PROFIBUS

PROFInet Guideline

Installation Guideline PROFInet

Version 1.8

November 2002

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Developed by the PROFIBUS Working Group „Electromechanics" (WG 6) in the Technical Committee for „Communication Profiles" (TC 2).

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1. Area of application and objectives

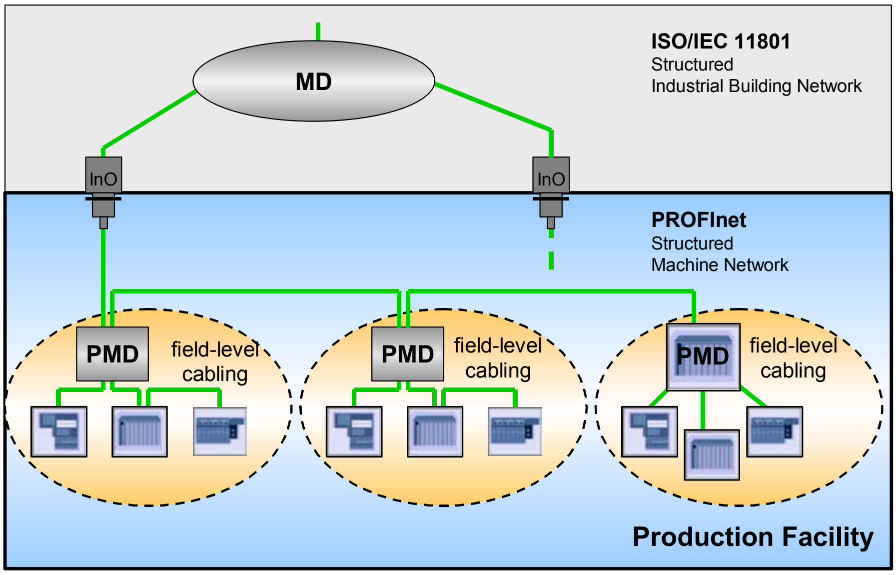
Communication landscapes in industrial corporations these days are largely designed on a two-track basis. LAN's on an Ethernet basis have established themselves as predominant communication network in offices, e.g. marketing and administration departments. The same applies for engineering and construction departments closely related to production with their electronic engineering and CAD tools.

On the other hand, fieldbuses with a variety of protocols are to be found direct on the production facilities (assembly lines, conveyor belts, process-related systems...). Differing protocols and differing networking components call for widespread knowledge among technical support personnel, costly stockkeeping for spare parts and a not inconsiderable expenditure for engineering in order to make the data of one network available in the other.

Horizontal communication between the automation and field equipment as well as vertical communication between corporate management level and production is guaranteed with PROFInet.

Automation engineering has been marked by a decentralisation based on field bus technology in recent years. New user needs have led to the Ethernet increasingly being used from the cell level right down to the field level.

Buildings and equipment at company management level are marked by their office character. The Ethernet with its high potential for innovation has established itself as communication network (LAN) over the years. Information technology cabling (IT cabling) is based on standards for "Cabling systems for customer premises" as described by ISO/IEC 11801 and EN 50173.



InO = Industrial Outlet
MD = Machine Distributor
PMD = PORFInet Machine Distributor

Figure 1-1: Differentiation between machine and building network

PROFInet takes the Ethernet networking standard into the production and field level range. The requirements there differ greatly from the office environment assumed in IEC 11801. The cabling structure depends greatly on the type of system. The components are generally subjected to rougher environmental conditions than those that prevail in the office sector.

The present PROFInet Guideline "Installation Guideline PROFInet" supplements the office-based cabling standards IEC 11801 and EN 50173 with the specific conditions of the production and field levels.

This PROFInet directive is intended to be used by

- manufacturer of PROFInet devices as well as
- manufacturer of PROFInet components like plugs and cables and
- the installation personal of PROFInet systems.

2. Integration of the PROFInet directive into existing standards

PROFInet is based on existing standards in communication technology. In general, these consist of internationally valid and available IEC standards. In cases where these are not (yet) available, use is made of standards with regionally limited validity, e.g. European Standards (EN).
This achieves decisive advantages for the user such as

- seamless integration of the production section in the existing company-wide communication landscape
- wide range of networking components
- "Standard Know-How" for IT offices.

2.1. Fundamental standards and directives for PROFInet

PROFInet conforms with the standard:

draft IEC 61784 Ed1:2002 CP 3/3 PROFInet, *Digital Communications for Measurement an Control - Fieldbus for use in industrial control systems - Profile sets for continuous and discrete manufacturing relative to fieldbus use in industrial control systems*

PROFnet Transmission Technology is based on the following international standards:

ISO/IEC 8802-3:2000, *Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier sense multiple access with collision detection (CSMA/CD) - access method and physical layer specifications*

ISO/IEC 9314-3:1990, *Information processing systems – Fibre distributed Data Interface (FDDI) - Part 3: Physical Layer Medium Dependent (PMD)*

ISO/IEC 9314-4:1999, *Information technology –Fibre distributed data interface (FDDI) – Part 4: Singlemode fibre physical layer medium dependent (SMF-PMD)*

The PROFInet cabling structure is oriented toward the following standards:

ISO/IEC 11801: Edition 2.0, *Information technology – Cabling systems for customer premises*

The components of the balanced cabling are based on:

IEC 61156-2 Edition 2.0, *Multicore and symmetrical pair/quad cables for digital communications – Part 2: Horizontal floor wiring – Sectional specification*

IEC 61156-3 Edition 2.0, *Multicore and symmetrical pair/quad cables for digital communications – Part 3: Work area wiring; Sectional specification*

The components of the optical fibre cabling are based on

Series IEC 60793: *Optical fibres*
Series IEC 60794: *Optical fibre cables*

IEC 60874-14:1993, *Connectors for optical fibres and cables – Part 14: Sectional specification for fibre optic connector - Type SC*

IEC 60874-10:1992, *Connectors for optical fibres and cables - Part 10: Sectional specification for fibre optic connector - Type BFOC/2,5*

The planning and installation of the PROFInet cabling are based on the European standards of the series EN 50174. IEC standards on these topics were not available at the time of writing of this directive.

EN 50174–1, *Information technology – Cabling installation - Part 1: Specification and quality assurance*

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

EN 50174–3, *Information technology – Cabling installation - Part 3: Installation planning and practices outside buildings*

The following standard shall be applied for the integration in the metallic balanced PROFInet cabling in an overall concept for grounding and equipotential bonding in buildings:

EN 50310, *Application of equipotential bonding and earthing in buildings with information technology equipment*

Where applicable, International Standards on electromagnetic emissions and immunity and local regulations shall be taken into account.

IEC 61000-6-2:1999, *Electromagnetic compatibility (EMC) -Part 6-2: Generic Standards - Immunity for industrial environments*

IEC 61000-6-4:1997, *Electromagnetic compatibility (EMC) - Part 6: Generic Standards - Section 4: Emission standard for industrial environments*

IEC 61131-2, *Programmable controllers - Part 2: Equipment requirements and tests*

3. Structured building cabling in comparison with industrial cabling

The international standard ISO/IEC 11801 and its European equivalent EN 50173 specifies an application independent generic cabling system, for use within commercial premises, which may comprise single or multiple buildings on a campus.
Both standards base on the assumption of an office type use of the building. Both standards claim to be application independent, i.e. the cabling "*... supports a wide range of services including voice, data, text, image and video*" . (quote ISO/IEC 11801).
The contents of ISO/IEC 11801 and EN 50173 are largely identical.
The specific demands of a production workshop or a process-based system are not taken into account. The application neutrality does not apply for PROFInet.
The present PROFInet directive "PROFInet - Transmission Technology and Cabling" defines industrial cabling for the "Fast Ethernet" connection on the basis of the fundamental requirements of ISO/IEC 11801.

Networks in the office sector differ from networks in production and field areas.
Table 3-1 provides a comparison of the main differences.

	Office area	**Production and field areas**
Installation conditions	• Fixed basic installation in a building • Laid under raised floors • Variable device connection at workplace • Pre-fabricated device connection cable (patch cables) • Largely standard workplaces (desk with PC,...) • Tree-shape network structures	• Largely system-related cabling • System-related cable routing • Connections points are seldom changed • Field-preparable device connections • Each machine/system requires an individual degree of networking • Quite often: line-form network structures and (redundant) ring structures
Transmission performance	• Large data packets (e.g. images) • Medium network availability • Transmission time within seconds range • Mainly acyclic transmission • Not transmitted isochronous	• Small data packets (measured values) • Very high network availability • Transmission time within micro-seconds range • High percentage of cyclic transmission • Transmitted isochronous
Environmental requirements	• Moderate temperatures • Low dust burden • No moisture • Virtually no vibrations • Low EMC burden • Low mechanical danger • Low UV radiation • Virtually no chemical danger	• Extreme temperatures • High dust burden • Moisture possible • Vibrating machines • High EMC burden • Danger of mechanical damage • UV burden in outer area • Chemical burden from oily or aggressive atmospheres

Table 3-1: Different requirements for office areas as opposed to industrial areas

4. Requirements placed on industrial networks

4.1. Network structures in production and field areas

The IEC 11801 is based on the assumption of star and tree-shaped network structures.
A specific number of connection points per area unit is assumed as standard in office premises. Industrial facilities are subject to a highly individual degree of networking. A production network must be adaptable to the plant topology. The chapter 6 shows examples for industrial networking.

4.2. Transmission performance in production and field areas

Communication in industrial areas places particular demands on the transmission performance of a network.

Requirement	Solution
• Efficient transfer of data packets	• Minimum overhead per data packet • Full duplex transmission to avoid collisions
• Very high network availability	• Redundant structures (e.g. ring topology)
• Transmission time within microseconds range	• High transmission speed 100 MBits per sec. (Fast Ethernet) • Full duplex transmission to avoid collisions • Network components with short run times • Message prioritization
• Isochronous transmission requirements	• Network components with deterministic behavior • Full duplex transmission to avoid collisions

Table 4.2-1: Requirements on the transmission performance in production and field areas

For PROFInet switches with certain requirements shall be used as signal distributors (see chapter 9), together with the protocols chosen for PROFInet ensure the ideal fulfillment of the requirements in the production and field areas.

4.3. Environmental conditions in production and field areas

Standard market components for information-related cabling (cables, plugs, switches...) were generally developed for operation in office-type environments. The office environment is covered by existing standards and is not taken into consideration here.
The special environmental conditions in production and field areas call for specially enhanced and rugged components.
Because the same high demands do not exist in all areas in the industrial sector either, differentiation has to be made between "inside" and "outside" protected areas from a technical point of view:

- **"Inside"** stands for an environment as found in control stations, electronic rooms or inside switch cabinets
- **"Outside"** stands for higher demands with regard to temperature, dust, moisture, vibration etc. as found when used direct in the field level.

Table 4.3-1 provides a comparison of the general environmental conditions for the passive PROFInet connection system (cable and plug connection) of the two areas.

	"Inside"	**"Outside"**
Application area (Examples)	Maintenance, electronic rooms, switch cabinets	Production and field areas (Measurement transducers, actuators, outside systems)
Pollution degree	IEC 60664-1 grade 2	IEC 60664-1 grade 3
IP protection type	IP 20	min. IP 65 + IP67
Shock	IEC 60512-4, test 6c 20 g / 11 ms 3 per axis in both directions	IEC 60512-4, test 6c 20 g / 11 ms 3 per axis in both directions
Vibration 10-500 Hz	IEC 60512-4, test 6d 0.35 mm or 5g	IEC 60512-4, test 6d 0.35 mm or 5g
Operating temperature range	0 ... +60°C	-20 ... +70°C

Table 4.3-1: General environmental requirements on passive PROFInet connection systems

4.4. Electromagnetic compatibility in industrial environment

Automation systems in an industrial environment are subjected to high levels of electromagnetic disturbance. Switching large electrical loads creates high interference levels that can be picked up in various ways by electronic devices with detrimental effects. Even under such conditions, electronic components within the automation system must still guarantee a continuous, uninterrupted production process.

The electromagnetic compatibility (EMC) of the entire plant must be ensured by using suitably designed components and assembling them correctly to make up the system.

All electronic devices must at least keep to the limit values for noise emission and noise immunity in an industrial environment as stipulated in the generic standards IEC 6000-6-4 and IEC 6000-6-2. If there are also regional or product-specific requirements (e.g. IEC 61131-2), the higher requirements must be met.

