PROFIBUS Installation Guidelines

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1. Preface

PROFIBUS is an extremely flexible and reliable communication technology, however, like all high-speed digital communications systems, problems can be caused by a large variety of simple errors. Sometimes these errors are caused by inappropriate or just plain wrong information that is handed down from people, who have extensive experience with traditional instrumentation and automation technologies, but little knowledge of high speed digital communications. Anyone involved with PROFIBUS at a technical level will require some training. This includes not only installers but also system designers, maintenance technicians and automation engineers. The basics of high speed digital communications are not at all obvious. However, with good quality training an understanding of the techniques and problems can be developed.

This document forms a first introduction to PROFIBUS technology and covers the essential practical requirements for installation and layout of networks that will operate reliably and that can be maintained with the minimum of disruption to plant operation. The document forms the main text that covers the learning outcomes of the Certified PROFIBUS Installer course which is accredited by PROFIBUS International. This one-day course is appropriate not only for installers, but for anyone involved with PROFIBUS at a technical level.

The document starts with an introduction to fieldbus and PROFIBUS for those that are not familiar with these technologies. It then goes on to provide simple practical guidance on the layout, installation and static wiring testing for PROFIBUS networks. The main body of the document is concerned with the various rules and guidance on PROFIBUS DP and PA layout and installation. The document provides not only the rules for installation, but also the reasons for these rules.

Important Notice
Although considerable care has been taken to ensure that the information contained in this document is accurate and complete, no responsibility can be taken for errors in the document or installation faults arising from its use.

2. Introduction to fieldbus and PROFIBUS

Fieldbus is a communications network designed for automation and control systems. There are many different fieldbusses in existence, but the most important are specified in the international fieldbus standard IEC 61158.

Fieldbus is a digital communication network providing two way communications for devices that are mounted in the field i.e. in the factory or plant being controlled or automated. Being a network, fieldbus can be used to communicate with many devices over one cable. Further, the communication is always two-way so, for example, sensors can not only communicate the process value back to the controller, but can also receive information for option settings, parameters etc. Devices can also report diagnostics and other maintenance information over the same fieldbus. The data communicated over the fieldbus can be diverse, from simple discrete devices that give only on/off values to sophisticated devices such as multi-function instruments, drives and servo systems. All can be combined on one fieldbus cable.

The main advantages of fieldbus over traditional, separately wired, devices include the following:

- Reduction in the amount of wiring involved. Cable supports, junction boxes and marshalling racks are also significantly reduced, saving cost, space and weight.
- The number of connections is drastically reduced. This is a very important consideration since connections are always a weak link, prone to problems such as water ingress, corrosion, high resistance, open and short circuits. Fewer connections can mean a more reliable system.
- Because of the more extensive data that can be transmitted, devices can show a level of intelligence that can provide self-diagnostic information, settings and parameters that can be downloaded over the network. This can drastically reduce the set up and commissioning time for a device.
- Fieldbus also makes it relatively easy to expand and modify the system. We no longer need to leave spare cores in multi-core cables. The network can normally be simply extended (within the rules of the fieldbus of course) so that additional devices can be added or devices moved without having to run cables all the way to the control room.

Unfortunately there are some disadvantages to using fieldbus which apply to any high-speed digital communications. That is, fieldbus cables are much more sensitive to wiring and layout faults than traditional wiring. Installers, and in fact anyone involved with fieldbus, must understand that the fieldbus cable is not just a wire. The cable is in fact a transmission line which has to have the correct characteristics and be installed correctly otherwise it may not work. Worse than that, the problems that occur can be difficult to diagnose without the correct tools and training. Faults are often intermittent and, strangely, the devices that show errors are often not the source of the fault. Devices that have a fault can often work perfectly, whereas other fault-free devices fail. This is quite different to the low-speed world of traditionally wired instrumentation and control systems, where generally if we have a connection, then the device tends to work.

So training is absolutely essential for anyone who is involved with fieldbus at a technical level. That is not only installers but also designers, maintenance staff, engineers and even sales and purchasing staff.

2.1. PROFIBUS development and history

PROFIBUS (PROcess Field BUS) is a well-proven, widely accepted open fieldbus standard, which is supported by an industry supplying a wide range of equipment, tools and assistance. PROFIBUS was introduced in 1989 as German standard DIN 19245. It was developed with funding from the German Government and involved 12 companies and 5 academic institutions. In fact some of the companies involved were not even German; Dutch and American companies were involved from the outset.

In 1993 the standard was adopted as European Standard EN 50170 and in 2000 it was incorporated into IEC 61158, the international fieldbus standard.

PROFIBUS is now the world's leading fieldbus system with over 40 million devices installed. There are approximately 3,000 products available from over 300 different suppliers. World wide support is provided by PROFIBUS International (PI), who run the extensive web site <www.profibus.com> with up to date and free downloadable information.

Regional PROFIBUS Associations (RPAs) are user groups that operate within PI. RPAs are set up in 27 countries across the world. Beneath these are PROFIBUS International Competency Centres (PICCs) and PROFIBUS International Training Centres (PITCs). Only accredited PITCs are able to provide accredited PROFIBUS training. Currently there are almost 50 PICCs and 27 PITCs. There are also 11 device test laboratories which are responsible for testing devices and issuing device certifications. There is no test lab in the UK.

2.2. The PROFIBUS Family

PROFIBUS comprises a family of compatible solutions, each developed for a particular range of applications and features.

PROFIBUS FMS - Fieldbus Message Specification

This was the original form of PROFIBUS developed by the German working group. FMS provided sophisticated multi-function communications which was aimed at cell or controller level. FMS provides very sophisticated, flexible transmission of structured data. Unfortunately, FMS was quite complex and expensive to implement. Thus after a few years of experience a new simplified but improved specification was developed (PROFIBUS DP). FMS is no longer supported by PI. However, some manufacturers (e.g. Siemens) continue to provide FMS capability. This is not a problem since FMS is totally compatible with the other versions of PROFIBUS.

PROFIBUS DP - Decentralised Periphery

PROFIBUS DP was developed from the basic FMS technology as a low cost, simple, high speed field-level communication. The DP specification was very well thought out to meet the requirements of the automation and control industries. PROFIBUS DP has now become the dominant technology used in factory automation and general control and monitoring systems. Thus it is not surprising that all modern PROFIBUS applications use DP.

PROFIBUS PA - Process Automation

PROFIBUS PA was developed in the mid 1990's specifically for the process industry to replace 4-20mA transmission. 4-20mA transmission provides device power and data over a single cable (two cores). PA similarly provides device power and data over a single cable. However, we must remember that PROFIBUS is a network, so PA provides power and data communications for many devices in one two-core cable. PA uses different transmission and wiring from DP, but the messages are identical. Therefore PA can be used in conjunction with DP (and FMS is desired).

