carried out in accordance with the test methods specified in ISO/IEC 14763-4.

The end-to-end link configurations can include any type of connection.

D.2 Specifications

The specifications for an end-to-end link include the following.

a) The configurations and structure shall meet the specifications outlined in Clause D.3.

b) The interfaces to the cabling shall meet the specifications of ISO/IEC 11801-1 or ISO/IEC 11801-3 with respect to mating interfaces and performance.

c) Connecting hardware at other places in the cabling structure shall meet the performance specifications specified in ISO/IEC 11801-1.

d) Installation shall be performed in accordance with IEC 61918 and ISO/IEC 14763-2.

e) The end-to-end links shall meet the specifications of Clause D.4.

f) Performance testing to the specifications of Clause D.4 shall be used to provide assurance of installed cabling to determine its capacity to support the applications described by IEC 61918 and ISO/IEC 11801-1.

g) The performance of end-to-end link as specified in Clause D.4 shall support the channel specifications specified in ISO/IEC 11801-1. Performance can be achieved by one of the following when the additional connections are included in the test results:

   1) an end-to-end link design and implementation ensuring that the prescribed transmission performance is met;

   2) attachment of appropriate components to a permanent link or CP link meeting the prescribed performance class of ISO/IEC 11801-1;

   3) using compatible cabling components that meet the specifications of ISO/IEC 11801-3 and ISO/IEC 11801-1.

D.3 End-to-end link configurations

There are multiple configurations of end-to-end links that are identified by the number of mated connections in the configuration including those at the ends of the end-to-end link. ISO/IEC TR 11801-9902 describes two-, three-, four-, five-, and six-connection end-to-end links. Figure D.1 shows a worst-case six-connection end-to-end link.

ISO/IEC TR 11801-9902:2017, Annex A provides information regarding CP cords.

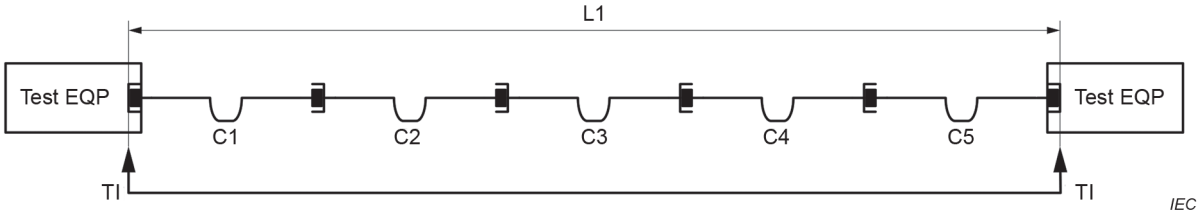


Figure D.1 – Five-segments, six-connections, end-to-end link

D.4 Performance specifications when using end-to-end link limits

D.4.1 General

The performance specifications of D.4.3 are based on the number of connections comprising the end-to-end link. These specifications are based on the modelling techniques described in ISO/IEC TR 11801-9903 using the balanced cabling components of Category 5, Category 6 and Category 6_A of ISO/IEC 11801-1 to provide the specification for Class D, Class E and Class E_A, respectively.

The worst-case limits of D.4.2 show the values calculated using the formulae of D.4.3 to D.4.8 for six connections as in Figure D.1.

D.4.2 Worst-case limits

Table D.1, Table D.2 and Table D.3 contain the informative worst-case limits for end-to-end links containing six connections for Class D, Class E and Class E_A. The tables summarize the values in D.4.3 to D.4.8, and D.4.9 to D.4.16 contain additional parameters and limits.

Table D.1 – Worst-case Class D end-to-end link performance at key frequencies

Frequency MHz	RL dB	IL dB	NEXT dB	PS NEXT dB	ACR-F dB	PS ACR-F dB
1	16,73	4,00	63,29	60,29	56,28	53,28
4	16,69	4,69	53,51	50,51	44,24	41,24
10	16,61	7,40	46,88	43,88	36,28	33,28
40	13,20	15,17	36,39	33,39	24,24	21,24
100	8,44	24,82	28,82	25,82	16,28	13,28

Table D.2 – Worst-case Class E end-to-end link performance at key frequencies

Frequency MHz	RL dB	IL dB	NEXT dB	PS NEXT dB	ACR-F dB	PS ACR-F dB
1	18,45	4,00	65,00	65,00	62,80	59,80
4	18,43	4,26	63,01	60,51	50,76	47,76
10	18,40	6,68	56,49	53,91	42,80	39,80
40	15,20	13,60	46,26	43,52	30,76	27,76
100	10,87	22,11	38,98	36,13	22,80	19,80
250	6,00	36,57	30,73	27,77	14,84	11,84