Data cabling is considered as a passive system and cannot be tested for EMC compliance individually. Nevertheless cabling and connecting elements for PROFInet support compliance with device requirements by providing a high-quality, comprehensive shielding concept.

You will find the requirements for shield quality in the cable and connector specifications in Chapter 10.

Installation regulations for shielded cables and connectors as well as guidelines for the EMC-compliant installation and assembly of automation systems can be found in Section 11.3.

5. PROFInet networking

5.1. Representation of the system landscape

Horizontal communication between the automation and field equipment as well as vertical communication between corporate management level and production is guaranteed with PROFInet based on international standards.

The PROFInet transmission technology defined in these specification complys with the Fast Ethernet Standard (100 MBits per sec) as specified in ISO/IEC 8802-3.
Transmission techniques with lower data rates (10 MBits per sec.) do not fulfill the requirements of transmission performance in automation systems. Signal transmission is carried out by balanced cables or optical fibre cables.

5.2. Data transmission through balanced cables

Signal transmission is through balanced cables according to 100BASE-TX with a transmission speed of 100 MBits per sec (Fast Ethernet).
The transmission medium is a shielded, balanced cable consisting of one or more metallic symmetrical cable elements (two twisted pairs or one quad) with an characteristic impedance of 100 ohms.
Twisted pair connections are fundamentally point-to-point connections between a transmitter and receiver.
The connection principle is shown in Figure 5.2-1.

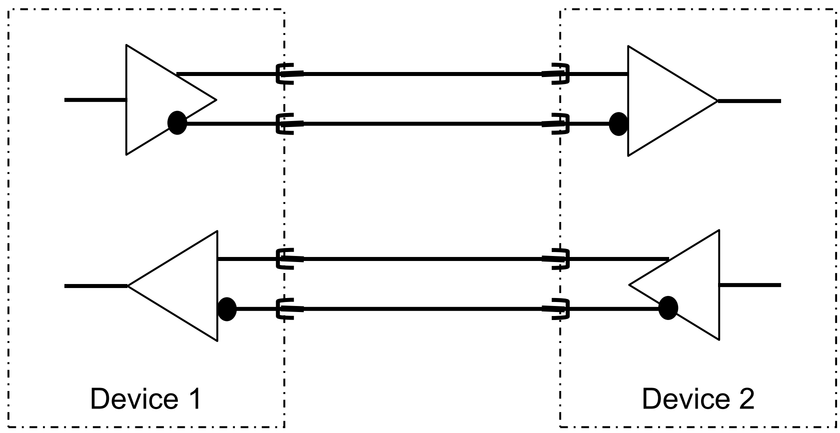


Figure 5.2-1: Principle of data transmission through balanced cables

The electrical interface of PROFInet devices concerning the isolation between the device electronic and the PROFInet network interface shall be in accordance with the requirements of the ISO/IEC8802-3.
The following requirements shall apply:

- 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in subclause 5.3.2 of IEC 60950: 1991.
- 2250 Vdc for 60 s, applied as specified in subclause 5.3.2 of IEC 60950: 1991.
- A sequence of ten 2400V impulses of alternative polarity, applied at intervals of not less than 1 s. Shape of the pulse: 1.2/50 µs (1,2 µs virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

5.3. Data transmission through optical fibre cables

PROFInet fibre optic transmission technology is based on ISO/IEC 8802-3 (100BASE-FX).
The transmission medium is a fibre optic cable with two fibre elements.
Optical fibre connections are fundamentally point-to-point connections between two electrically active components. The connection must be designed so that the sender of one component is always connected with the receiver of the other component.
The connection principle is shown in Figure 5.3-1.

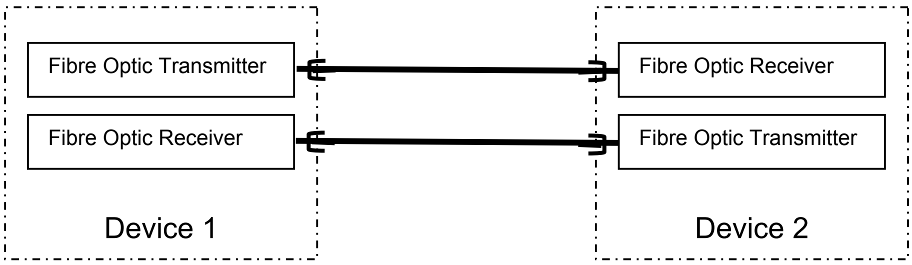


Figure 5.3-1: Principle of data transmission through optical fibres

The 100BASE-FX PMD (and MDI) is specified by incorporating the FDDI PMD standard, ISO/IEC 9314-3:1990. The optical interfaces of PROFInet devices must comply with the specifications ISO/IEC 9314-3 (multimode fibre) or ISO/IEC 9314-4 (singlemode fibre). Supplementary specifications for further common industrial fibres (HCS fibres, plastic optical fibres) are in preparation at PROFIBUS International (TC 2 WG 2).

6. Integration of industrial PROFInet cabling into on-site cabling according to ISO/IEC 11801

Information technology basic cabling in compliance with IEC 11801 is generally found in an industrial plant.
In comparison, the production area requires a system-related cabling. Integration of both areas into a general network is carried out at the campus or at the building distributor. If a router is being used as distributor, measures can be implemented there to protect against unauthorized access between the network areas. Figure 6-1 shows an appropriately structured network.
In the example, two PROFInet sub-networks from the production areas are structured to suit the system with the help of PROFInet machine distributors (PMD). The term "machine" stands for any specific style of industrial plant or system. In the example, "Machine 1" could be a transport line with terminals arranged in a line. Networking follows the linear system structure and is designed accordingly as line topology. "Machine 2", for example, consists of a group of networked CNC machines which are spread evenly over an area at small distances. A network with star topology would appear to be suitable.
The following sub-chapter describes usual industrial topologies and the outline conditions to be observed for networking.

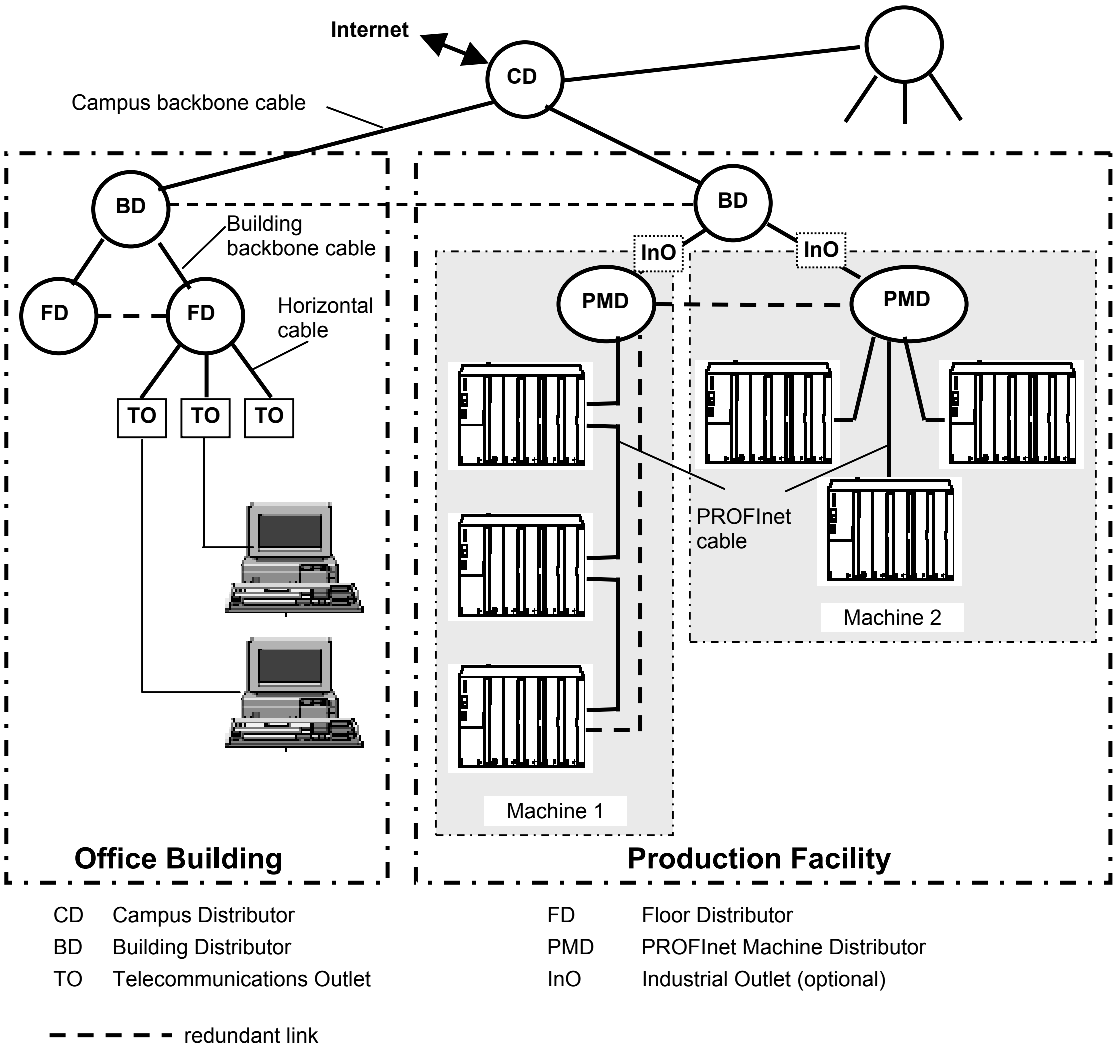


Figure 6-1: Examples for the integration of industrial networks into cabling according to IEC 11801

PROFInet cabling at the field level complies with the cabling specified by IEC 11801 and achieves this using an optional TO (Telecommunications Outlet) which has been given the designation InO (Industrial Outlet). It has been adapted to industrial requirements. The optional InO marks the transition into an industrial ambient condition. In this way, the PROFInet directive supplements the non-application based cabling with the machine networks.

6.1. Summary of network topologies

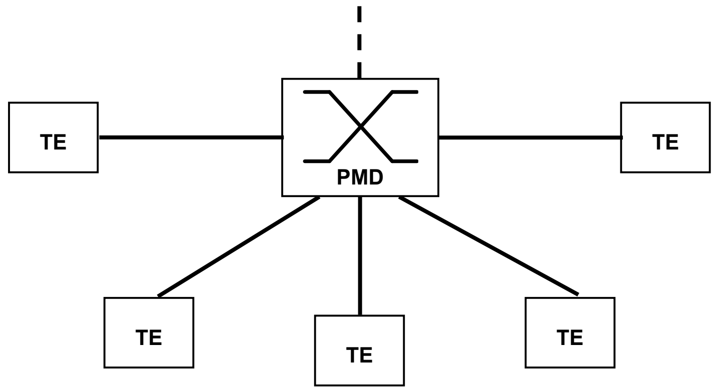
The network topologies must be oriented towards the requirements of the equipment to be networked. Star and tree-shaped structures as prescribed by IEC 11801 have proven successful and established themselves in the office area.
The conditions for networking in the automation environment differ greatly from those of the office environment.
The main differences are:

- The number of terminals in the network
- Terminal density or distribution of the terminals
- Expansion between the terminals
- Arrangement of the terminals (e.g. linear arrangement in a transfer line in contrast to a cluster arrangement on an office storey)
- Demands placed on availability

Ethernet-based networking in automation calls for appropriately optimised network infrastructures taking into account the above-mentioned outline conditions.
The network topologies section describes usual structural principles for communication cabling. The star, line, tree and ring structures are described in their pure form in order to clarify their structural principles. In practice, a system will consist of a mixture of the individually described structures below.
All described topologies can be achieved using both balanced cabling and optical fibre cabling. It is recommend to keep switch ports free on all signal distributors for later expansion of the system or for the temporary connection of service equipment for local diagnosis.

6.1.1. Star topology

The star structure is characterized by a central signal distributor (switch) with individual connections (TP or fibre optic) to all terminals within the network.



TE = Terminal Equipment
PMD = PROFInet Machine Distributor

Figure 6.1-1 Star topology

Applications for star-shaped network structures include areas with a high density of equipment with low linear expansion e.g.:
- small production cells
- a single production machine
- the control area of a major system

User benefits of star-shaped structures are:
- favorable network component costs per port through high port density
- flexible addition / removal of new stations
- easy administration, monitoring, diagnosis of the network
- active network components are brought together at one location, providing easy protection against unfavorable environmental conditions such as temperature, dirt etc.