Thus all three members of the PROFIBUS family can operate together on the same network. DP and FMS share the same electrical transmission system, based on RS485, an international standard used by many different fieldbusses and other communication applications. PA uses a different electrical transmission system called "Manchester Bus Powered" (MBP).

Because of the two current versions (DP and PA), PROFIBUS is applicable to a wide range of applications and industries involving both manufacturing automation and process control:

- High-speed, simple factory automation.
- Drives and motor control.
- Process control applications.
- Operation in explosive environments (gas and oil etc.).
- Functional safety systems (safeguarding and interlocking).
- High-speed servos (machine tools and robotics).

PROFINET

PROFINET is another addition to the family providing industrial communications over Ethernet. PROFINET is completely standard Ethernet (IEEE802.3) which operates at 100Mbit/s over copper or fibre-optic cables. PROFINET is a modern Ethernet system which exclusively uses switches and full duplex operation to completely eliminate so called collisions. PROFINET makes use of existing IT standards such as the Internet Protocol (IP), TCP, UDP etc. But, unlike these IT standards, PROFINET is “real-time” and deterministic. Determinism means that the timing on PROFINET systems is known and predictable (just like it is on PROFIBUS). In fact PROFINET is able to provide similar performance to PROFIBUS DP with highly synchronized timing between several devices.

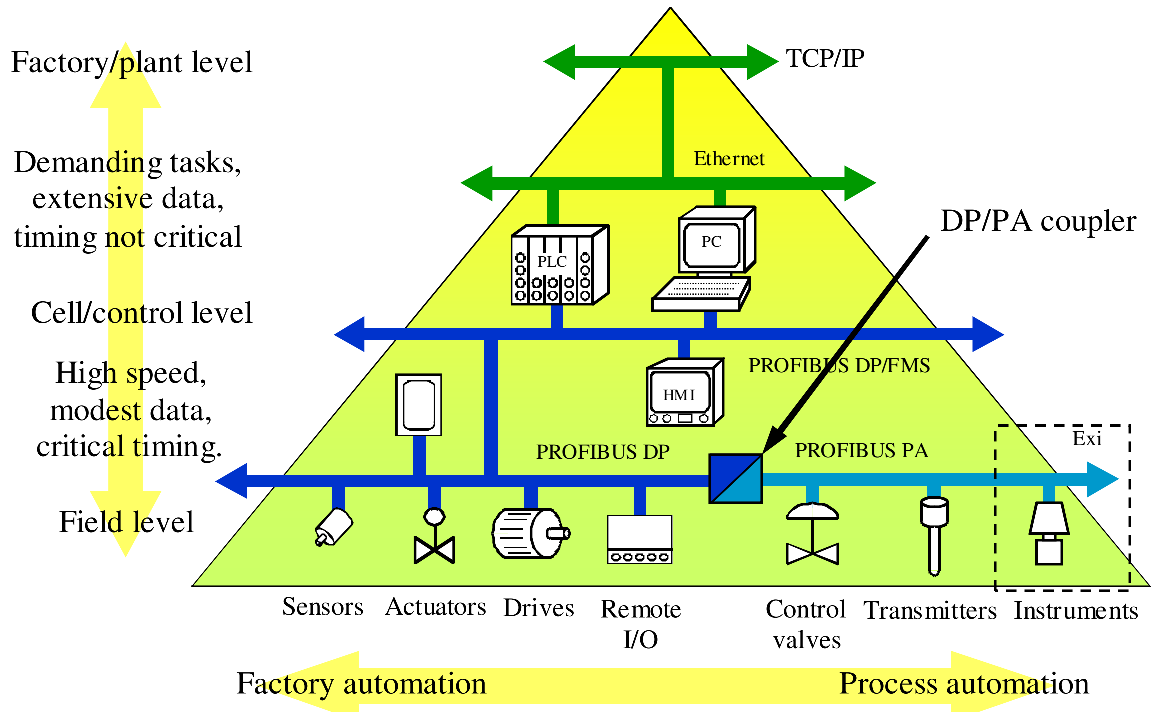
PROFINET is not PROFIBUS over Ethernet, but has its own encoding. However, PROFINET is very well thought out to incorporate all the requirements of automation and control systems. All the lessons that have been learned over the 25 years of experience with PROFIBUS have been applied to PROFINET. PROFINET is also totally compatible with PROFIBUS and integrates via simple standardised gateways.

In the future, it may be that PROFINET will overtake the huge lead of DP. However, in the author’s opinion PROFIBUS will remain as the dominant fieldbus technology for many years to come.

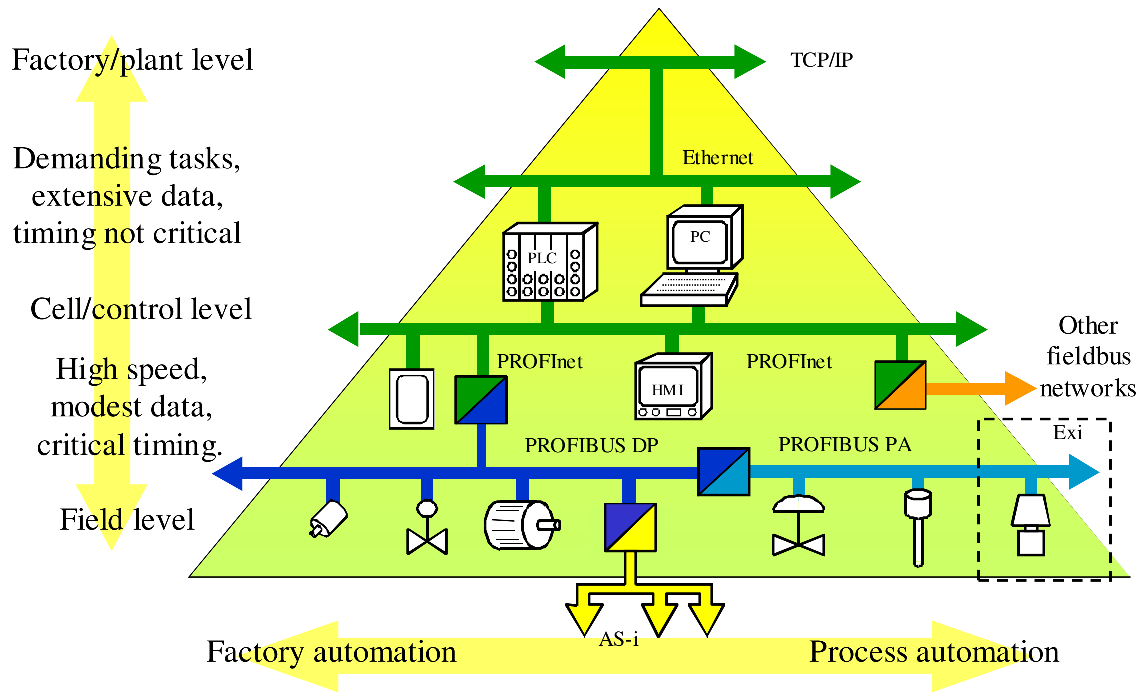
The control system hierarchy

PROFIBUS thus fits into the control system hierarchy from field level up to control level and across factory and process automation. Ethernet, using standard IT protocols (TCP/IP) is widely used at the highest level for implementing communication for Supervisory Control and Data acquisition (SCADA) systems and engineering functions such as tuning controllers or setting up devices. FMS was originally conceived as operating at this level, but has now almost universally been replaced by Ethernet.