Table D.3 – Worst-case Class E_A end-to-end link performance at key frequencies

Frequency MHz	RL dB	IL dB	NEXT dB	PS NEXT dB	ACR-F dB	PS ACR-F dB
1	19,0	4,0	65,0	62,0	63,3	60,3
16	18,0	8,2	53,2	50,6	39,2	36,2
100	12,0	20,9	39,9	37,1	23,3	20,3
250	8,0	33,9	33,1	30,2	15,3	12,3
500	6,0	49,3	27,9	24,8	9,3	6,3

D.4.3 Return loss (RL) limits

Table D.4 contains the return loss limits for Class D, Class E and Class E_A end-to-end links.

Table D.4 – End-to-end link return loss limits

Class	Frequency MHz	Minimum return loss dB
D	$1 \le f < 20$	$17 - \left(0,27 + \left(1,29 \times \left(\frac{f-1}{99}\right)\right)\right)$
	$20 \le f \le 100$	$30 - 10\lg(f) - \left(0,27 + \left(1,29 \times \left(\frac{f-1}{99}\right)\right)\right)$
E	$1 \le f < 10$	$19 - \left(0,55 + \left(1,47 \times \left(\frac{f-1}{249}\right)\right)\right)$
	$10 \le f < 40$	$24 - 5\lg(f) - \left(0,55 + \left(1,47 \times \left(\frac{f-1}{249}\right)\right)\right)$
	$40 \le f \le 250$	$32 - 10\lg(f) - \left(0,55 + \left(1,47 \times \left(\frac{f-1}{249}\right)\right)\right)$
E_A	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\lg(f)$
	$40 \le f < 398,1$	$32 - 10\lg(f)$
	$398,1 \le f \le 500$	6,0

D.4.4 Insertion loss (IL) limits

Table D.5 contains the insertion loss limits for Class D, Class E and Class E_A end-to-end links.

Table D.5 – End-to-end link insertion loss limits

Class	Frequency MHz	Maximum insertion loss dB
D	$1 \le f \le 100$	$(1,05) \times \left(1,910\,8 \times \sqrt{f} + 0,022\,2 \times f + \frac{0,2}{\sqrt{f}}\right) + \left(6 \times 0,04 \times \sqrt{f}\right)$
E	$1 \le f \le 250$	$(1,05) \times \left(1,82 \times \sqrt{f} + 0,016\,9 \times f + \frac{0,25}{\sqrt{f}}\right) + \left(6 \times 0,02 \times \sqrt{f}\right)$
E_A	$1 \le f \le 500$	$1,05 \times \left(1,82\sqrt{f} + 0,009\,1 \times f + 0,25/\sqrt{f}\right) + 4 \times 0,02 \times \sqrt{f}$ [a]

[a] Insertion loss (IL) at frequencies that correspond to calculated values of less than 4,0 dB shall revert to a maximum requirement of 4,0 dB.

D.4.5 NEXT limits

Table D.6 contains the NEXT limits for Class D, Class E and Class E_A end-to-end links.

Table D.6 – End-to-end link NEXT limits

Class	Frequency MHz	Minimum NEXT [a] dB
D	$1 \le f \le 100$	$\left(-20\lg\left(10^{\frac{65{,}3-15\lg(f)}{-20}}+2\times10^{\frac{83-20\lg(f)}{-20}}\right)\right)-\left(1{,}26\times\left(\frac{f-1}{99}\right)\right)$ [b]
E	$1 \le f \le 250$	$\left(-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}}+2\times10^{\frac{94-20\lg(f)}{-20}}\right)\right)-\left(2{,}38\times\left(\frac{f-1}{249}\right)\right)$ [b]
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}}+2\times10^{\frac{94-20\lg(f)}{-20}}\right)$ [a, b]

[a] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term $1{,}4((f - 450)/50)$ from the formula stated above for the range of 450 MHz to 500 MHz.

[b] The terms in the formulas are not intended to imply component performance.

D.4.6 PS NEXT limits

Table D.7 contains the PS NEXT limits for Class D, Class E and Class E_A end-to-end links.

Table D.7 – End-to-end link PS NEXT limits

Class	Frequency MHz	Minimum PS NEXT [a] dB
D	$1 \le f \le 100$	$\left(-20\lg\left(10^{\frac{62{,}3-15\lg(f)}{-20}}+2\times10^{\frac{80-20\lg(f)}{-20}}\right)\right)-\left(1{,}26\times\left(\frac{f-1}{99}\right)\right)$
E	$1 \le f \le 250$	$\left(-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times10^{\frac{90-20\lg(f)}{-20}}\right)\right)-\left(2{,}38\times\left(\frac{f-1}{249}\right)\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times10^{\frac{90-20\lg(f)}{-20}}\right)$ [b, c]

[a] PS NEXT at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

[b] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term $1{,}4((f - 450)/50)$ from the formula stated above for the range of 450 MHz to 500 MHz.