The following points must be observed:
- high line costs and cabling expenditure for widespread systems
- reduced availability because of central network nodes

6.1.2. Tree topology

The tree topology is created by the combination of several stars into a network, if necessary by including a mixture of fibre optic and balanced cabling.
Functionally related system sections are grouped together into star points. These are combined into a network through neighbouring switches.
The function of the signal distributor in the star point is taken over by a switch (see chapter 9). Because the switch forwards messages address-related, messages only reach neighbouring distributors that are needed outside the star point. The higher level structure is not burdened with purely local data traffic.

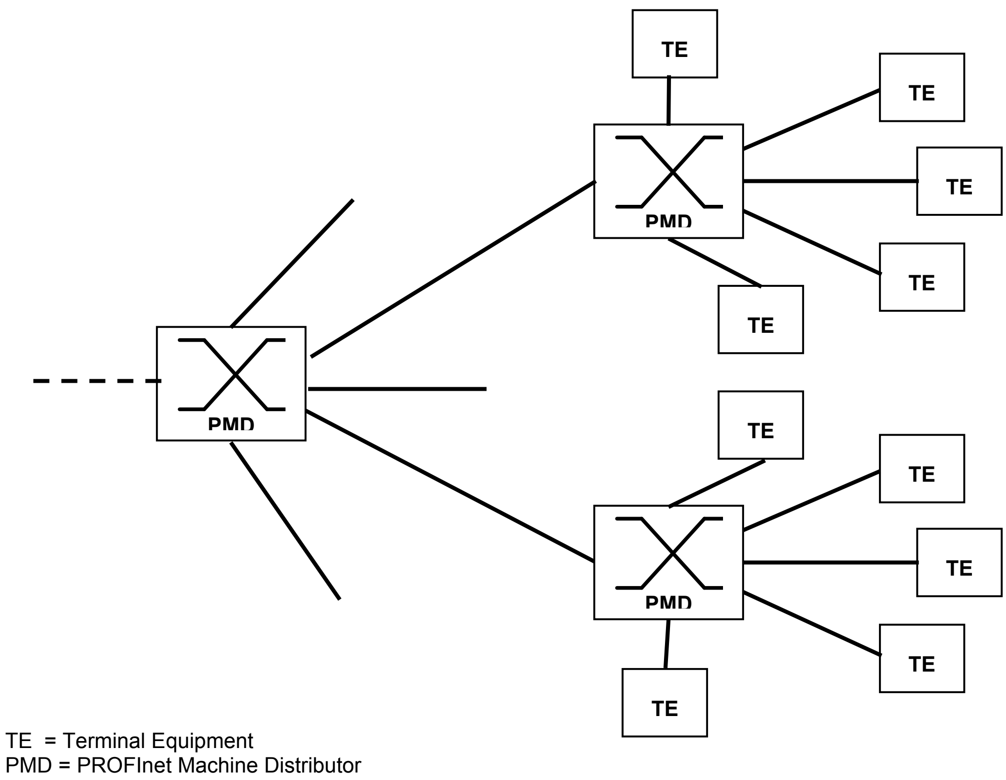


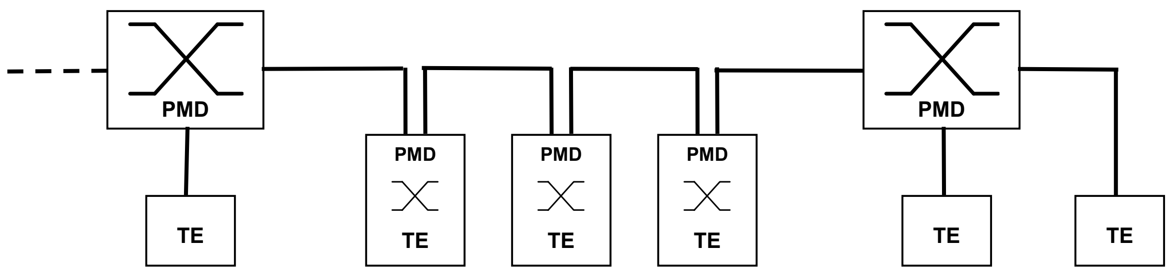
Figure 6.1-2 Tree topology

Tree topology is used for
- splitting complex systems into autonomous system sections.

Tree topology has the following advantages:
- high transparency through segmentation and adaptation of the communication structure to the system structure
- high transmission capacity of the complete network because local data traffic remains restricted to the star point
- greater data security because local data traffic remains restricted to the star point
- greater availability of independent parts of the automation system
- the transmission medium for connecting the stars with each other can be changed if necessary, e.g. in order to achieve greater channel lengths

6.1.3. Line topology

A large number of applications in the cell and field area are realized with PROFIBUS in a line structure. This system-related network structure is also available with PROFInet. The line structure can be achieved by a switch nearby each terminal or through a switch integrated into the terminal.



TE = Terminal Equipment
PMD = PROFInet Machine Distributor

Figure 6.1-3 Line topology

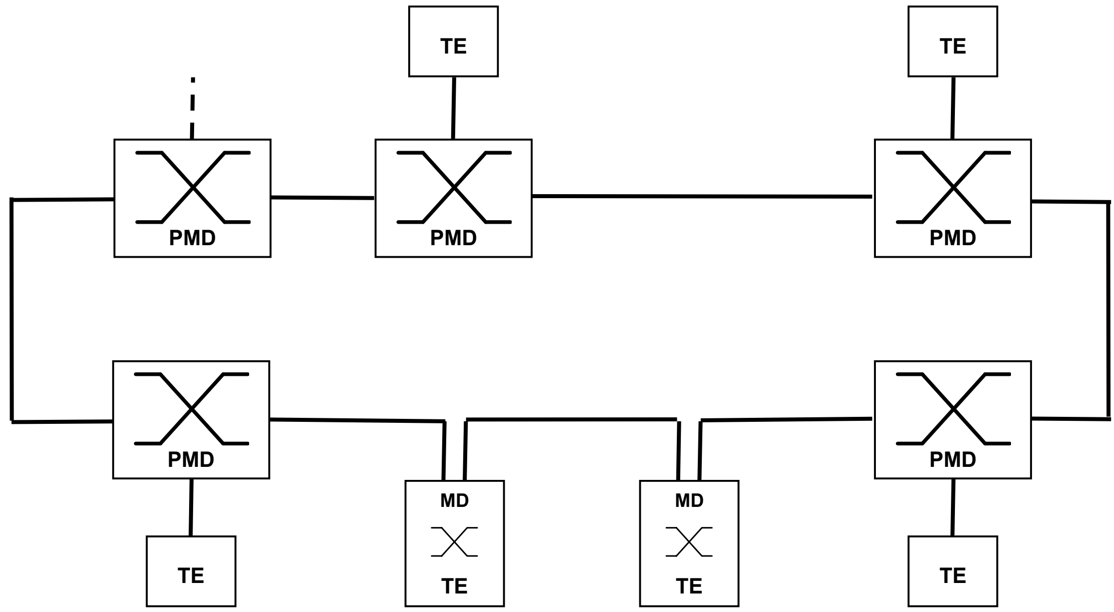
Line structure is used in particular for:
- systems with widespread structures, e.g. conveyor systems
- for connection of production cells

Line structures have the following benefits for users:
- cost-optimised cabling of widespread system
- corresponds with usual field bus structure
- active network components and automation components are located in the same switch cabinet; this simplifies the power supply and protection against environmental influences.

The following points must be observed:
- Attention must be paid that only switches with lowest possible run through times are used. The delay time of a message accumulates while running through each switch in a line.
- A break in the line leads to a split into two functionable segments.

6.1.4. Ring topology

Closing the ends of a line with an additional connection results in a ring structure. Naturally, a special mechanism in at least one network component in the ring must ensure that the ring remains a logical line. This defined break point may only then be closed if the ring has been broken at another point, e.g. as a result of line breakage.



TE = Terminal Equipment
PMD = PROFInet Machine Distributor

Figure 6.1-4 Ring topology

Ring topologies are used in
- systems with higher availability requirements

Application benefits of ring topologies include
- increased system availability through protection against line breakage or failure of a network component.

The following points must be observed:
- The return line for closing the ring must be laid in a separate path.
- Network components must ensure by means of a special mechanism that the ring remains a logical line.

7. Design of PROFInet cabling

7.1. General instructions for industrial PROFInet cabling

In industrial plants, the communication cabling is mostly linked to the life time of the system.
If no further flexibility is required the tertiary cabling structure as proposed in IEC 11801 is not necessary in the industrial area.
Continuous connections between terminal and network components reduce costs and error sources during installation. This applies in particular for fibre optic cable connections.
Industrial-purpose cables can be subject to extreme mechanical stress. For instance, the cables have to survive extreme bending cycles in power chains (drag chains) and festoon systems. Such cables require special fabrication which, in turn, may affect the transmission properties. That is why only shorter transmission paths may be possible when using special cables. The respective manufacturer's instructions must be observed.
In order to meet a wide variety of demands, the PROFInet cabling directive supports the following procedures:

- **Simplified cabling engineering** based on IEC 11801 with standard cables, connecting elements and structures described in tabular form.
- **Plant dependent engineering**, i.e. channel lenth calculation based on manufacturer specifications for special cables and/or connecting elements.

PROFInet "simplified cabling engineering" allows the installation of connecting lines to regulations without having to carry out a special calculation of the transmission channel. The basis for any such - for the user simplified - installation, however, is the stipulation of significant basic parameters for the cables and the connectors.
If the equipment location requieres the use of special cables and/or connecting elements not complying with the transmission-related requirements of this specification, the cable/connector manufacturer must provide the necessary information for determining the channel length.

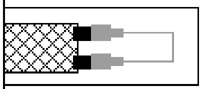
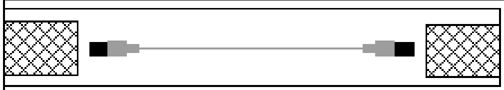
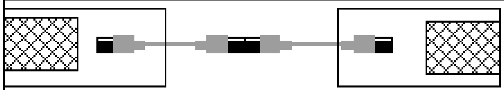
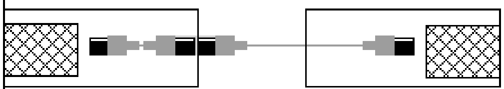
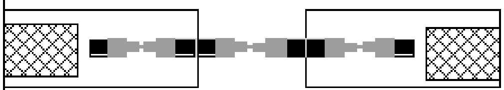
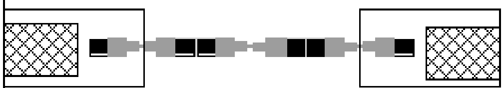
7.2. PROFInet cabling with balanced cables

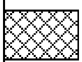
Only shielded cables and connecting elements are permitted.
Permanent connections must ensure a lasting connection and should be easy to apply, e.g. in the form of IDC contacts (IDC= Insulation Displacement Contact).
Separable connections are to be established using RJ45 or M12 plug-in connection systems.
If working with plug-in connectors, socket type connections must be used for appliance and information-system connections. Connecting cables (unit connection cable, equipment cable, patch cords) must be fitted accordingly with plugs at both ends.

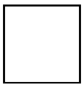
The individual components must conform with the requirements of category 5 of IEC 11801:Ed. 2.0. The complete PROFInet transmission channel must conform with the requirements of class D according to IEC 11801:Ed. 2.0.

Transmission channel lengths therefore are determined by the type of cable being used (see chapter 10.1 for cable specification).
The choice of cable has to be such that a transmission channel length of 100 m is achieved between two active network components. The use of a high number of plug connections has a negative effect on attenuation and reflection and consequently reduces the transmission channel length.

The following table contains examples of the transmission channel lengths in relationship to the cabling.

Cabling Example	Number of pairs	Maximum permitted channel length for cable type A,B,C
	2	100 m
	2	100 m
	2	100 m
	4	100 m
	4	100 m
	6	100 m
	6	100 m


TE = Terminal Equipment
PMD = PROFInet Machine Distributor


Enclosure of an inside environment


Copper connector

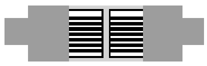

Coupling connector or wall feed through

Figure 7.2-1: Transmission channel lengths

The above-stated transmission channel lengths apply if using the cable types specified in the cable chapter and the plug types specified in the plug chapter. A combination of plug and socket is always regarded as a pair. A maximum of 6 pairs may be inserted into the connection between two active devices or network components without reduction of the transmission channel lenghts of 100 m.