Ethernet is now moving down in the hierarchy and is being used more at the control level and at field level. PROFINET provides the required functionality over Ethernet to do this. Many devices that are available on DP are now also available with a PROFINET interface.



The Control system hierarchy and use of PROFIBUS and Ethernet technology



Ethernet is moving down in the hierarchy – PROFINET provides control capability

Actuator Sensor interface (AS-i) is a low level, low cost fieldbus which is very widely used for interfacing to simple digital devices such as proximity switches, solenoid valves etc. AS-i can be used to replace dumb devices which are connected to PROFIBUS remote IO devices. The use of a PROFIBUS/AS-i gateway allows the advantages of fieldbus and intelligent devices to be taken down to the lowest and simplest level. PROFIBUS would not be cost effective in a simple proximity switch, whereas many manufacturers produce proximity switches with an integrated AS-i interface at a competitive price. AS-i gateways are available for simple interfacing to PROFIBUS DP, PROFINET and most other fieldbusses.

2.3. The OSI model

The International Standards Organisation uses an Open System Interconnection (OSI) model for specifying standardised communication systems. The OSI model splits the communication into 7 layers, extending from the physical layer (wiring and electrical specification) up to the application layer (the device functions and encoding).

Layer 1 – The physical layer

The PROFIBUS physical layer has three different specifications. DP and FMS use RS485 wiring which is very widely used by other fieldbus and communication standards. DP (and FMS) can also use fibre-optic communication. PA uses a different standard, called Manchester Bus Powered (MBP) defined in IEC61158-2 which allows device power to be delivered over the bus cable.

RS485

RS485 (also sometimes called H2) was developed in the 1960s by Telecommunications Industry Association/Electronic Industries Alliance (TIA/EIA). RS485 is used by many different communication and fieldbus systems to provide simple, robust, high-speed communication over two-core shielded twisted pair cable. RS485 allows up to 32 stations or devices to be connected together on a single cable. We call such a single cable a "segment". A segment has electrical continuity from one end to another.

Fibre optic (FO)

DP (and FMS) can also use fibre-optic communication where optical (light) signals pass down plastic or glass fibre-optic cable. Fibre optic transmission gives high speed, interference free communication with electrical isolation between devices.

MBP (H1)

Manchester Bus Powered (MBP) transmission is used by PA (also sometimes called H2). MBP transmission uses shielded twisted pair wire allowing up to 32 stations per segment. However, MBP uses different cable to RS485. Using the wrong cable is one of the common problems in PROFIBUS systems causing communications to fail, or even worse, intermittent or spurious faults. MBP wiring provides power supply and data over the same cable.

Layer 2 – The data link layer

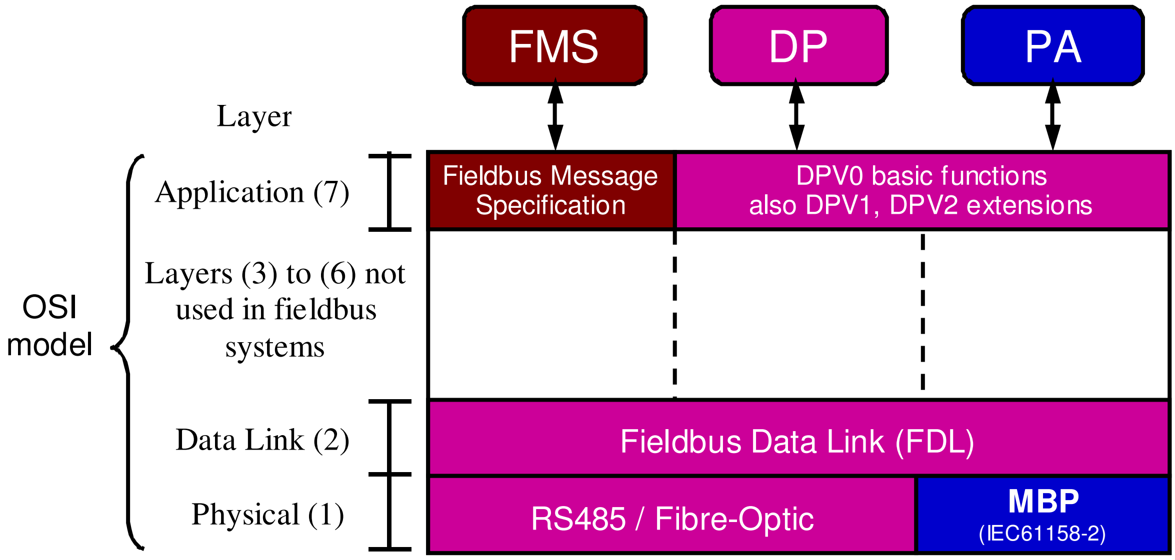
The layer 2 protocol is called the Fieldbus Data Link (FDL) layer. This is common to all versions of PROFIBUS and is the reason that they can all run together within a network.

Layer 7 – The application layer

Layers 3 to 6 are not used in any fieldbus system. These layers are provided for much more complex and flexible systems like IT networks and the internet etc.

Layer 7, the Application Layer, defines the functions, services and message contents for PROFIBUS communications. There are two separate specifications defined here: the

Fieldbus Message Specification that is used by only FMS, and the DP specification which is used by both DP and PA. Thus even though DP and FMS can be used on the same network, and even on the same cable, a DP device cannot talk to an FMS device because the Application Layer is different. On the other hand a PA device can communicate with a DP device even though they use different cables.



The PROFIBUS Open System Interconnection model

Various extensions have been added to the DP Application Layer specification over the years to provide additional functions that have allowed the application areas to be extended. These optional extensions have however been added in a totally backwardly compatible way so that devices that do not support the extensions can still be used alongside devices that do.

DPV0 is the basic protocol which defines cyclic communications, bus start up and diagnostics etc. DPV1 adds acyclic communications, alarm and status handling. DPV1 functions are widely used in many more complex devices such as drives, process instruments etc. DPV2 provides some additional functions that are used in high speed servo systems and functional safety systems.

All PROFIBUS devices generally support DPV0 functions. DPV1 and DPV2 extensions are optional (however, DPV1 is mandatory for all PA devices).