[c] The terms in the formulas are not intended to imply component performance.

D.4.7 ACR-F limits

Table D.8 contains the ACR-F limits for Class D, Class E and Class E_A end-to-end links.

Table D.8 – End-to-end link ACR-F limits

Class	Frequency MHz	Minimum ACR-F [a, b] dB
D	$1 \le f \le 100$	$\left(-20\lg\left(10^{\frac{63,8-20\lg(f)}{-20}}+4\times10^{\frac{75,1-20\lg(f)}{-20}}\right)\right)-1,12$
E	$1 \le f \le 250$	$\left(-20\lg\left(10^{\frac{67,8-20\lg(f)}{-20}}+4\times10^{\frac{83,1-20\lg(f)}{-20}}\right)\right)-0,46$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{67,8-20\lg(f)}{-20}}+4\times10^{\frac{83,1-20\lg(f)}{-20}}\right)$

[a] ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] The ACR-F limit at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

D.4.8 PS ACR-F limits

Table D.9 contains the PS ACR-F limits for Class D, Class E and Class E_A end-to-end links.

Table D.9 – End-to-end link PS ACR-F limits

Class	Frequency MHz	Minimum PS ACR-F [a, b] dB
D	$1 \le f \le 100$	$\left(-20\lg\left(10^{\frac{60,8-20\lg(f)}{-20}}+4\times10^{\frac{72,1-20\lg(f)}{-20}}\right)\right)-1,12$
E	$1 \le f \le 250$	$\left(-20\lg\left(10^{\frac{64,8-20\lg(f)}{-20}}+4\times10^{\frac{80,1-20\lg(f)}{-20}}\right)\right)-0,46$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{64,8-20\lg(f)}{-20}}+4\times10^{\frac{80,1-20\lg(f)}{-20}}\right)$

[a] PS ACR-F at frequencies that correspond to calculated PS FEXT values of greater than 67,0 dB are for information only.

[b] The PS ACR-F limit at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

D.4.9 DC loop resistance limits

Table D.10 contains the DC loop resistance limits for Class D, Class E and Class E_A end-to-end link.

Table D.10 – End-to-end link segment DC loop resistance

Class	Maximum DC end-to-end link segment loop resistance Ω
D, E, E_A	25

D.4.10 DC resistance unbalance within a pair

The DC resistance unbalance between the two conductors within each pair of a channel shall not exceed 3 % or 0,200 Ω, whichever is greater. The maximum DC resistance unbalance between pairs within a channel shall not exceed 7 % or 100 mΩ, whichever is greater.

NOTE For the purposes of field measurements, calculations that provide values of less than 200 mΩ revert to 200 mΩ.

For applications requiring remote power delivery, see ISO/IEC TS 29125 for the DC resistance and DC resistance unbalance (within, and between pairs) component specifications.

D.4.11 Propagation delay limits

Table D.11 contains the maximum propagation delay limits for Class D, Class E and Class E_A end-to-end links.

Table D.11 – End-to-end link delay

Class	Frequency	Maximum end-to-end link delay ns
D, E, E_A	$1 \le f \le f_u$ [a]	$0{,}534 + 0{,}036/\sqrt{f} + 4 \times 0{,}002\,5$
[a] f_u is the upper frequency of the Class.		

D.4.12 Delay skew limits

Table D.12 contains the delay skew limits for Class D, Class E and Class E_A end-to-end links. The delay skew is length dependent.

Table D.12 – End-to-end link delay skew

Class	Maximum end-to-end link delay ns
D, E, E_A	0,050 [a, b]
[a] This is the result of the calculation 0,045 + 4 × 0,001 25. [b] Delay skew of any given installed cabling channel shall not vary by more than 0,010 µs within this requirement, due to effects such as the daily temperature variation.	

D.4.13 TCL specifications

Table D.13 contains the TCL limits for Class D, Class E and Class E_A end-to-end links for unscreened cabling.

Table D.13 – End-to-end link TCL

Class	Frequency MHz	Environmental classification		
		E_1	E_2 [c]	E_3 [c]
		Minimum TCL[a] dB		
D, E, E_A	$1 \le f < 30$	$53 - 15\lg(f)$	$63 - 15\lg(f)$	$73 - 15\lg(f)$
	$30 \le f \le f_u$ [b]	$60{,}3 - 20\lg(f)$	$70{,}3 - 20\lg(f)$	$80{,}3 - 20\lg(f)$
[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB. [b] TCL at frequencies above 250 MHz are for information only, where fu is the upper frequency of the Class. [c] The reference implementations of this document and other parts of the ISO/IEC 11801 series do not ensure conformance with this requirement for E_2 or E_3.				