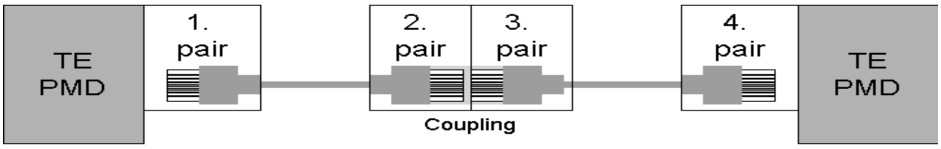


Figure 7.2-2: Counting the pairs (Example)

Every additional pair reduces the length of the transmission channel. Explicit calculation must be carried out if using more than 6 pairs. The calculation is described in ISO/IEC 11801.
After installation it is recommended to verify the transmission quality of the channel. Additional information is given in ISO/IEC 11801.

7.3. PROFInet cabling with multimode optical fibre cables

Optical fibre channels for PROFInet basing on multimode fibres must conform with the requirements of ISO/IEC 9314-3. Table 7.3-1 provides a summary of characteristic parameters for information purposes. The attenuation of the complete optical fibre channel should be checked by measurement upon completion of the installation and must not exceed the upper limits contained in Table 7.3-1.

Parameter	**Value**		Reference ISO/IEC 9314-3
Type of fibre according to ISO/IEC 60793-2	Multimode glass fibre A1b	 A1a	10.1.1
Core diameter	62,5/125 µm	50/125 µm	10.1.1
Minimum modal bandwidth	500 MHz*km	500 MHz*km	10.1.2.2
Largest permitted channel attenuation (bei 1300 nm)	11 dBm	6 dBm	10.1.2.2
Connection-related channel length L)*1 x = No. of plug connections y = No. of spliced connections d= specific attenuation of the fibre optic cable (at 1300 nm)	$L = \frac{11 - 0,5x - 0,3y}{d}$	$L = \frac{6 - 0,5x - 0,3y}{d}$	
Maximum permitted channel length)*2	2000 m	2000 m	10.1
Plug	SC-D BFOC/2,5	SC-D BFOC/2,5	
)*1 Channel: the end-to-end transmission path connecting any two fiber optic interfaces. Attenuation of 0.5 dB is assumed for each plugged and 0.3 for each spliced connection)*2 ISO/IEC 9314-3 specifies a system for 2000 m. Greater channel lengths are possible according to manufacturer's specifications.			

Table 7.3-1: Channel specification for multimode optical fibre cables

7.4. PROFInet cabling with singlemode optical fibre cables

Optical fibre channels for PROFInet basing on singlemode fibres must conform with the requirements of ISO/IEC 9314-4 (category 1). Table 7.4-Table 7-2 provides a summary of characteristic parameters for information purposes.
The attenuation of the complete optical fibre channel should be checked by measurement upon completion of the installation and must not exceed the upper limits contained in Table 7-2.

Parameter	**Value**	Reference ISO/IEC 9314-4
Type of fibre according to ISO/IEC 60793-2	Single mode glass fibre B1	8.1
Core/cladding diameter	8.7 ...10/125 µm	8.1.2
Largest permitted channel attenuation)*1 (at 1300 nm)	10 dBm)*2	8.1.1
Channel length	<= 14 km)*3	Annex B
Plug	SC-D BFOC/2,5	
)*1 Channel: the end-to-end transmission path connecting any two fiber optic interfaces.)*2 according to ISO/IEC 9314-4 (category 1))*3 See ISO/IEC 9314-4 Annex B for a guide to estimating cable plant length		

Table 7.4-1: Channel specification for singlemode optical fibre cables

8. Areas of application of hybrid cabling and data cabling

Depending on the application PROFInet offers a pure data and a combined hybrid cabling. Hybrid cable combine the date and the 24 Volt power supply. A hybrid cabling structure appears in the machine network because the devices have to be supplied with 24 volts as well as data. Line topology is supported by hybrid cabling.

The 24 volt power supply is not necessary in areas that form an interface to the office network (InO Industrial Outlet). In this case it is possible to use a pure data cabling. Data cabling can be used for terminals without hybrid connections. Devices have to be connected to 24 Volt separately.

Suitable network components must be used for the transition from hybrid to non-hybrid cabling.

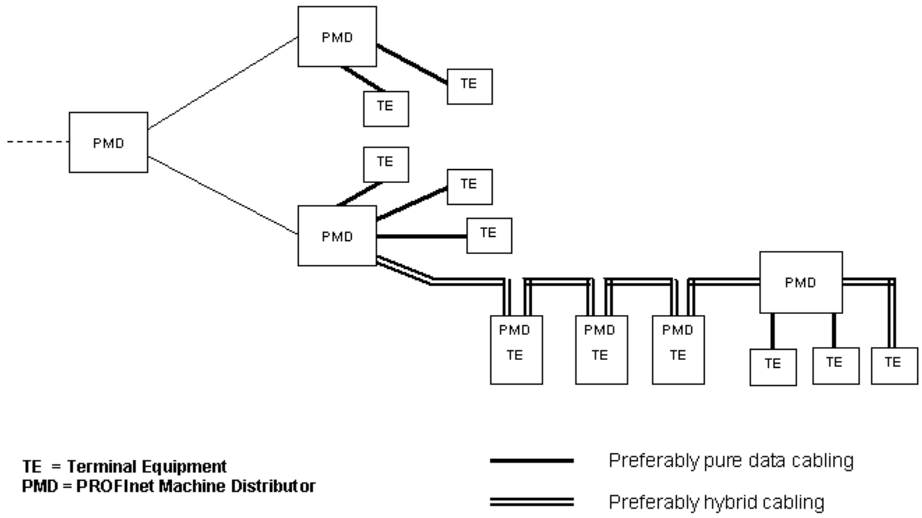


Figure 8-1: Example of hybrid and data cabling applications

9. Network components

In this directive, "Network components" describe devices that

- lie between terminals in the transmission path and
- regenerate signals and forward them selectively

Network components are used for structuring of networks (star, line, tree, ring) and enable data communication between segments.
Network components suitable for PROFInet must be designed for Fast Ethernet (100 MBit/s) and full duplex transmission.
In full duplex mode, a network component receives and transmits data simultaneously at the same port. There are no collisions. Consequently, there is no bandwidth which is lost through the Ethernet collision process. Network engineering is made a lot simpler because there is no need for checking the section length within a collision domain.
The interfaces should also support the operation of 10BASE-T (10 MBit per sec, CSMA/CD) in order to ensure compatibility to older systems or individual older terminals or hubs.

PROFInet only uses units with switch functionality as signal distributor.
A switch receives data packets at its network interface and forwards them selectively. Data is only output at that interface through which it can reach its destination. A switch can send and receive different data simultaneously at all interfaces.
A switch must fulfil at least the following functions for use in a PROFInet network:

- Support of Ethernet according to ISO/IEC 8802-3 (10/100 MBit/s)
- Support of Ethernet according to IEEE802.1D and IEEE802.1Q
- Support of standardized diagnosis paths
- Full duplex operation
- Support of the Auto Cross-Over function

A switch is symbolized in the following way within this directive:

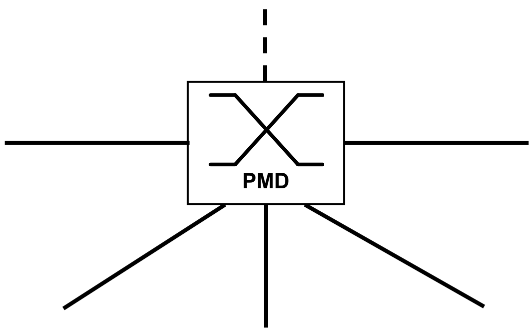


Figure 9-1: Switch symbol PMD (PROFInet Machine Distributor)

10. PROFInet interconnect systems

PROFInet machine cabling differs from the building cabling in main points. The stipulation of three application methods covers a large section of industrial applications:

- Fixed/Permanent cabling
- Flexible cabling
- Highly flexible cabling, e.g. in drag chains and frequently moving machine parts

PROFInet connectors and cables are used for the connection of devices or complete network segments. The cable and connector have to represent a matched system.
An arrangement of the components to comply with industrial ambient requirements is necessary so that this connection is functioning reliably.
The integration of the 24 volt power supply is referred as hybrid cabling.

Application	Data Cabling Inside of switching cabinet environment	Data Cabling Outside of switching cabinet environment	Hybrid cabling Outside of switching cabinet environment
Type	J45 plug compatible)[*1]	J45 plug compatible)[*1] or M12	J45 plug compatible)[*1]
Number of wires / used Data Power	8/4 (4/4 M12) ---		8/4 4/4
Rated voltage Data Power	48 VDC (44 ... 57 V) ---		48 VDC (44 ... 57 V) 24 VDC (20,4 ... 28,8 V)
Current (min.) Data Power	350 mA ---		350 mA 10 A
Outer cable diameter	5,5 mm to 8,5 mm		6,0 mm to 12 mm
Wire cross section Data Power	AWG24 to AWG22 ---		AWG24 to AWG22 1,5 mm^2 to 2,5 mm^2
Wire construction	solid / stranded		
Transmission performance	ISO/IEC 11801 Edition 2.0		
Category (min.)	ISO/IEC 11801 Edition 2.0 Connector Category 5		
Shielding	yes		
Cable can be fabricated in the field	yes		
Cable strain relief	IEC 61984		
Mating cycles	min. 50 (IEC 61984)		
Protection class Degree of pollution Shock Vibration Operating temperature range	see Table 4.3-1 „inside“	see Table 4.3-1 „outside“	

)[*1] RJ-45 pinning compatibility applies only to the pins themselves. For full plug-in compatibility, the shape of the casing of industrial connectors must also be taken into account (see chapter 10.2). The specified RJ 45 receptacle (Jack) for „outside“ applications has to be mating compatible with the RJ 45 Plug according to IEC 60 603-7.

Table 10-1: Plug connector specifications

Passive T-pieces are not possible with PROFInet. All devices are connected through an active network component defined in chapter 9. The transmission cable is designed the same at both ends (connector design and pin assignment) in order to ensure the easiest possible installation.

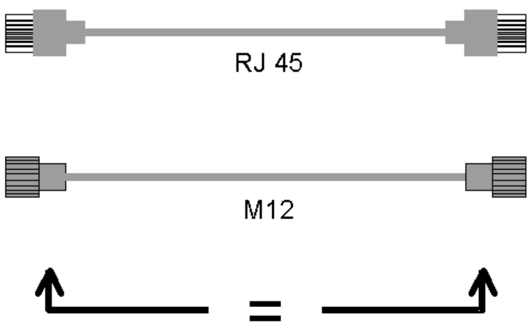


Figure 10-1: Connecting lines

Extension cables or floating connectors can be achieved using coupler connectors. These connectors are available for all listed plug connectors (M12, RJ45).

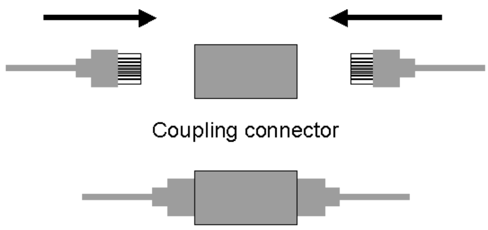


Figure 10-2: Coupling connectors

Inserting coupling connectors creates additional transition points which influence the maximum channel length.

The contact arrangement on the connectors and the colour coding of the cable is specified as follows:

Signal	Function	Wire colours	Contact assignment	
			RJ-45	M12
TD +	Transmission data +	yellow	1	1
TD -	Transmission data -	orange	2	3
RD +	Receiver data +	white	3	2
RD -	Receiver data -	blue	6	4

Table 10-2: Contact and wire assignment

The selected contact assignment of the RJ45 is compatible with the Ethernet standard, i.e. compatible with ISO/IEC 8802-3.
Attention must be paid that units which are only designed for use within the switch cabinet are always designed with the RJ45. For field devices in IP65/67 design either an RJ45 or an M12-based solution depending on the application is possible.

Cross Over:

The cross over changes the signal over from transmitter to receiver. A cross over is avoided because of possible installation cabling errors. Network components are designed so that they carry out an automatic cross over.