3. Basic PROFIBUS networks

A PROFIBUS device is any piece of equipment that has a PROFIBUS interface. PROFIBUS devices can include a wide variety of electronic equipment including sensors, actuators, controllers, Programmable Logic Controllers (PLCs), drives, servos, instruments, valves bar code readers, Radio Frequency Identification (RFID) devices operator interface panels etc. PROFIBUS devices also include remote IO units where digital and/or analogue inputs and/or outputs are provided in the field. A remote IO device allows us to connect traditional (non PROFIBUS) devices to our network. A PROFIBUS network allows many PROFIBUS devices to be connected together to communicate over copper or fibre-optic cable.

3.1. Device types

There are two types of PROFIBUS device that are employed within a network: Masters and Slaves. Masters control the bus communications, slaves can only respond to master requests. Masters can be further divided into two classes:

Class-1 masters

e.g. PLCs, controllers etc. Class-1 masters are in permanent cyclic data exchange with allocated slaves.

Class-2 masters

e.g. engineering tools, certain diagnostic tools etc. These are optional, used as and when required (acyclic communication).

Slave devices

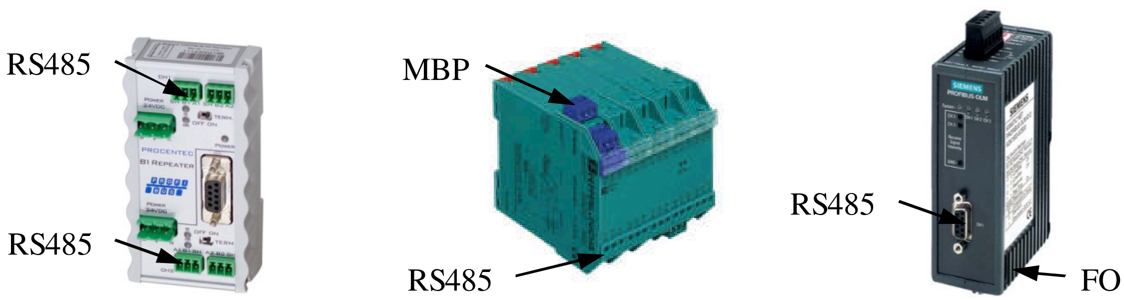
everything else, e.g. I/O blocks, transmitters, sensors, actuators, valves, drives etc.

Data is exchanged in all PROFIBUS networks using messages or telegrams that pass between the masters and slaves. Master stations can request information from other devices, slave stations can only respond to telegrams from a master. Thus masters are in control of the communication. A network can have one or more master stations. Each master can communicate with many slaves. However, each slave can only be in data exchange with one master. A slave is locked to a particular class-1 master. Class-2 masters can talk to anyone on the network even if locked to a class-1 master. Class-2 masters do not lock the slave.

There is no prioritisation within a PROFIBUS network. No master is more important than any other, no slave is more important than any other. The network, when properly set up, guarantees that all devices can communicate and cannot be blocked by other devices.

3.2. Networks and segments

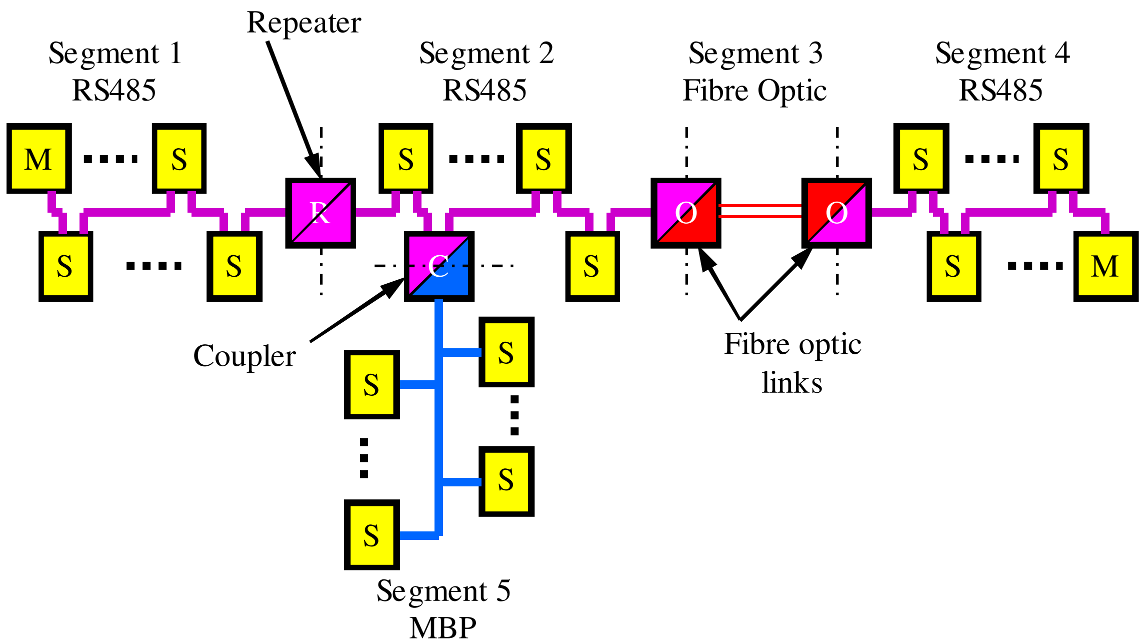
A single PROFIBUS network can incorporate up to 126 devices. However, we have seen that the limitations of RS485 and MBP mean that each segment cannot have more than 32 devices. Segments are formed by using repeaters, couplers or fibre-optic links. These devices provide two-way communication but with electrical isolation.



Repeaters Couplers Fibre-optic links

Devices that provide segmentation

Within the network any PROFIBUS device can exchange information with any other, even when on different segments that are separated by repeaters, couplers or fibre-optic links.



The concept of a single network with many segments

Each RS485 segment is best laid out as a "linear bus", where the cable daisy-chains from device to device. A linear bus is a cable with just two ends. The MBP segments can be laid out in a more flexible manner using Tee junctions to create spur lines.

3.3. Addressing

Within a network, every PROFIBUS device or station is given an address through which communication is directed. There are 128 different addresses provided (numbered 0 to 127). However, address 127 is reserved for broadcast messages and so cannot be used for a device. Address 126 is also reserved for devices whose address is set over the bus. The remaining 126 addresses (0 to 125) are available for PROFIBUS devices.