NOTE TCL specifications apply to all end-to-end links.

D.4.14 ELTCTL specifications

Table D.14 contains the ELTCTL limits for Class D, Class E and Class E_A end-to-end links for unscreened cabling.

Table D.14 – End-to-end link segment ELTCTL

Class	Frequency MHz	Environmental classification		
		E_1	E_2	E_3
		Minimum ELTCTL[a] dB		
D, E, E_A,	$1 \leq f < 30$	$30 - 20\lg(f)$	$40 - 20\lg(f)$	$50 - 20\lg(f)$
[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.				

D.4.15 Coupling attenuation specifications

Table D.15 contains the coupling attenuation limits for Class D, Class E and Class E_A end-to-end links for screened cabling.

Table D.15 – Minimum end-to-end link coupling attenuation

Class	Frequency MHz	Environmental classification		
		E_1	E_2	E_3
		Minimum coupling attenuation dB		
D, E, E_A	$30 \leq f \leq 100$	40	50	60
	$100 \leq f \leq f_u$ [a]	$80 - 20\lg(f)$	$90 - 20\lg(f)$	$100 - 20\lg(f)$
[a] f_u is the upper frequency of the Class.				

D.4.16 Alien crosstalk

Alien crosstalk requirements, applicable to Class E_A end-to-end links, are specified in ISO/IEC 11801-1:2017, 6.3.3.13.

D.5 End-to-end link performance

D.5.1 General

Performance testing can be undertaken either:

a) in a laboratory, where end-to-end links contain cabling components in a specific design configuration; or

b) in the field, after installation, using field test equipment. This testing is independent from any specifications for acceptance testing and is specified as explained in ISO/IEC 14763-2 and IEC 61918.

Performance testing of both kinds may be performed by independent or third party organizations in order to give greater guarantees of compliance. Reference testing is also known as type testing.

D.5.2 Reference performance testing

This testing is performed on a sample of installed cabling in a laboratory where an assessment against the conformance criteria of this document is required. The assessment documentation shall include details of the number of channels or links tested, test evaluation criteria, supplier's declarations and certification, laboratory accreditation and calibration certification.

This testing can also be used for the comparison of measurements performed with laboratory and field test instruments:

a) assessing cabling models in a laboratory environment;

b) assessing parameters that cannot be tested in an installation.

D.5.3 Installation performance testing

This testing is performed in accordance with Clause D.6, on a complete installation of cabling in the field where an assessment against the conformance criteria of an ISO/IEC 11801 series standard is required.

D.5.4 Installation performance testing of end-to-end links

Testing to determine performance with the specifications of Clause D.3 is optional. Testing shall be performed in the following cases:

a) end-to-end links with lengths exceeding, or having more components than, those specified in reference implementations of the cabling design documents;

b) end-to-end links using components whose transmission performance is lower than those described in ISO/IEC 11801-1;

c) end-to-end links created by adding more than one cord to either end of a link meeting the specifications of ISO/IEC 11801-1;

d) evaluation of cabling to determine its capacity to support a certain group of applications;

e) confirmation of performance of cabling designed in accordance with the reference;

f) free connector at the end of end-to-end link is terminated in the field.

Table D.16 contains the test regime for reference performance and installation performance.

Table D.16 – Test regime for reference performance and installation performance for balanced cabling of Classes D, E and E_A

Transmission parameter [a]	Reference performance testing	Installation performance testing
Return loss	N	N
Insertion loss	N	N
Pair-to-pair NEXT	N	N
PS NEXT	C	C
Pair-to-pair ACR-N	C	C
PS ACR-N	C	C
Pair-to-pair ACR-F	N	N
PS ACR-F	C	C
Direct current (DC) loop resistance	N	N
Direct current (DC) resistance unbalance within a pair	N	O
Direct current (DC) resistance unbalance between pairs	N	O
Propagation delay	N	N
Delay skew	N	N
Unbalance attenuation, near-end (TCL)	N	O
Unbalance attenuation, far-end (ELTCTL)	N	O
Coupling attenuation	N	O
PS ANEXT	N	N_s
PS $ANEXT_{avg}$	C	C
PS AACR-F	N	N_s
PS $AACR\text{-}F_{avg}$	C	C
Wire-map	N	N