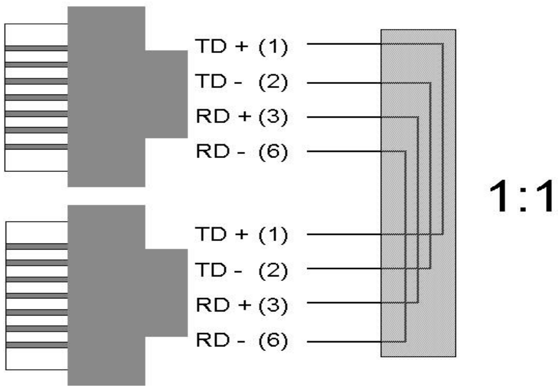


Figure 10-3: Cable connection

Connecting technique:

Controllability of the connecting technique on site is a major criterion for applicability. Appropriate plug connectors are available for this both for the M12 as well as for the RJ45. These plug connectors can be fitted easily on site using standard tools. Preference is to be given to plug connector solutions that have this option.

10.1. PROFInet cables

10.1.1. Balanced cables

PROFInet cables being used base electro-technically on LAN balanced cables of category 5 according to ISO/IEC 11801 Edition 2.0.
In case of special applications (e.g. the use of drag chains and frequently moved machine parts), cables are permitted whose design and mechanical parameters (see Table 10-3) while retaining the electrical parameters (impedance levels etc.), can deviate from the specifications of this directive. Highly flexible copper cables generally have finest stranded conductors and, for example, a highly resistant polyurethane outer sheath.
Various outer sheath materials are permitted in order to meet the various demands with regard to resistance in industrial environments and exterior/underground laying (natural and synthetic oil, grease, coolants/lubricants, chemicals, high and low temperatures, UV radiation).
Industrial-type plug connectors type RJ45, protection type IP67, or a tried and tested industrial round plug connector M12, category 5, are to be used as plug connectors.
All balanced cables being used must comply with the following parameters:

Cable Type	**Application Type A**	**Application Type B**	**Application Type C**
Design	data cable	data cable	data cable
Cable installation type	stationary, no movement after installation	flexible, occasionally movement or vibration	highly flexible, permanently movement or vibration or torsion (special applications)
System concept:			
Cable marking (at least)	PROFInet Type A	PROFInet Type B	PROFInet Type C
Core cross section	AWG 22/1	AWG 22/7	AWG 22/19 or similar
Outer cable diameter	5,5 - 8,0 mm		
Core diameter	1,4 +/- 0,2 mm		
Colour (outer sheath)	green RAL6018		
Core identification (colours) star quad 2 pair	 white, yellow, blue, orange Pair 1: white, blue Pair 2: yellow, orange		
Number of cores	4		
Cable design	2 pairs or 1 star quad		
Shielding design type	aluminium foil + copper braiding		
Which plug for which cable type	RJ45 (IP 20 or IP 65/67) / M12 (see table 10-1)		
Transmission performance requirements:			
Relevant standard	ISO/IEC 11801 Edition 2.0, IEC 61156 (minimum Category 5)		
Transfer impedance	<=50 mΩ/m at 10 MHz		
Ambient conditions:			
Minimum tensile strength	50 N		
Pollution degree Shock Vibration Operating temperature range	see Table 4.3-1: General environmental requirements on passive PROFInet connection systems		

Table 10.1.1-1: Balanced cable specification

The wire assignment of the star-quad cable is indicated by the colour coding:

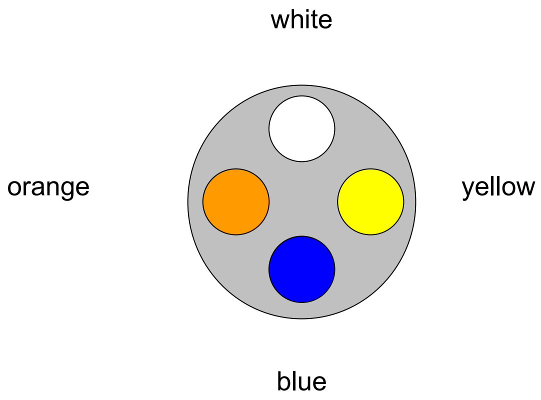


Figure 10.1.1-1: Wire assignment of the star-quad cable

The following parameters should preferably adhered to:

- Sheathing materials shall be suitable for the intended application
- Flame retardance shall be tested in accordance with IEC 60332-1
- For special applications materials should be free of substances (i.e. silicone) destructive to laquer-coatings

10.1.2. Optical fibre cables

Glass optical fibre cables allow greater network expansion than metallic balanced cables and are insensitive to electromagnetic influences.
Multimode and singlemode optical fibres can be used depending on the necessary channel length.
The combination of optical fibre and optical interface must be of the same type e.g. multimode/singlemode to operate correctly.
Fiber optic cables should meet the transmission performance requirements as specified in Table 10-4 and Table 10-5 respectively. This provides a simple engineering without having to carry out a special calculation of the transmission channel length.

Cable construction and materials depend on the application (movement, ambient condition, ...) and are not specified in this document.

Cable type	**Multimode optical fibre cables**	
Design	data cable	
Cable installation type	stationary, flexible, highly flexible depending on cable construction	
System concept:		
Cable marking (at least)	PROFInet + fibre type (i.e.: "PROFInet 2G50/125")	
Outer cable diameter	---	
Core diameter	---	
Colour (outer sheath)	green RAL6018	
Colours (fibre marking)	---	
Number of fibres	2	
Transmission performance requirements:		
Relevant standard	IEC 60793-2	
Type according to IEC 60793-2	A1a	A1b
Core/cladding diameter	50/125 µm	62,5/125 µm
Nominal wavelength	1300 nm	
Minimum bandwidth	500 MHz*km	
Maximum attenuation	1,0 dB/km	
Ambient conditions:		
Minimum tensile strength	600 N	
Pollution degree Shock Vibration Operating temperature range	see Table 4.3-1: General environmental requirements on passive PROFInet connection systems	

Table 10.1.2-1: Requirements for multimode optical fibre cables

Cable type	**Singlemode optical fibre cables**
Design	data cable
Cable installation type	stationary, flexible, highly flexible depending on cable construction
System concept:	
Cable marking (at least)	PROFInet + fibre type (i.e.: "PROFInet 2E10/125")
Outer cable diameter	---
Core diameter	---
Colour (outer sheath)	green RAL6018
Colours (fibre marking)	---
Number of fibres	2
Transmission performance requirements:	
Relevant standard Type according to IEC 60793-2	IEC 60793-2 B1
Cladding diameter	125 µm ±2 µm
Mode field diameter	(8,7 ... 10 µm) ±0,5 µm
Cable cut-off wavelength (λcc)	<= 1 270 nm
Maximum dispersion	3,5 ps/[nm*km] (1 285 to 1 330) nm
Maximum attenuation (at 1310 nm)	1,0 dB/km
Ambient conditions:	
Minimum tensile strength	600 N
Pollution degree Shock Vibration Operating temperature range	see Table 4.3-1: General environmental requirements on passive PROFInet connection systems

Table 10.1.2-2: Requirements for singlemode optical fibre cables

The following parameters should preferably adhered to:

- Sheathing materials shall be suitable for the intended application
- Flame retardance shall be tested in accordance with IEC 60332-1
- For special applications materials should be free of substances (i.e. silicone) destructive to laquer-coatings

10.1.3. Hybrid cables

Hybrid cables contain wires for the signal and voltage supply.

- Cu/Cu design (4 wire data transmission / 4 wire for power transmission).

Cable Type	**Application Type B**	**Application Type C**
Design	hybrid cable	hybrid cable
Cable installation type	flexible, occasionally movement or vibration	highly flexible, permanently movement or vibration or torsion (special applications)
System concept:		
Number of wires data power	 4 4	 4 4
Core cross section data power	 AWG 22/7 1,5 mm^2	 AWG 22/19 or similar 1,5 mm^2
Cable marking (at least)	PROFInet Hybrid Typ B	PROFInet Hybrid Typ C
Outer cable diameter	8,0 ... 12,0 mm	
Core diameter data power	 1,4 +/- 0,2 mm	
Colour (outer sheath)	green RAL6018	
Core identification (colours) star quad 2 pair power	 white, yellow, blue, orange Pair 1: white, blue Pair 2: yellow, orange numbers 1,2,3,4	
Cable design	2 pairs or 1 star quad + 4 power wires	
Screening design type	aluminium foil + copper braiding (data wires)	
Which plug for which cable type	RJ45 (hybrid)	
Transmission performance requirements (data wires):		
Relevant standard	ISO/IEC 11801 Edition 2.0, IEC 61156 (minimum Category 5)	
Transfer impedance	<=50 mΩ/m bei 10 MHz	
Ambient conditions:		
Minimum tensile strength	50 N	
Pollution degree Shock Vibration Operating temperature range	see Table 4.3-1: General environmental requirements on passive PROFInet connection systems	

Table 10.1.3-1: Hybrid wire cable specification

Note:

The possible channel length of the hybrid cable depends on the power consumption of the connected devices.

10.2. PROFInet plug connectors

10.2.1. Plug connectors for switch cabinet environmental conditions (balanced cabling)

Selection of RJ45 plug connector products must comply with the criteria for industrial machinery and equipment. The use of plug connectors with altered technical specifications (dielectric strength, connecting system...) in comparison with those for office use is stipulated.

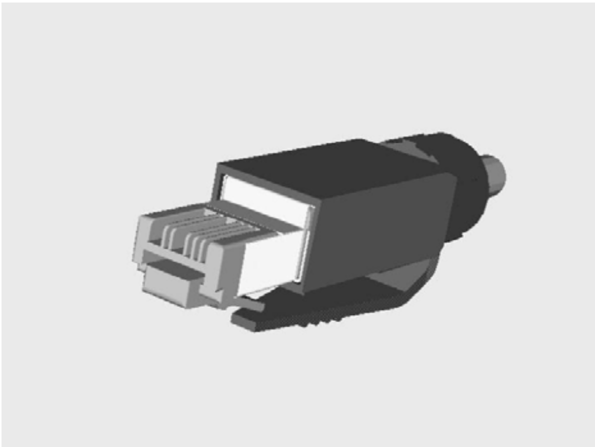


Figure 10.2.1-1: RJ45 plug in IP20 with industrial performance

10.2.2. Plug connectors for switch cabinet environmental conditions (optical fibre cables)

The connection of optical fibre cables and device or optical fibre cables with each other complies with ISO/IEC 11801. On new equipment, it is preferably connected with the duplex SC plug connector system.
This plug connector system is prescribed in IEC 60874-14.
Devices are to be fitted with the socket, connecting cables with the plug.

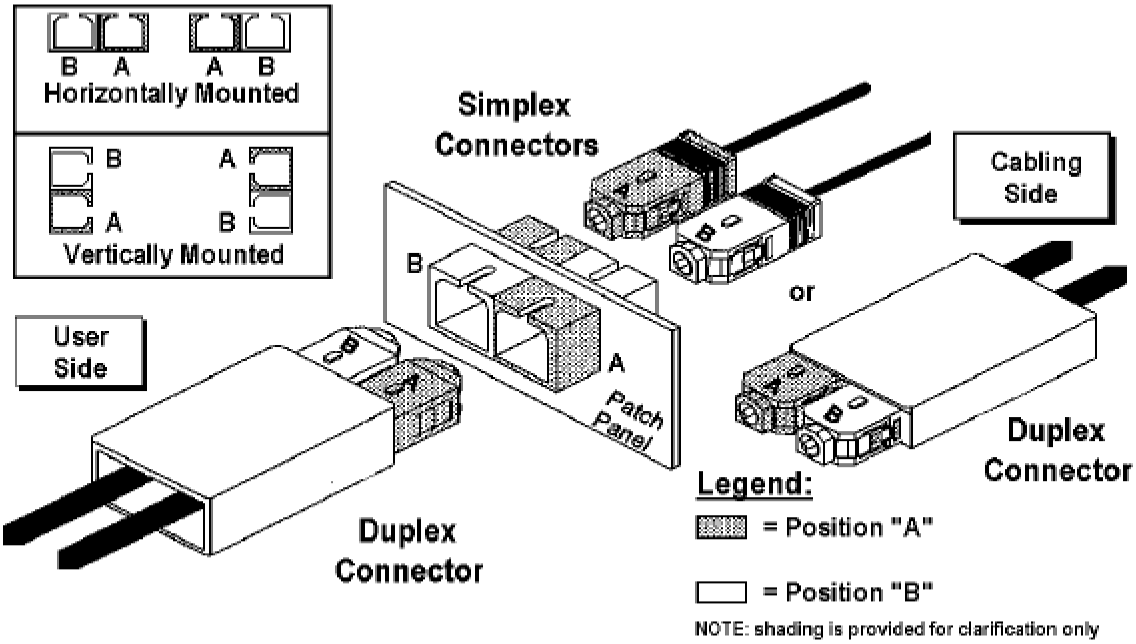


Figure 10.2.2-1: Duplex SC plug connector system

The fibre optic cable plug connector BFOC/2.5 according to IEC 60874-10 can be used as an alternative.