3.4. PROFIBUS data rates

The network runs at a certain data rate (also called the bit rate or sometimes baud rate). The standard PROFIBUS DP data rates are:

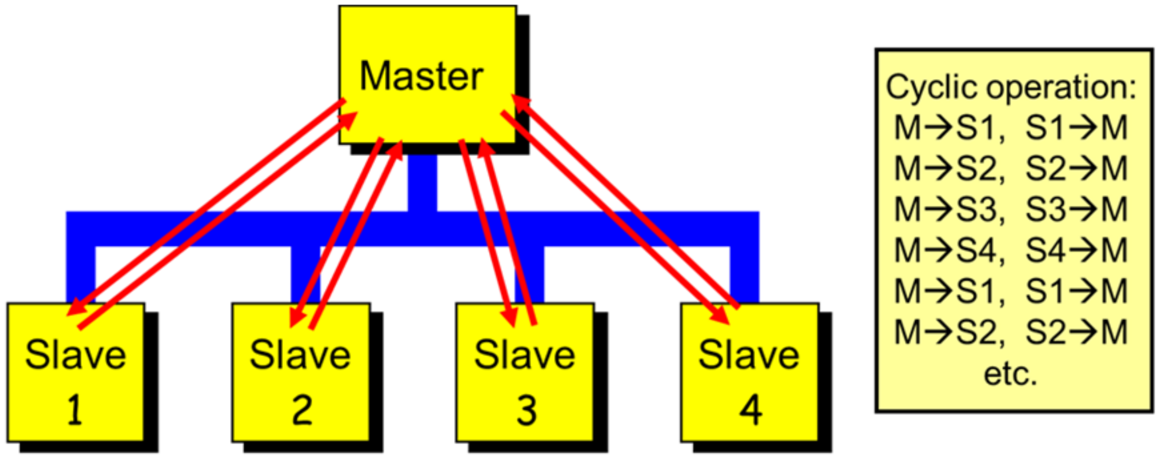
9.6 kbit/s	1.5 Mbit/s
19.2 kbit/s	3.0 Mbit/s
93.75 kbit/s	6.0 Mbit/s
187.5 kbit/s	12.0 Mbit/s
500.0 kbit/s	

Some DP devices from Siemens also use 45.45 kbit/s. However this is a non-standard bit rate. Most modern DP slaves support all the data rates and further will automatically detect and adjust to the network speed. Very occasionally the data rate needs to be set using switches on the device.

PROFIBUS PA is quite different in that it always runs at a fixed rate of 31.25 kbit/s. Note that this is not one of the DP rates, so PA always runs at a different speed to DP.

4. PROFIBUS network operation

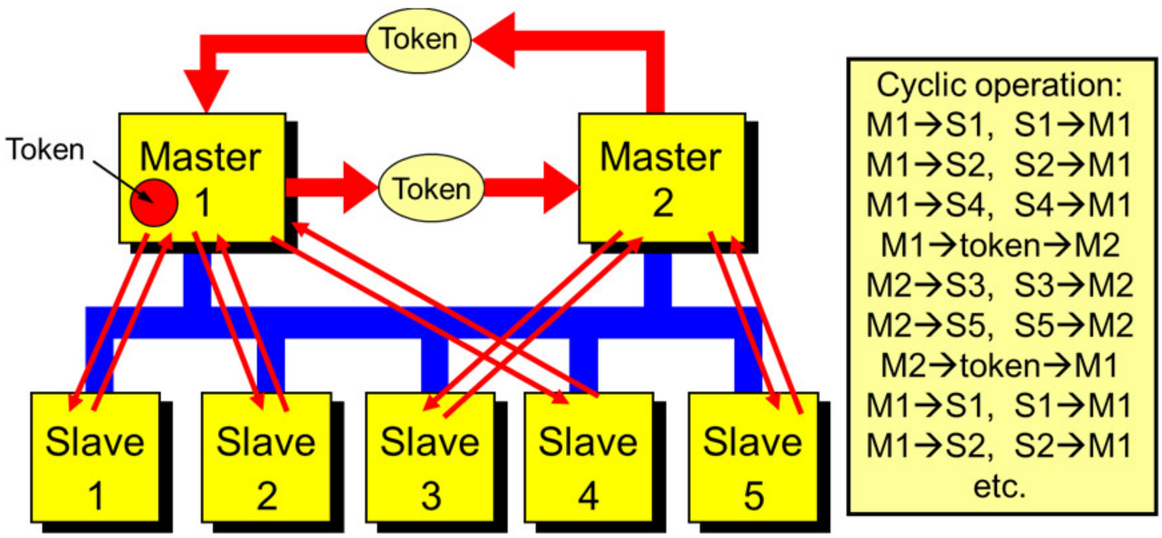
During operation the class-1 master is in cyclic communication with all its allocated slaves. The master sends a request message to the first slave, which responds. The request message incorporates the output data for the slave and the response incorporates the input data from the slave. After the response from each slave is received the master then sends a request to the next slave. When the last slave has responded, the master repeats the cycle from the first slave again.



Single Class-1 master in cyclic communication

4.1. *Token passing*

The network can have more than one master. So "token passing" is used in order to avoid multiple masters talking at the same time. A token is a special message that passes between masters and carries permission to control the network. The first master initially holds the token and therefore can cyclically communicate with its allocated slaves. But after the last slave has responded, the master must then pass the token over the network to the second master so that it can communicate cyclically with its allocated slaves. When the second master has the token, the first master must remain quiet and must not send any requests. After the last slave has responded to the second master it must pass the token back to the first master so that the cyclic data exchange can proceed.



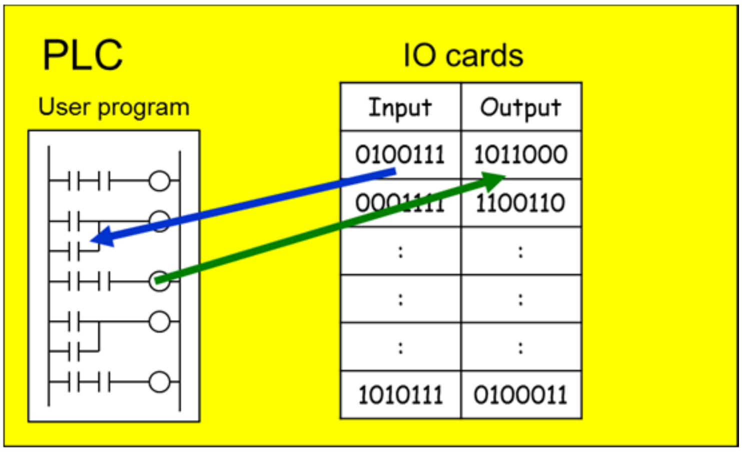
Two masters share the token so that each can enter cyclic data exchange with its slaves

Actually, even if we have just one master in our network, it still has a token. A single master will pass the token to itself.

Data exchange between the class-1 master and its allocated slaves and token passing between masters is all automatic. The master requires no additional programming over and above the normal programming that is used on traditional PLCs.