Transmission parameter [a]	Reference performance testing	Installation performance testing
Continuity: • signal conductors; • screen conductors (if present); • short circuits; • open circuits.	N	N
Length [b]	I	I
C is calculated with pass/fail criteria. I is informative testing without pass/fail criteria, if not met by design. N is normative (100 %) testing with pass/fail criteria, if not met by design. N_s is normative (sampled) testing, if not met by design. The sample size to be tested should be in accordance with ISO/IEC 14763-2. O is optional testing with pass/fail criteria, if not met by design.		
NOTE The term "met by design" refers to a requirement which can be met by the selection of appropriate materials and installation techniques.		
[a] Only those parameters specified for each Class of cabling need to be tested, as required in Clause D.4. [b] Length is not a pass/fail criterion.		

D.6 Testing of end-to-end links

Refer to ISO/IEC 14763-4 for testing of end-to-end links.

NOTE The measurement of Class E and Class E_A end-to-end links is specified in ISO/IEC 14763-4:2021.

Annex E
(normative)

Requirements for 1-pair cabling channels up to 600 MHz

E.1 Balanced 1-pair cabling channels

E.1.1 General

Channel signal transmission specifications for balanced 1-pair cabling are referenced from three physical layer specifications, namely ISO/IEC/IEEE 8802-3:2017/AMD4, ISO/IEC/IEEE 8802-3:2017/AMD1 and IEEE 802.3cg; they cover five link segment specifications: 1000BASE-T1 Type A, 1000BASE-T1 Type B, 100BASE-T1, 10BASE-T1S and 10BASE-T1L. IEEE single-pair Ethernet (SPE) link segment specifications and physical layer standards are summarized in ISO/IEC TR 11801-9906:2020, Annex C.

The SPE link segment specifications are identified by their respective upper frequency specification, i.e. 600 MHz, 66 MHz, and 20 MHz.

The SPE signal transmission functional space covered by the five link segment specifications is given in Table E.1.

Table E.1 – SPE signal transmission functional space

Upper frequency	Frequency range	Reach	Screen type	Data rate	SPE link segment	Physical layer standard
MHz	MHz	m		Mb/s	Specification	
600	$1 \leq f \leq 600$	15	Screened and unscreened	1 000	1000BASE-T1 Type A	ISO/IEC/IEEE 8802-3:2017/AMD4
600	$1 \leq f \leq 600$	40	Screened	1 000	1000BASE-T1 Type B	ISO/IEC/IEEE 8802-3:2017/AMD4
66	$0{,}3 \leq f \leq 66$	15	Unscreened	100	100BASE-T1	ISO/IEC/IEEE 8802-3:2017/AMD1
20	$0{,}1 \leq f \leq 20$	15	Screened and unscreened	10	10BASE-T1S	IEEE 802.3cg
20	$0{,}1 \leq f \leq 20$	1 000	Screened and unscreened	10	10BASE-T1L	IEEE 802.3cg

NOTE Limits involving more than one pair within a channel; the following parameters are not applicable to balanced 1-pair cabling channels: NEXT, PS NEXT, ACR-F, PS ACR-F, ACR-N, PS ACR-N, delay skew and pair-to-pair resistance unbalance.

E.1.2 Component specifications

Balanced 1-pair cabling channel characteristics are specified using balanced 1-pair cabling component specifications. Balanced 1-pair cable and connector component specification references are given in Annex A and Annex B of ISO/IEC TR 11801-9906:2020, respectively.

The characteristics of a channel are specified between connections to active equipment. The channel comprises only passive sections of cable, connecting hardware and cords. The connections at the hardware interface to active equipment are not taken into account.

Application support depends on channel performance, which in turn depends on cable length, number of connections, connector termination practices, workmanship and performance. It is possible to achieve equivalent channel performance over greater lengths by the use of fewer connections or by using components with higher performance.

E.1.3 Environmental classifications

ISO/IEC 11801-1 classifies the environments for generic cabling according to three "MICE" levels.

The balanced 1-pair cabling specifications referenced in ISO/IEC/IEEE 8802-3:2017/AMD1, ISO/IEC/IEEE 8802-3:2017/AMD4 and IEEE 802.3cg include channel EMC related specifications for electromagnetic isolation levels E_1, E_2 and E_3, which are defined according to the MICE standard environmental characterization system specified in ISO/IEC 11801-1.

The channel EMC related specifications are unbalance attenuation, coupling attenuation, and alien (exogenous) crosstalk, which are specified for channels and components in accordance with E_1, E_2 and E_3.

E.1.4 Channel reference implementations

The 15 m channel comprises a 2 m cord (50 % derated), attached at each end of a permanent link of 11 m length and four connectors, based on components referenced in Annex A and Annex B of ISO/IEC TR 11801-9906:2020.