Figure 10.2.2-2: Fibre optic cable plug connector BFOC/2.5 according to IEC 60874-10

With individual BFOC connectors, it must be possible to distinguish the send and receive direction of assembled cables, for example by color-coding the anti-kink sleeves at both ends of a fiber.

10.2.3. Plug connectors outside the switch cabinet (IP65 / IP67) (balanced cabling)

RJ45 plug connector

The RJ45-compatible IP67 plug connectors being used are standardized and are described in the following standard: IEC 61076-3-106 – RJ 45 - Industrial RJ45 Variant 04

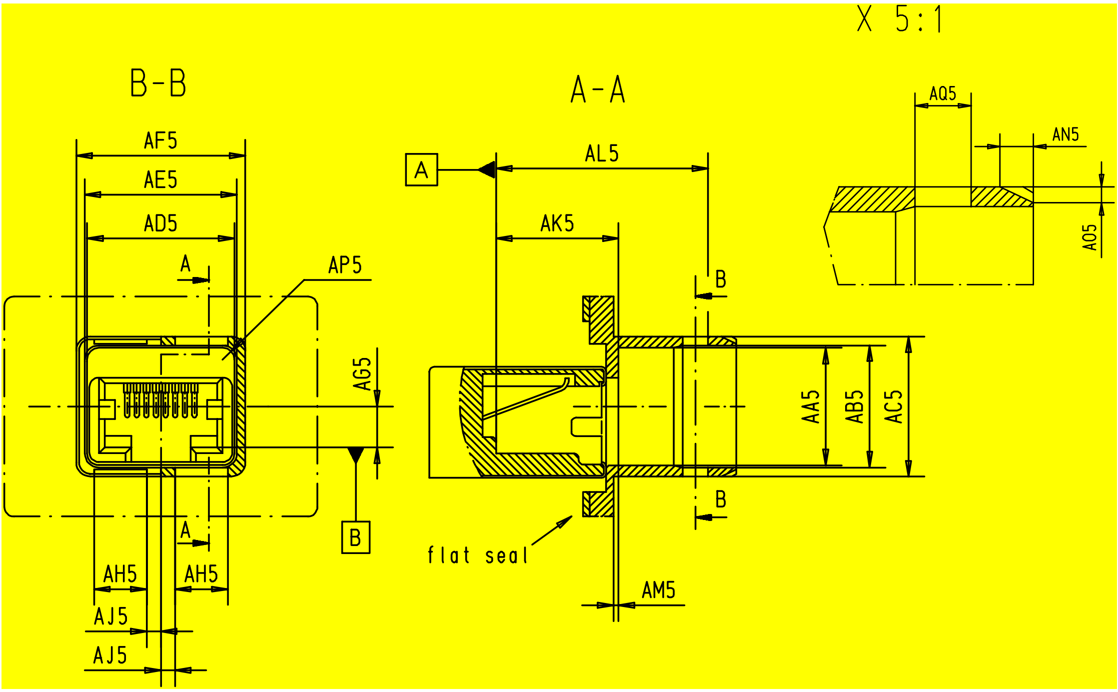
Figure 10.2.3-1: IP67 RJ45 plug connector

RJ 45 compatibility is defined as such that the contact geometry ensures the plug-in and function of a standard RJ45 plug in combination with a jack defined here. The "office" patch cable must be pluggable under all circumstances to ensure a reverse compatibility to the office equipment.

The unprotected plug situation does not fulfill the industrial requirements and therefore represents an exception which can occur as part of a diagnosis or commissioning.

The defined installation system on the basis of IP65 / IP67 RJ45 has the following components:

- Assembled hybrid cable with 2-pair, shielded data cable
- Plug connector for above-mentioned cable with protection type IP 65 or higher
- Coupling connector
- Wall break-through and Industrial Outlets (InO)
- Field assemblies and network components



Letter	Maximum mm	Minimum mm	Nominal mm
AA₅	12,51	12,45	12,48
AB₅	13,01	12,95	12,98
AC₅	14,90	14,80	14,85
AD₅	15,67	15,61	15,64
AE₅	16,17	16,11	16,14
AF₅	18,00	17,90	17,95
AG₅	4,74	4,62	4,68
AH₅	5,70	5,50	5,60
AJ₅	1,60	1,40	1,50
AK₅	13,35	13,05	13,20
AL₅	22, 95	22,65	22,80
AM₅	0.65	0,55	0.60
AN₅	1.70	1.50	1.60
AO₅	0.80	0.70	0.75
AP₅	R 1,28	R 1,22	R 1,45
AQ₅	2.80	2.60	2.70

Figure 10.2.3-2: IP 67 RJ45 plug for PROFInet

The IP 67 RJ45 plug for PROFInet is based on a RJ45 newly developed for industrial applications. This is located in a rugged housing with push-pull locking. The cable shield is fitted inside the housing. Standard industrial plug connector housing can be used as an alternative for special applications. This housing is available in metal and plastic designs. Special designs allow a protection level up to IP68.

Implementation instructions for the device design

The following device implementation concepts exist:

- Implementation through wall feed through (panel feed through)
- Implementation on printed circuit boards inside the device and standard housing
- Implementation on an in-device printed circuit board and direct implementation of the housing contour

Wall feed through:
Device connection at a wall feed through is done by a connecting cable.
An attachment housing is fitted onto the device housing. Appropriate standard products are being made available for this.

Printed circuit board adaptation:
The RJ45 connector in low profile design can be a direct component of the printed circuit board of the device.

M12 plug connectors

Connections between transmission cables and the device or between transmission cables are to be carried out with a 4-pin M12 plug connector system.
Devices are fitted with sockets, connecting and transmission wires are fitted with male connectors. The coding version „D“ from IEC 61076-2-101 for industrial Ethernet will be applicable.

For contact and wire assignment see Table 10-2.

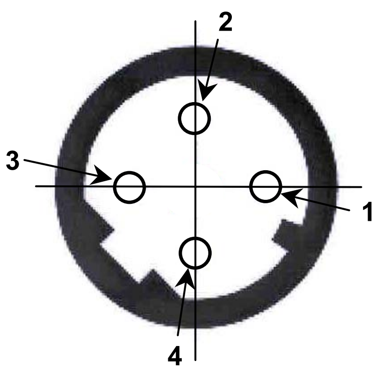
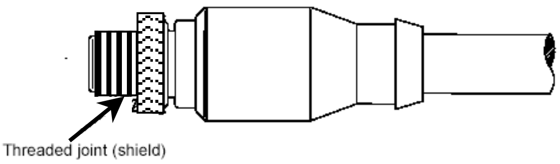


Figure 10.2.3-3: M12 Contact assignment and coding



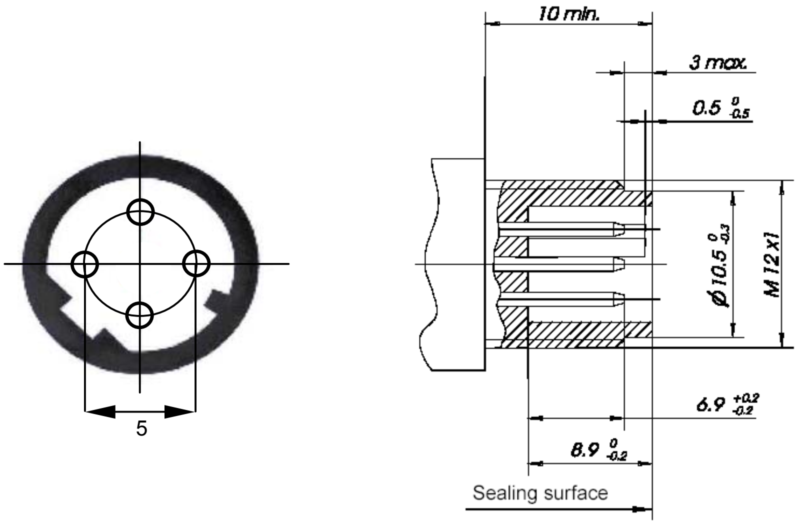


Figure 10.2.3-4: View of plug with basic dimensions

The coding must be used to prevent connection errors.
The contact chamber 5 must be closed. The socket must always be fitted to the terminal and the double-end male connectors on the connecting cable.

This makes it virtually impossible to plug incorrectly into previously installed field buses.

The dimensions for the plug connector comply with the mentioned standards, only the electrical values have been adapted to the requirements of PROFInet.

The defined installation system on the basis of M12x1 has the following components:

- Standard transmission path with 2-pair shielded or star-quad shielded data cable
- Plug connector M12x1 of IP67 type protection or higher
- Coupling flange
- Wall break-through and Industrial Outlets (InO)
- Field assemblies and network components

Implementation instructions:

The following device implementation concepts exist:

- Implementation through cable feed through in switch cabinets
- Implementation through wall feed through
- Implementation on printed circuit boards inside the device and standard housing
- Implementation on an in-device printed circuit board with user-related integration into the housing contour

Device connection at a wall feed through is done by a connecting cable. Appropriate products are being produced for this.
Products are already available for printed circuit board adaptation. Special attention has to be paid to an appropriate connection of the printed circuit board adapter to the housing for grounding.

10.2.4. Plug connectors outside the switch cabinet (IP65 / IP67) (multimode optical fibre cables)

Key elements of the IP 67 connector are standard multimode conncetors type SC. The SC-connectors are fixed by means of a insert into a housing of a standard industrial connector, comparable to those of the IP 67 Hybrid data connector and the active fibre optic connector.

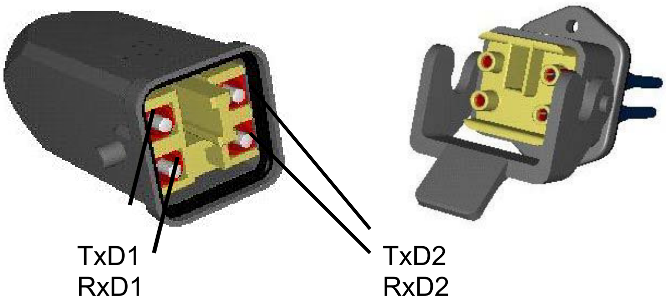
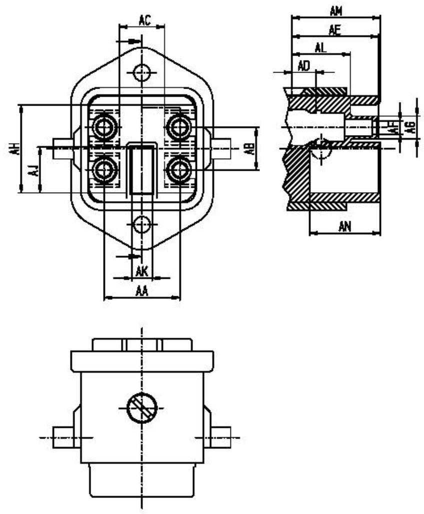
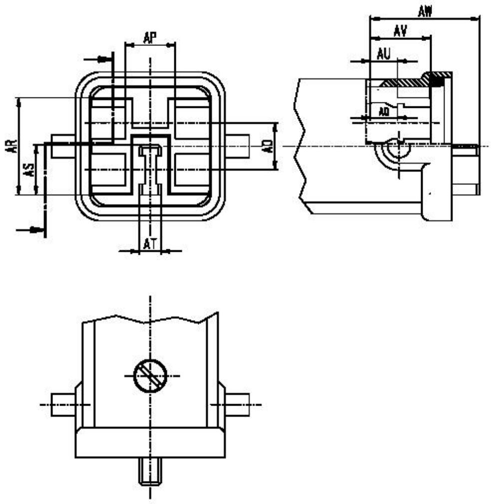


Figure 10.2.4-1: IP67 Connector for multimode optical fibre cables





	Max	Min	Nominal
AA	15	14,9	14,95
AB	8,45	8,35	8,4
AC	8,95	8,85	8,9
AD	4,85	4,75	4,8
AE	17,15	17,05	17,1
AF	Ø2,73	Ø2,67	Ø2,7
AG	Ø4,7	Ø4,65	Ø4,7
AH	17,45	17,35	17,4
AJ	9,05	8,95	9
AK	4,05	3,95	4
AL	11,7	11,5	11,6
AM	17,6	17,4	17,5
AN	14,2	13,8	14
AO	8,45	8,35	8,4
AP	8,95	8,85	8,9
AQ	4,85	4,75	4,8
AR	17,35	17,25	17,3
AS	8,95	8,85	8,9
AT	3,95	3,85	3,9
AU	4,9	4,7	4,8
AV	10,8	10,6	10,7
AW	19,6	19,2	19,4

Figure 10.2.4-2: PROFInet fibre optic connector IP 67 (mechanical dimensions)

These housings are available in different versions. Industrial cables with up to four fibres are supported.