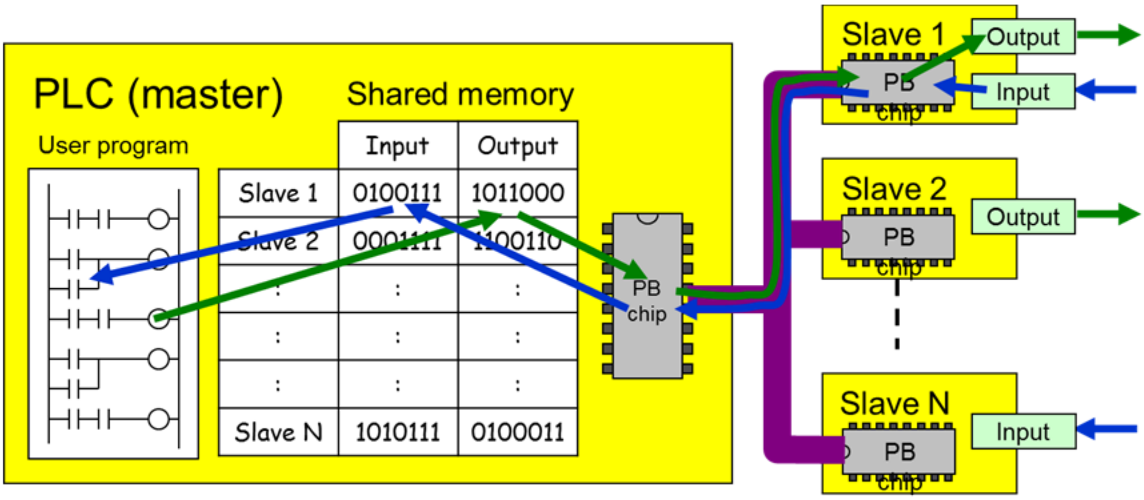
4.2. PLC programming

Traditional PLCs have local IO often in the form of digital or analogue IO modules. The PLC is normally programmed in a special control language such as ladder diagram, statement list or other such language. The program reads data from the local input cards then, using these inputs, calculates the required outputs and finally writes these outputs to the output cards:



Traditional PLC programming

When the PLC incorporates PROFIBUS master functionality the local IO cards are no longer present. Instead a PROFIBUS master chip communicates the IO data from a shared area of the PLC memory to the salve devices that are attached to the network.



PLC with PROFIBUS Class-1 master functionality

The user program reads data from, and writes data to, the shared memory in the same way that the traditional PLC program reads and writes data from/to the local IO. However, in the case of a PLC with PROFIBUS master functionality, the IO memory is shared with a PROFIBUS master chip. When the time is right, the chip reads the output data for a particular slave and inserts it into an addressed telegram that is sent out over the bus. The slave with the correct address then reads the telegram and extracts the output data, which is written to the slave's physical outputs. The slave's inputs are then read and inserted it into an addressed telegram that is sent back to the master. The master, upon receiving the response, extracts the data and places it into the correct input area of the shared memory. The master and slave chips that do this job require no user programming and all functions are automatically carried out.

4.3. Network configuration

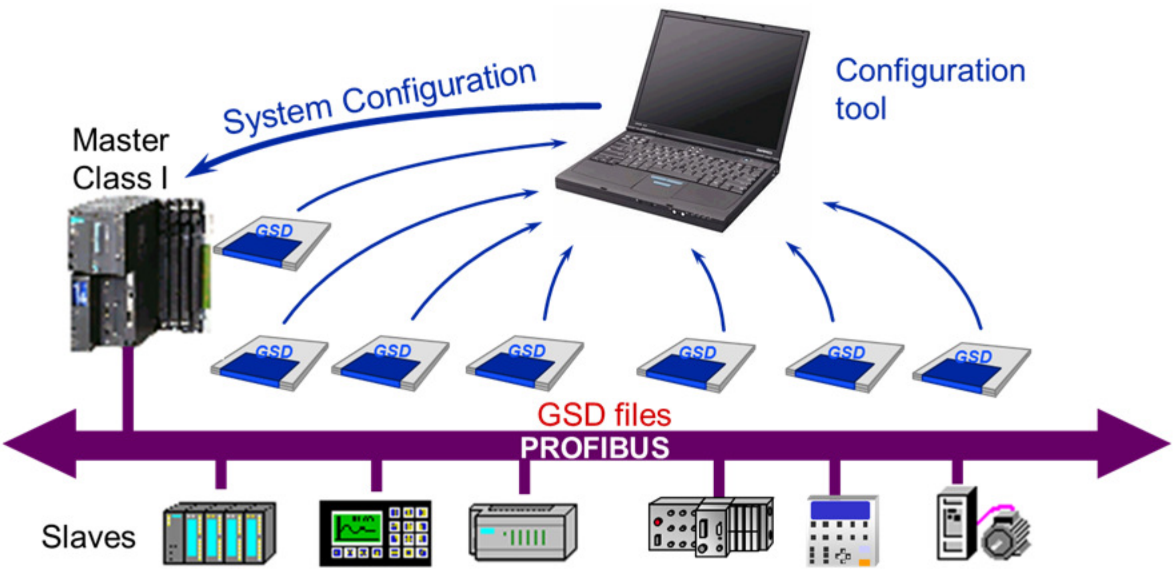
Even though the PROFIBUS master operates without additional user programming, before any PROFIBUS system can operate the system must be configured. That is the class-1 master must be made aware of the allocated slaves and their characteristics such as the slave addresses, amount of IO etc.

Configuration is normally carried out using a proprietary software tool supplied for the PROFIBUS master station. That is a PLC from a particular manufacturer requires the manufacturer's configuration tool. A different PLC will require a different configuration tool. One manufacturer's configurator can generally not be used to configure a different manufacturer's PLC. The configuration tools are applications (software) that typically run on a PC or laptop.

GSD files

PROFIBUS stations have different capabilities and characteristics, such as the amount of IO, supported bit rate, meaning of diagnostic messages etc. In order to facilitate device configuration all PROFIBUS equipment suppliers provide standard "General Station Description" or GSD files. These GSD files can be read by the configuration tool to provide detailed information on the devices being used on the network. GSD files make integration of devices from different vendors in a bus system simple.

Every PROFIBUS device is given a unique identification number (ID number) which identifies the type of device and provides a simple check that the configuration is correct. The GSD file is specific to a particular ID number, so if we know the device ID number we can easily identify the GSD file. GSD files contain all the information required for configuring a particular type of device. The information includes the bus timing requirements, supported bit rates, amount of IO, options that can be set up by the user and even the meaning of diagnostics messages that the device may generate when there is a problem.



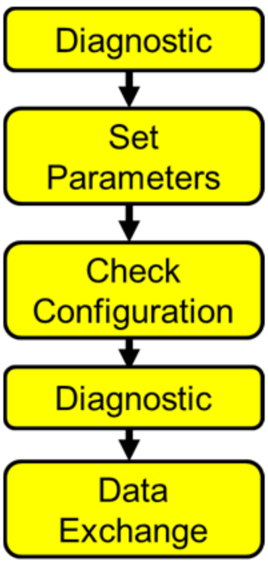
System configuration

Configuration is the process of selecting the correct GSD file, setting the correct device address and selecting required options. Each different type of device requires a unique ID number and GSD file. However several devices of the same type can share the same ID number and GSD file.