The 40 m channel comprises a 2 m cord (50 % derated), attached at each end of a permanent link of 36 m length and four connectors, based on components referenced in Annex A and Annex B of ISO/IEC TR 11801-9906:2020.

The 1 000 m channel comprises a 2 m cord (50 % derated), attached at each end of a permanent link of 996 m length and 10 connectors, based on components referenced in Annex A and Annex B of ISO/IEC TR 11801-9906:2020.

E.2 Balanced 1-pair cabling channel signal transmission specifications

E.2.1 Return loss (RL)

The balanced 1-pair cabling channel return loss (RL) specifications are given using the formulae in Table E.2.

Table E.2 – Balanced 1-pair cabling channel return loss (RL)

Upper frequency	Frequency range	RL	Length	Screen type
MHz	MHz	dB	m	
600	$1 \le f \le 10$	19,0	15	Screened and unscreened
	$10 < f \le 40$	$24 - 5 \lg(f)$		
	$40 < f \le 130$	16		
	$130 < f \le 400$	$37 - 10 \lg(f)$		
	$400 < f \le 600$	11		
600	$1 \le f \le 10$	19,0	40	Screened
	$10 < f \le 40$	$24 - 5 \lg(f)$		
	$40 < f \le 130$	16		
	$130 < f \le 400$	$37 - 10 \lg(f)$		
	$400 < f \le 600$	11		
66	$0,3 \le f \le 20$	18,0	15	Unscreened
	$20 < f \le 66$	$31 - 10 \lg(f)$		
20	$0,1 \le f \le 10$	14	15	Screened and unscreened
	$10 < f \le 20$	$14 - 10 \lg(f/10)$		
20	$0,1 \le f \le 0,5$	$9 + 9f$	1 000	Screened and unscreened
	$0,5 < f \le 20$	13,5		

E.2.2 Insertion loss (IL)

The balanced 1-pair cabling channel insertion loss (IL) specifications are given using the formulae in Table E.3.

Table E.3 – Balanced 1-pair cabling channel IL

Upper frequency	Frequency range	Channel IL	Length	Screen type	IEC cable
MHz	MHz	dB	m		**61156-x**
600	$1 \le f \le 600$	$0,42\times\left(1,8\sqrt{f}+0,0050f+\frac{0,25}{\sqrt{f}}\right)+4\times0,02\sqrt{f}$	15	Screened and unscreened	-11, -12
600	$1 \le f \le 600$	$0,152\times\left(3,36\sqrt{f}+0,015f+\frac{0,42}{\sqrt{f}}\right)+4\times0,02\sqrt{f}$ [a,b]	40	Screened	-11, -12
66	$0,3 \le f \le 66$	$0,152\times\left(5,06\sqrt{f}+0,059f+\frac{0,53}{\sqrt{f}}\right)+4\times0,02\sqrt{f}$ [a,b]	15	Screened and unscreened	-11, -12
20	$0,1 \le f \le 20$	$0,152\times\left(5,06\sqrt{f}+0,059f+\frac{0,53}{\sqrt{f}}\right)+4\times0,02\sqrt{f}$ [a,b]	15	Screened and unscreened	[c]
20	$0,1 \le f \le 20$	$10\times\left(1,23\sqrt{f}+0,01f+\frac{0,2}{\sqrt{f}}\right)+10\times0,02\sqrt{f}$	1 000	Screened and unscreened	[c]

[a] This channel was created by rearranging the link segment formula.

[b] The ($a\sqrt{f}$ + bf + $c/\sqrt{f}$) factor in the "cable" IL term, factored from the corresponding link segment IL specifications, see Annex C of ISO/IEC TR 11801-9906:2020, is for information, for comparison and modelling purposes.

[c] Cables with transmission characteristics up to 20 MHz will be specified in future parts of IEC 61156 (IEC 61156-13 and IEC 61156-14).

E.2.3 Unbalance attenuation and coupling attenuation

E.2.3.1 General

Unbalance attenuation parameters, transverse conversion loss (TCL) and equal level transverse conversion transfer loss (ELTCTL), are used for differential-mode-to-common-mode conversion loss specifications, for unscreened cabling.

Coupling attenuation is used for differential-mode-to-common-mode conversion loss specifications, for screened cabling.

Differential-mode-to-common-mode conversion loss specifications correspond to balanced 1-pair cabling channel EMC specifications in accordance with E_1, E_2 and E_3 electromagnetic characterizations.

See ISO/IEC 11801-1 for detailed information on balanced cabling, unbalance attenuation parameters and E_1, E_2 and E_3 environment characterization specifications.