10.2.5. Plug connectors outside the switch cabinet (IP65 / IP67) (hybrid cable)

The RJ45-compatible IP67 plug connectors being used are standardized and are described in the following standard: IEC 61076-3-106 – RJ 45 - Industrial RJ45 Variant 05.

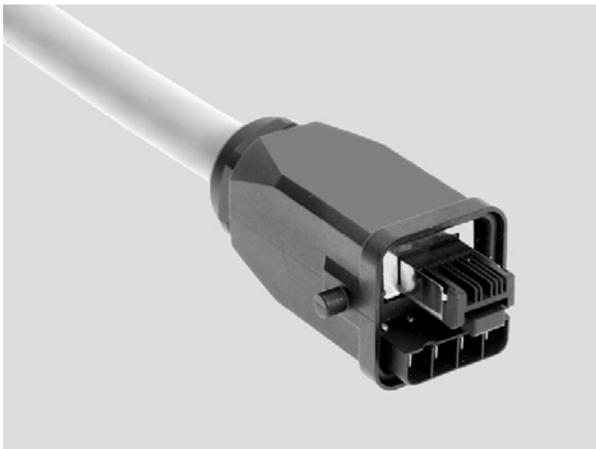
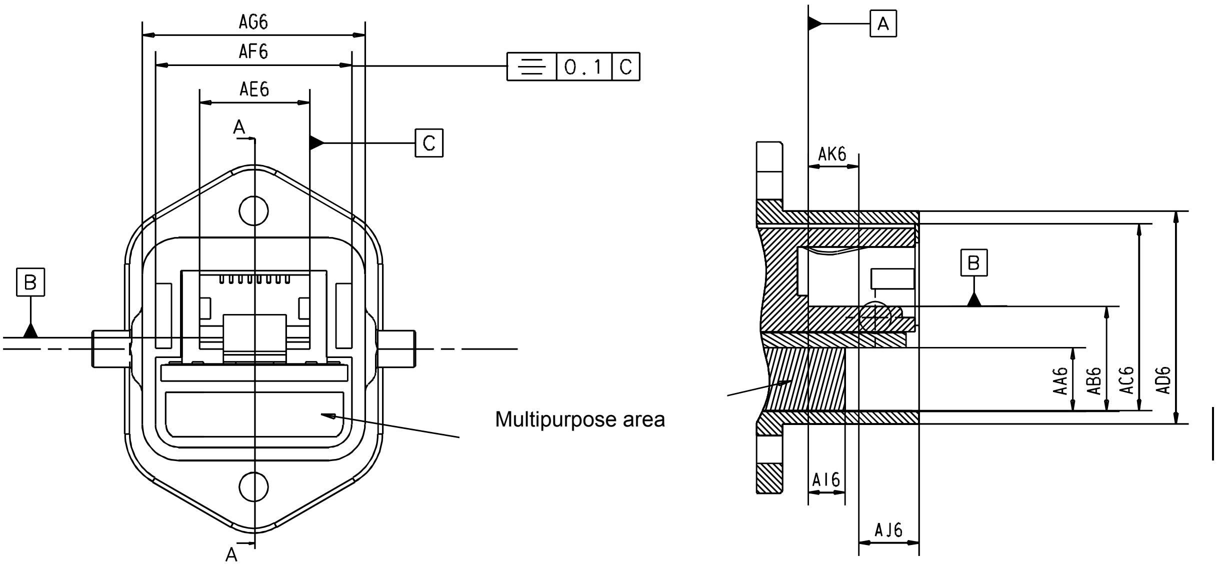


Figure 10.2.5-1: Picture of the hybrid plug connector

The hybrid plug connector is to be used where decentralized field devices are to be connected via **one** combined plug connector with data and power supply. A complete contact-protected plug connector enables the use of the same plug connectors at both ends because no pin-socket change is necessary.

The defined installation system on the basis of hybrid plug connector IP 67 has the following components:

- Assembled hybrid cable with 2-pair, shielded data cable for communication and 4 Cu conductors for power voltage supply.
- Hybrid connector for above-mentioned cable with protection type IP 65 or higher
- Coupling connector
- Wall feed through and Industrial Outlets (InO)
- Field assemblies and network components



Letter	Maximum	Minimum	Nominal(ref)
	mm	mm	mm
AA6	7,06	7,00	7,00
AB6	11,50	11,14	11,29
AC6	21,40	21,30	21,30
AD6	24,20	24,00	24,20
AE6	12,40	11,84	11,94
AF6	21,40	21,30	21,30
AG6	24,20	24,00	24,20
AH6	0,00	0,00	0,00
AI6	4,78	4,33	4,55
AJ6	7,25	6,65	6,90
AK6	6,10	5,80	5,95

Figure 10.2.5-2: Dimensions of the PROFInet Hybrid plug connector IP 67

Implementation instructions for the device design

The following device implementation concepts exist:

- Implementation through wall feed through
- Implementation on printed circuit boards inside the device and standard housing
- Implementation on an in-device printed circuit board and direct implementation of the housing contour

Wall feed through:
Device connection at a wall feed through is done by a connecting cable. An attachment housing is fitted onto the device housing. Appropriate standard products are being made available for this.

Printed circuit board adaptation:
The RJ45 connector in low profile design can be a direct component of the printed circuit board of the device.
Special attention has to be paid to an appropriate connection of the printed circuit board adapter to the housing for grounding.
The following dimensions must be observed for contact safety:

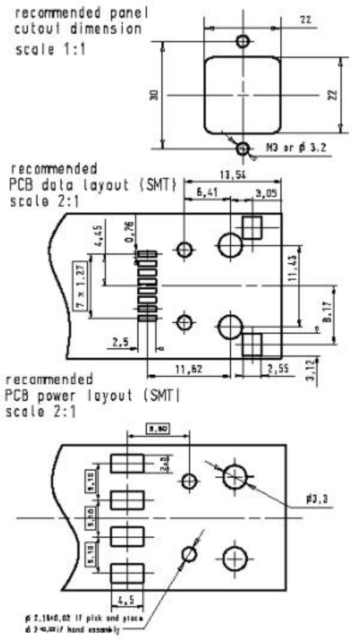


Figure 10.2.5-3: PROFInet hybrid plug connector printed circuit board adaptation

11. Installation instructions

11.1. Installation instructions for electrical and optical data cables

In general
At installation time, attention must be paid that data cables can only take a certain amount of stress. Excessive pulling, pressure, twisting and buckling can result in the cable being damaged or the conductor broken. The following instructions will help you to avoid damage when installing data cables.
Cables that have been subjected to excess stress for one or more of the aforementioned reasons should always be replaced.

Installing data cables separately
We recommend laying data cables in a separate cable duct in combination with other measures for improving EMC properties. If only one combined cable duct is available, the data cables should at least be bunched together into a separate bundle.
Separation provides a number of advantages:

- Improvement of the EMC
- Better protection against indirect damage, e.g. if pulling sturdier power cables into the same cable duct at a later date
- Easier localisation if troubleshooting becomes necessary

Protecting data cables against potential mechanical damage
Data cables are to be laid in one-piece enclosed aluminum or steel conduits or a steel cable tunnel in pathway areas of building and machine sections as well in the region of transport routes and through-ways.

Installing redundant data cables in separate cable routes
Redundant cables should always be installed in separate cable routes in order to prevent simultaneous damage through the same occurrence.

Storage and transportation
During storage, transportation and laying, delivered data cables must be kept closed at both ends with a shrink cap in order to prevent any oxidation of the individual wires and the shielding sheath and avoid any collection of moisture in the cable.

Temperatures
The prescribed minimum and maximum temperatures for transportation, handling and operation must not be exceeded as this could have a negative influence on the electrical and mechanical properties of the cable. The permitted temperature range of your cable can be found on the manufacturer's data sheet.

Tensile strength
The tensile strengths acting on the cable must not exceed the maximum tensile strength of the cable during handling (e.g. rewinding) or when installed. The permitted tensile strength of your cable can be found on the manufacturer's data sheet.

Fitting strain relief
Fit a strain relief device at about 1 m distance to the connecting point of all cables subject to tensile strength. Cable clamps attached to shielding sheaths are not sufficient as strain relief!

Pressure loads
Excess stress on the data cable from pressure, e.g. through crushing as a result of incorrect fastening, must also be avoided.

Torsion (twisting)
Torsional stress can result in shifting individual cable construction elements and therefore may have a negative influence on the electrical properties of the cable. For this reason, data cables must not be twisted unless they are specially designed cables for torsional strain (e.g. robotic applications).

Bending radius
The permitted bending radius of a data cable must not be undercut at any time. Failure to observe this could lead to damage or non-permitted restrictions to the specified transmission characteristics.
Please observe that the permitted bending radii

– are greater while pulling in under tensile load than in a resting, installed state
– only apply for the flat side when bending flattened cables! Bending over the rounded side requires much greater radii! The permitted tensile bending radii of your cable can be found on the manufacturer's data sheet.

Avoid forming loops
Wind the data cable from the cable drum tangentially when laying or use a suitable rotary table. This avoids loop formation and any resulting buckling and cable twisting (torsion). The cables must be installed torsion-free.

Subsequent installation
When laying data cables, make sure that they are not subjected to any non-permitted stress in a laid state. This could be possible if the cables have been laid on a combined tray or in a joint cable route (insofar as electrical safety permits this) and new cables are being pulled through at a later date (e.g. for repairs, extensions).

11.2. Additional instructions for the installation of optical fibre cables

Danger from fibre optic cables
Installation waste must be treated with care and collected in suitable containers (not by hand) and disposed of through an authorized agency.
Openly accessible fibre ends must be kept away from skin and eyes.
Looking direct into open fibre ends is forbidden insofar as the output of the fibre optic cable is not deemed safe in compliance with EN 608 25.
Frames that contain connecting points for fibre optic cabling must be fitted with appropriate warning signs or texts.

Keeping plugs clean
Fibre optic cable plugs are sensitive to dirt. Plugs and sockets not in use are to be protected by the supplied dust protection caps.

Attenuation change under load
The fibre optic cables must not be twisted, stretched or crushed when laying. For this reason, the specified limit values for tensile strength, bending radii and temperature ranges must be observed. A slight change in attenuation values is possible during laying. These deviations, however, are reversible insofar as the load limits have not been exceeded.

Fitting strain relief
Even if the plugs of the fibre optic cables are fitted with strain relief and buckling protector, we recommend fitting the fibre optic cable close to the connected device with an additional strain relief against mechanical strain.

Plan adequate attenuation reserves
When installing cables over greater distances, it is advisable to take into account one or more repair splices in the power loss budget.

EMC ruggedness
Optical fibre cables are resistant to electromagnetic influences! This means that laying the cable in cable ducts together with other cables (e.g. 230 V / 400 V supply cable) is not a problem. When laying in cable ducts, however, make sure that the permitted strain limits of the optical fibre cables are not exceeded when pulling through other cables.