4.4. *Bus start-up*

After configuration is complete, the master can be put into operate mode where it goes into data exchange with the configured slaves. However, in order to make sure that the configuration is valid, the controlling master performs several checks before entering data exchange with the slave:

1. The master first checks that the slave is present on the bus and is not controlled by another master with a Diagnostic request. The slave, if correctly addressed, will respond with a diagnostic response. The master thus knows that there is a slave present at the correct address.
2. The master next checks that the device is of the correct type by checking the ID number and setting device parameters. This is done with a "Set Parameters" telegram.
3. The master then checks that the allocated I/O is present and available on the slave. This is done with a "Check Configuration" telegram.
4. A second diagnostic request is then sent to the slave to check that the Set Parameters and Check Configuration telegrams were checked as ok.
5. The slave will only enter data exchange if the checks are passed without error.



4.5. *Data exchange*

During cyclic data exchange, the master continually checks that the slave is responding and healthy by looking for the slave responses. Should a slave fail to respond, the master will normally retry immediately. If the retry also fails, then the master will indicate a “Bus Fault” by illuminating a red indicator LED on the PLC. When a bus fault is detected the master will try to establish data exchange once again by running through the start-up sequence again for the missing slave.

In addition each slave is constantly checking that the master is operational and healthy by looking for the regular master requests. Should a slave detect a problem, the outputs will automatically “fail safe”; i.e. the outputs will switch to a safe condition (typically off).

The watchdog timer

Every PROFIBUS slave incorporates a “watchdog timer” to enable it to check for master inactivity. The Watchdog time is one of the parameters sent from the master during start-up. The Watchdog timer counts down from the set watchdog time towards zero, but is reset to the programmed watchdog time every time the slave receives an error free message from the controlling master. However, if no valid message is received within the watchdog time then the slave assumes a communication error and sets the outputs to fail-safe condition. Slaves normally also have a “Bus Fault” indicator which lights red when the slave is not in communication or when the watchdog times out.

5. PROFIBUS PA

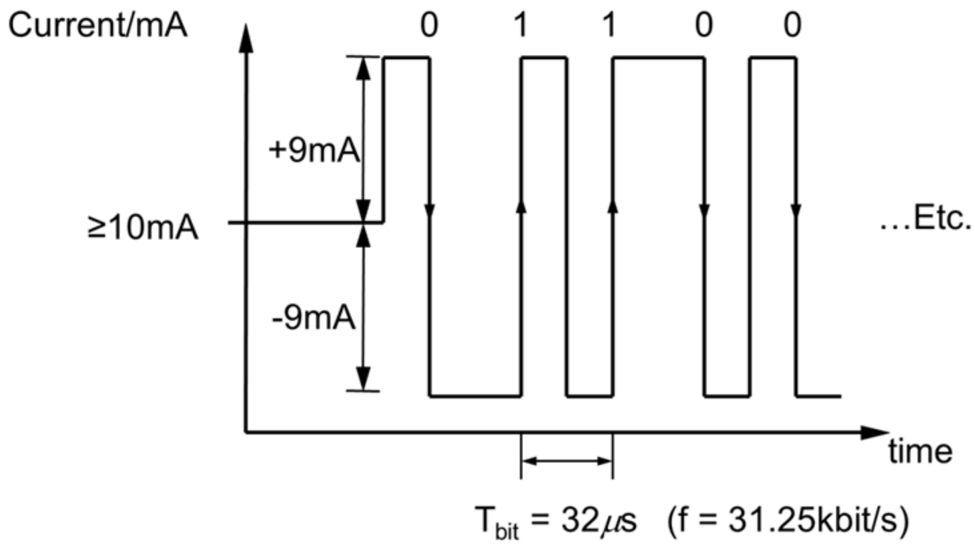
Everything we have covered in sections 3 and 4 applies equally to DP and PA. However, PROFIBUS PA uses Manchester Bus Powered (MBP) transmission at the physical layer. The different transmission technology means that a “DP/PA coupler” is required to connect PA to a DP network. However, the common layer 2 and 7 protocol means that the PA devices integrate transparently with the DP devices.

MBP transmission was specifically designed for the process industries, to replace 4-20mA technology, where power is supplied to the device over the communication cable. A separate power supply is not necessary. However, there is a fundamental difference between PROFIBUS PA and 4-20mA devices: PA uses MBP transmission, which is digital (operating at 31.25 kbit/s), whereas 4-20mA devices transmit an analogue signal which represents the scaled process value as the current varies from 4mA to 20mA. 4-20mA devices will not work on a PROFIBUS network unless they are connected to a remote IO unit with a properly scaled 4-20mA analogue input.

MBP transmission uses changing current to transmit the data transmission over two wires. A fixed transmission speed of 31.25 kbit/s is used and a special “Manchester encoded” synchronous protocol is used. Manchester encoding simply means that the individual bits are transmitted as transitions rather than simply logic levels. MBP transmission allows device power and data to be combined on one pair of wires.

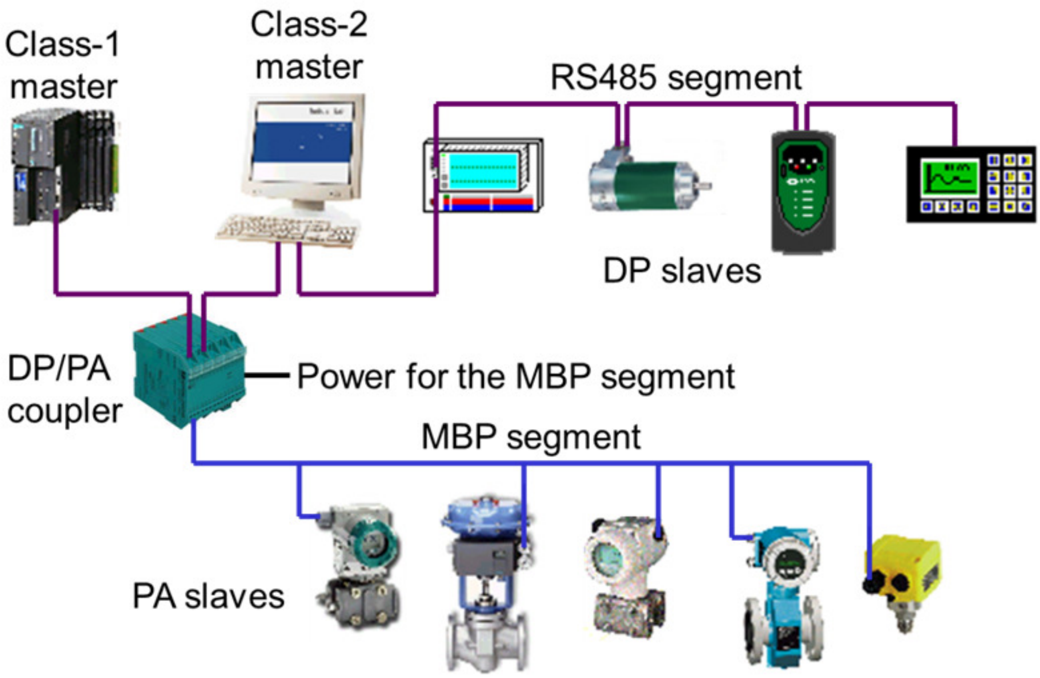
Each PA device draws a constant basic current from the MBP cable. This basic current must be at least 10mA, but typically 12 to 14mA is used. The basic current provides power to the device. When the PA device needs to communicate it modulates the basic current with a digital current of ±9mA at a frequency of 31.25kbit/s. The transition +9mA to -9mA represents a logic zero and the transition -9mA to +9mA represents a logic one.