E.2.3.2 Transverse conversion loss (TCL)

The balanced 1-pair cabling channel transverse conversion loss (TCL) specifications are given using the formulae in Table E.4.

Table E.4 – Balanced 1-pair cabling channel TCL

Upper frequency	Frequency range	TCL			Length	Screen type
		E_1	E_2	E_3		
MHz	MHz	dB	dB	dB	m	
600	$1 \le f \le 600$	Not specified	Not specified	Not specified	15	Screened and unscreened
600	$1 \le f \le 600$	Not specified	Not specified	Not specified	40	Screened
66	$0{,}3 \le f \le 33$	43,0	Not specified	Not specified	15	Screened and unscreened
	$33 < f \le 200$	$43 - 20 \lg(f/33)$	Not specified	Not specified		
20	$0{,}1 \le f \le 20$	$53 - 15 \lg(f)$	$63 - 15 \lg(f)$	Not specified	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	$53 - 15 \lg(f)$	$63 - 15 \lg(f)$	Not specified	1 000	Screened and unscreened

E.2.3.3 Equal level transverse conversion transfer loss (ELTCTL)

The balanced 1-pair cabling channel equal level transverse conversion transfer loss (ELTCTL) specifications are given using the formulae in Table E.5.

Table E.5 – Balanced 1-pair cabling channel ELTCTL

Upper frequency	Frequency range	ELTCTL			Length	Screen type
		E_1	E_2	E_3		
MHz	MHz	dB	dB	dB	m	
600	$1 \le f \le 600$	Not specified	Not specified	Not specified	15	Screened and unscreened
600	$1 \le f \le 600$	Not specified	Not specified	Not specified	40	Screened
66	$0{,}3 \le f \le 33$	Not specified	Not specified	Not specified	15	Screened and unscreened
	$33 < f \le 200$	Not specified	Not specified	Not specified		
20	$0{,}1 \le f \le 20$	Not specified	Not specified	Not specified	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	$30 - 20 \lg(f)$	$40 - 20 \lg(f)$	Not specified	1 000	Screened and unscreened

NOTE While no ELTCTL link segment specifications are given by ISO/IEC/IEEE 8802-3:2017/AMD1, ISO/IEC/IEEE 8802-3:2017/AMD4 and IEEE 802.3cg for these applications, they are important for long lengths; these values are implicit from the TCL values and correspond to ISO/IEC 11801-1 values.

E.2.3.4 Coupling attenuation

The balanced 1-pair cabling channel coupling attenuation specifications are given using the formulae in Table E.6.

Table E.6 – Balanced 1-pair cabling channel coupling attenuation

Upper frequency	Frequency range	Coupling attenuation			Length	Screen type
		E_1	E_2	E_3		
MHz	MHz	dB	dB	dB	m	
600	$1 \le f \le 600$	$72 - 11{,}5 \lg(f)$	Not specified	Not specified	15	Screened and unscreened
600	$1 \le f \le 600$	$80 - 20 \lg(f)$	$90 - 20 \lg(f)$	$100 - 20 \lg(f)$	40	Screened
66	$0{,}3 \le f \le 33$	43	Not specified	Not specified	15	Screened and unscreened
	$33 < f \le 200$	$43 - 20 \lg(f/33)$	Not specified	Not specified		
20	$0{,}1 \le f \le 20$	$53 - 10 \lg(f)$	$63 - 10 \lg(f)$	$73 - 10 \lg(f)$	15	Screened
20	$0{,}1 \le f \le 20$	$53 - 10 \lg(f)$	$63 - 10 \lg(f)$	$73 - 10 \lg(f)$	1 000	Screened

NOTE This corresponds to ISO/IEC 11801-1 values.

The coupling attenuation for the pair of a channel meets the limits computed, to one decimal place, using the formulae of Table E.6. See IEC 62153-4-5, IEC 62153-4-14, and IEC 62153-4-9:2018/AMD1 for testing procedures.

It is possible to assess coupling attenuation by laboratory measurements of representative samples of channels assembled using their component and connector practices.

E.2.4 Alien (exogenous) crosstalk

E.2.4.1 General

For unscreened cabling alien (exogenous) crosstalk parameters, power-sum alien near-end crosstalk (PS ANEXT) and power-sum alien attenuation to crosstalk ratio far-end (PS AACR-F) are used for differential-mode-to-differential-mode alien noise loss specifications.

For screened cabling, E_1 coupling attenuation specifications of ISO/IEC 11801-1:2017, 6.3.3.12, may be substituted for alien noise loss specifications.

These alien noise loss specifications are based on the 6-around-1 measurement setup in accordance with IEC 61156-1.