11.3. Guidelines to ensure the electromagnetic compatibility (EMC)

11.3.1. Introduction

Electromagnetic compatibility (EMC) is the capability of an electrical appliance to function satisfactorily in an electromagnetic environment without having a non-permitted influence on that environment which can include other equipment.
This mutual influence can be caused by electrical, magnetic and electromagnetic effects. These can be transmitted through cable connections (e.g. mutual power supply) as well as through non-cable based radiation. These effects must be restricted to a minimum in order to avoid interference to electrical equipment. Limiting measures include appropriate arrangement and wiring of all electrically conductive system components to ensure EMC fulfillment. These include the electrical power supply and the signal and data cables as well as conductive constructional components (pipelines, steel girders etc.).
If appropriate attention is paid to EMC while planning automation systems as well as the related buildings, it is possible to achieve economical EMC measures on a near cost-neutral basis. Any subsequent changes that become necessary invariably cause considerable costs.
The following points must be observed during the planning phase:

- An equipotential bonding system must be set up at the installation site to include all inactive metal parts of the equipment and building, electrical installations and shielding sheaths of the data cables.
- Equipment and building are to be supplied from a power distribution system with current-free PE (e.g. to TN-S-System as described in IEC 60364-3).
- The PROFInet bus system may only contain components and data cable that support an uninterrupted shielding concept.
- Attention must be paid to lowest possible crosstalk when deciding on positions of equipment and cables.
- The component manufacturer's installation regulations must be observed. All limit values specified by manufacturers for electromagnetic radiation are only valid if the prescribed installation regulations have been observed.
- Extreme sources of radiation must be suppressed through special measures.
- Optical fibre cables are not sensitive to electromagnetic influences because of the optical transmission principle. The use of optical fibre cables is recommended for bus connections in EMC-critical areas as well as between buildings and/or external devices! If in doubt, electrical safety regulation requirements have priority over EMC regulations.

Adherence to the standards when installing communication cabling (EN 50174-2) and the requirements for bonding (EN 50310) is strongly recommended. There are currently no international standards to compare with these European standards in terms of detail.

11.3.2. Equipotential bonding systems

The shielding of metallic data cables form conductor loops together with the ground leads of the electrical installations or possibly with other electrically conductive building sections. Currents flowing in the environment, e.g. caused by electrical consumers or lightning strikes, induce interference voltage in these conductor loops. The resulting current flow must be controlled by an equipotential bonding system to such an extent that it does not cause any interference or destruction.
According to EN 50310 buildings with information-related systems are to be fitted with a common bonding network (CBN) consisting of the closest-knit structure possible of conductive elements. This spreads the flow of interference over so many paths that it avoids any overload to any individual junction. The equipotential bonding system is generally grounded.

The following measurements provide an EMC-favourable grounding and equipotential bonding system:

- A common bonding network (CBN) with low impedance and high current carrying capacity is to be formed from all metallic constructional components of a building.
- The main grounding terminal or rail, grounding conductor, metal pipelines, construction steel, reinforcement rods, equipotential bonding ring conductors, cable trays and any additional equipotential bonding conductors must be connected closely.
- All inactive metal parts, particularly in the immediate vicinity of automation components and data cables must be connected with the equipotential bonding system so that good conductance is achieved. This includes all metal parts of cabinets, construction and machine parts etc. that do not have any electrical conducting function in the automation system.
- Metallic conductive cable ducts/trays are to be included in the equipotential bonding of the system and between the individual system sections. In addition, the individual segments of the ducts/trays must be connected at low inductance and low impedance with each other and as often as possible with the equipotential bonding system CBN. Expansion joints and joint connections are to be bridged by flexible grounding strips. The connections between the individual duct segments must be protected against corrosion to ensure long-term stability.
- If necessary, lay any additional required equipotential bonding conductors immediately next to the data cable so that there is the smallest possible space between the two.
- Equipotential bonding conductors should be made of copper or galvanized steel.

11.3.3. Demands on alternating current distribution systems

Because the shields of the balanced cables are a component of the equipotential bonding system, all currents that are injected into the equipotential bonding system of a building or a system flow there. These shield currents can cause faults in data communications depending on the intensity and frequency range. For this reason, avoid having the alternating current supply system of a plant including the equipotential system in the power return line.
End units and/or network components which are connected via shielded, metallic balanced cables may only be fed from alternating current distribution systems with grounding conductors which do (can) not contribute to power transmission. There must not be any PEN conductors in any part of the complete system. This condition is fulfilled, for example, by a TN-S-System. Detailed guidelines on the design of a network system for supplying information-based systems are provided by EN 50310:2000.

11.3.4. Shielded components and data cable

PROFInet may only contain components and data cable that support an uninterrupted shielding concept. Limit values for electromagnetic radiation specified by component manufacturers are only valid if the specified shielded cables and connecting elements have been installed correctly.

Pay attention to sufficient shield attenuation
The specified transfer impedance specified in mOhm/m is a measure for the shielding effect. The lower the value, the better the shielding effect. The transfer impedance should not exceed the limiting values specified in chapter 10.1.

Grounding cable shields at both ends
PROFInet operates within a frequency range of about 10 MHz to 100 MHz. Cable shielding sheaths must be grounded at **both ends** if they are to operate within this frequency range!
If unacceptably high shield currents occur, either lay a equipotential binding conductor parallel or use optical fibre cables for the connection.

Design of shielding connections
The following points must be observed when fitting cable shielding:

- Establish an all-round contact to the shielded housing when fitting plugs.
- Connect shielded cables to the housing direct at the point of entry and exit of switch cabinets or housing or connect the cable shield to a shielded/protective conductor bar (PE bar).
- Fasten braided shielding with metal cable clips.
- Cable contacts may only be established to copper braided shielding sheaths, not aluminum foil shielding sheaths which are often also present. The foil shielding sheath is usually fastened on one side to a plastic film to increase its tear resistance and is therefore non-conductive!
- Do not damage the cable shielding foils and braids while stripping the outer sheath of the PROFInet cable.
- Tin plated or galvanically stabilized surfaces are ideal for establishing a good contact. With galvanized surfaces, the necessary contact must be established using a suitable screw connection. Contact points with painted surfaces are not suitable
- Shielding sheath clamps/contacts should not be used as strain relief - unless explicitly designed for such purpose. The contact could come loose or tear off.

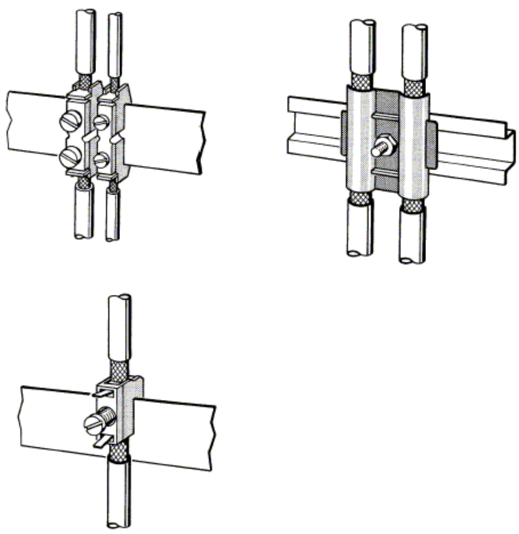


Figure 11.3.4-1: Examples for shielding application

11.3.5. Spatial arrangement of equipment and cables

Reducing electrical interference through distance

An equally easy and effective method of reducing electrical interference can be achieved through establishing distance between interfering and interfered equipment and cables. Inductive and capacitive interference reduce by the square of the distance of the involved elements. This means doubling the distance reduces the interference by a factor of 4. These layout aspects should already be taken into account in the planning phase of a building. Recommendations for spatial arrangement of equipment and cables with the objective of ensuring the lowest possible mutual influence can be found in EN 50174-2.
The following details for the arrangement of electrical equipment and cables base on the statements of this European standard.

Planning the electrical installation

In order to avoid influence to sensitive equipment by the current distribution system,
EN 50174-2 recommends taking into consideration the following points when planning electrical installations:

- Possible sources of interference, e.g. voltage sub-distributors, voltage transformers, lifts, high currents in power supply rails, must be positioned away from sensitive equipment;
- Metal pipes (e.g. for water, gas, heating) and cables should enter the building at the same point;
- The choice of a mutual route for low-voltage and signal with adequate separation (through distance or shielding) between both in order to avoid large induction loops which are formed by the various low voltage cables;
- The use of either a single multi-conductor cable for all net supply sources or - in the case of a higher power level - busbars with low magnetic fields.

Cable categories and spacing

Category division

It is advisable to classify cables into various categories according to the effective signals they bear, possible fault signals and their electromagnetic compatibility. These categories can be assigned specific minimum distances which allow a fault-free operation under normal operating conditions.
The following categories are recommended in EN 50174-2:

- Network voltage cable (low voltage supply)
- Auxiliary conductors (fire alarms, door openers etc.)
- Information-related cables (data cable)
- Sensitive cables for measurements and instrumentation.

Cables for various purposes (e.g. power supply cables and information-related cables) if they are not in the same bundle. Electromagnet separation should be provided for individual bundles. Ideally, they should be on separate cable racks. The bundles should be positioned at a certain minimum distance if only one mutual rack is available.

Optical fibre cables

Only regulations for mechanical safety, not for EMC effects, have to be taken into consideration if using optical fibre cables.

Compatibility conditions

The following spacing requirements are viewed exclusively from an EMC point of view. Valid regional safety regulations, in particular, can require larger spacing or separate laying between power and information-related cables!
In the case of the following spacing requirements, it is assumed that all components within an automation system, as well as all system components that it controls (e.g. machines, robots etc.), fulfil all the requirements for electromagnetic compatibility in an industrial environment. Higher interference voltage has to be expected in the case of faulty or incorrectly installed equipment!
In this respect, it should be noted that there are no limit values for sporadic interference (e.g. caused by switching actions) insofar as they do not exceed any specific frequency. A greater distance or separate cable ducts for the power supply cables are recommended if any such interference is to be expected.

It is assumed that
- only shielded and correctly installed cables are being used
- the cables are lying in an electrically conductive cable rack which is connected to the grounding surface of the system

Greater distances are necessary if the cable duct has only poor or no electrical conductivity, e.g. in the case of plastic or concrete trays or if the cables are installed hanging free on supporting wires.

Cable routing inside cabinets

Please observe the following regulations for cable routing inside cabinets:
- Lay the cables in metal, electrically conductive cable ducts.
- Screw the cable ducts with low impedance and low inductance onto the struts of the frame or cabinet paneling about every 50 cm.
- Separate the cables into individual bundles according to the above-stated categories.
- A minimum distance between the bundles of different categories is not necessary for fulfilling the above-named conditions.
- Any crossing of individual categories should be at right angles wherever possible (smallest sections of parallel laying).
- The shielding sheaths of all cables that are fed into a cabinet from outside are to be bonded with the cabinet ground over a large area at the point of entry into the cabinet casing.

Cable routing inside buildings

Please observe the following regulations for cable routing inside buildings (outside cabinets):
- Cables must be laid on metal, electrically conductive cable racks. The racks must be made of sheet metal trays. Large-meshed grating structures are ineffective from an EMC point of view.
- Include the metal cable racks in the equipotential bonding system of the building or plant. Observe the instructions for equipotential bonding in chapter 11.3.2 of this guideline!
- Separate the cables according to the above named categories and lay the various categories on individual racks.
- A minimum distance of 50 mm must be observed between PROFInet cables and low voltage power cables or the individual categories must be separated from each other by a metal partition if only one mutual metal cable rack is available for several categories . The connection of the partition to the duct must be low resistance and low inductance.
- Crossing of cable routes must be at right angles.

Cable routing outside buildings

The PROFInet balanced cabling is designed for use within buildings. If copper cabling is used in areas exposed to overvoltage appropriate strokes of lightening protection devices are recommended.
The use of optical fibre cables is recommended for connections between buildings and between buildings and external facilities. Optical fibre cables are insensitive to electromagnetic influences because of the optical transmission principle. Measures for equipotential bonding and overvoltage protection can be omitted in the case of optical fibre cables if the cable does not contain any metal, conductive components (power supply wires, metal foil as moisture protection, metal rodent protection...).

11.3.6. Special interference suppression measures

Connecting switched inductances to suppressors
Connecting inductors (e.g. relay) creates interference, the extent of which is a multiple of the connected operating voltage. Interference from inductors is to be limited by connecting them to suppressors.

Mains connection for service equipment
We recommend providing a socket for mains supply to service equipment in every cabinet. The socket must be supplied from the distributor to which the protective conductor for the cabinet is connected.

Cabinet lighting
Incandescent lamps should preferably be used for cabinet lighting. Fluorescent lamps and energy-saving lamps should be avoided because they generate interference fields. If fluorescent lamps have to be used, the lamp should be fitted with a screen grid and a mains filter as well as shielded mains cables are to be used for the connection.

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