E.2.4.2 PS ANEXT

The balanced 1-pair cabling channel PS ANEXT specifications are given using the formulae in Table E.7.

Table E.7 – Balanced 1-pair cabling channel PS ANEXT

Upper frequency	Frequency range	PS ANEXT	Length	Screen type
MHz	MHz	dB	m	
600	$1 \le f \le 600$	$54 - 10 \lg(f/100)$	15	Screened and unscreened
600	$1 \le f \le 600$	$72{,}8 - 10 \lg(f/100)$	40	Screened
66	$0{,}3 \le f \le 66$	$31{,}5 - 10 \lg(f/100)$	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	$31{,}5 - 10 \lg(f/100)$	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	$37{,}5 - 17 \lg(f/20)$	1 000	Screened and unscreened

E.2.4.3 PS AACR-F

The balanced 1-pair cabling channel PS AACR-F specifications are given using the formulae in Table E.8.

Table E.8 – Balanced 1-pair cabling channel PS AACR-F

Upper frequency	Frequency range	PS AACR-F	Length	Screen type
MHz	MHz	dB	m	
600	$1 \le f \le 600$	$67 - 20 \lg(f/100)$	15	Screened and unscreened
600	$1 \le f \le 600$	$61 - 20 \lg(f/100)$	40	Screened
66	$0{,}3 \le f \le 66$	$16{,}5 - 20 \lg(f/100)$	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	$16{,}5 - 20 \lg(f/100)$	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	$38 - 18 \lg(f/20)$	1 000	Screened and unscreened

E.2.5 DC loop resistance

The balanced 1-pair cabling channel DC loop resistance specifications are given using the formulae in Table E.9.

Table E.9 – Balanced 1-pair cabling channel DC loop resistance

Upper frequency	Frequency range	DC loop resistance	Length	Screen type
MHz	MHz	Ω	m	
600	$1 \le f \le 600$	Not specified	15	Screened and unscreened
600	$1 \le f \le 600$	Not specified	40	Screened
66	$0{,}3 \le f \le 66$	Not specified	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	To be determined	15	Screened and unscreened
20	$0{,}1 \le f \le 20$	To be determined	1 000	Screened and unscreened

E.2.6 Propagation delay

The balanced 1-pair cabling channel propagation delay specifications are given using the formulae in Table E.10.

Table E.10 – Balanced 1-pair cabling channel propagation delay

Upper frequency	Frequency range	Propagation delay	Length	Screen type
MHz	MHz	ns	m	
600	$1 \leq f \leq 600$	94	15	Screened and unscreened
600	$1 \leq f \leq 600$	234	40	Screened
66	$0{,}3 \leq f \leq 66$	Not specified	15	Screened and unscreened
20	$0{,}1 \leq f \leq 20$	Not specified	15	Screened and unscreened
20	$0{,}1 \leq f \leq 20$	8 834	1 000	Screened and unscreened
NOTE 8 834 ns corresponds to 1 485 m of cable, which is the maximum length possible, using 1,6 mm (AWG 14) or larger conductor, while conforming to attenuation requirements.				

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International Standards	*Title*
IEC 61918	Industrial communication networks — Installation of communication networks in industrial premises
IEC 61754-20	Fibre optic interconnecting devices and passive components — Fibre optic connector interfaces — Part 20: Type LC connector family
IEC 61784-5	Industrial communication networks — Profiles — Part 5:Installation of fieldbuses — Installation profiles for CPF
IEC 63171-6	Connectors for electrical and electronic equipment — Part 6: Detail specification for 2-way and 4-way (data/power), shielded, free and fixed connectors for power and data transmission with frequencies up to 600 MHz
IEC 61156-11	Multicore and symmetrical pair/quad cables for digital communications — Part 11: Symmetrical single pair cables with transmission characteristics up to 600 MHz — Horizontal floor wiring — Sectional specification
IEC 61156-12	Multicore and symmetrical pair/quad cables for digital communications — Part 12: Symmetrical single pair cables with transmission characteristics up to 600 MHz — Work area wiring
ISO/IEC 14763-2	Information technology — Implementation and operation of customer premises cabling — Part 2: Planning and installation
ISO/IEC 14763-4	Information technology — Implementation and operation of customer premises cabling — Part 4: Measurement of end-to-end (E2E) links, modular plug terminated links (MPTL) and direct attach cabling
ISO/IEC 30129	Information technology — Telecommunications bonding networks for buildings and other structures

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

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Amendments Issued Since Publication

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Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

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Eastern	: 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	2367 0012 2320 9474
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Southern	: C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113	2254 1442 2254 1216
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