The average current does not change from the basic current since the ±9mA modulation always comes in pairs which on average cancel out. The intermediate transitions that occur between bits are ignored because they occur at the wrong time. Only the changes that are separated by 32µs ($1/31.25\times10^3$) are used.



MBP transmission

Up to 32 PA devices can be connected to a MBP segment (the coupler and up to 31 PA slaves). The coupler supplies the basic current to all the connected PA devices and also translates between the RS484 signals and the MBP signals. The coupler also changes the bit rate, since DP cannot run at 31.25kbit/s. The coupler is a simple device that, like a repeater, does not have a PROFIBUS address, but simply translates the telegrams from one side to the other transparently.



PA and DP integrated into one network

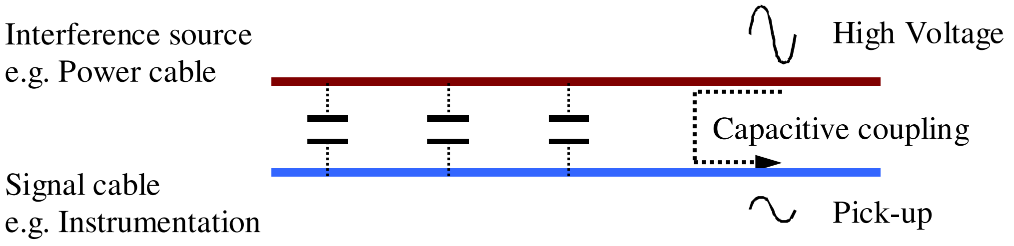
6. PROFIBUS installation

6.1. Pick-up in fieldbus cables

Pick-up occurs when outside influences such as cables or equipment carrying high voltages and/or high currents induce unwanted signals in our fieldbus cables. There are two main mechanisms for pick-up of interference from other electrical cables or equipment.

Electrostatic pick-up

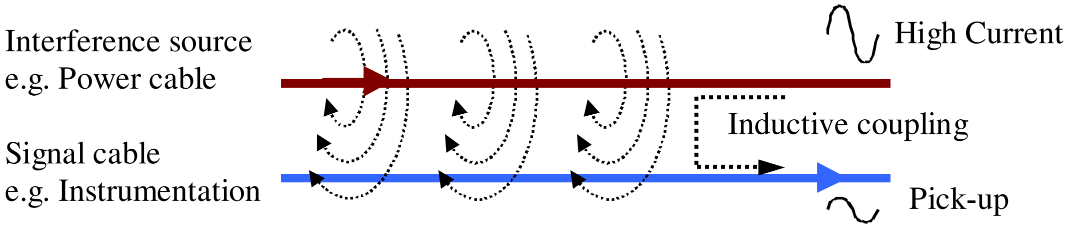
Here, electrostatic or capacitive coupling between the interference source and the fieldbus cable induces electrical voltages in the cable. The closer the cables the greater the coupling between the cables and hence the worse the pick-up will be. Cables carrying high voltages, high frequencies or rapidly changing voltages are particularly prone to inducing electrostatic pick-up.



Electrostatic pick-up

Electromagnetic pick-up

Here, magnetic or inductive coupling between the interference source and the fieldbus cable induces electrical currents in the cable. Again, the closer the cables the greater the coupling and the worse the pick-up will be. Cables carrying high current or rapidly changing current are particularly prone to inducing electromagnetic pick-up.



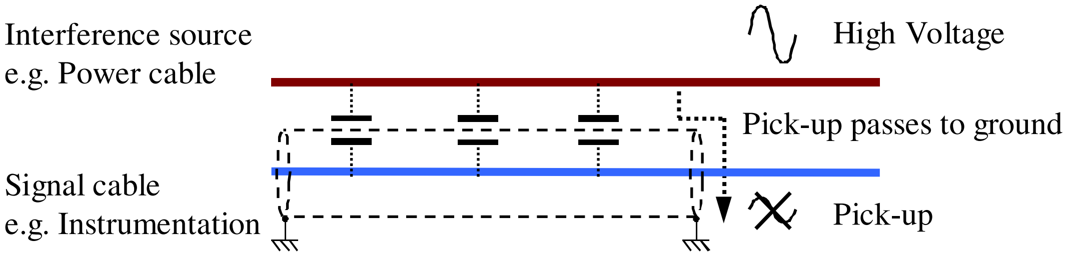
Electromagnetic pick-up

Both capacitive and inductive coupling are frequency dependent; the higher the frequency, the worse the pick-up. One might think that the pick-up will not be induced from cable carrying DC. This is partially true, but even DC current and voltage can change abruptly when devices are switched on or off. This DC can also produce transient pick-up.

In practice most pick-up is a combination of electrostatic and electromagnetic effects. There is no way to differentiate between these types by looking at the pick-up on an oscilloscope. However in order to minimise pick-up we must reduce both electrostatic and electromagnetic effects.

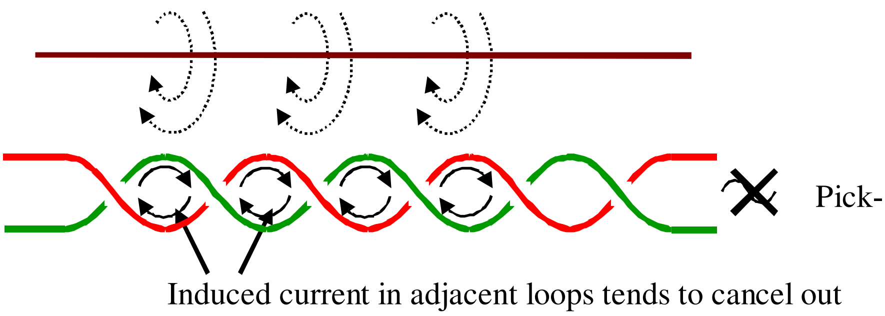
Pick-up reduction

Screening or shielding of the signal cable can reduce electrostatic pick-up. However, shielding is only effective when the shield is properly connected to earth (ground). Unearthed screening has no effect whatsoever; in fact it can make the pick-up worse!



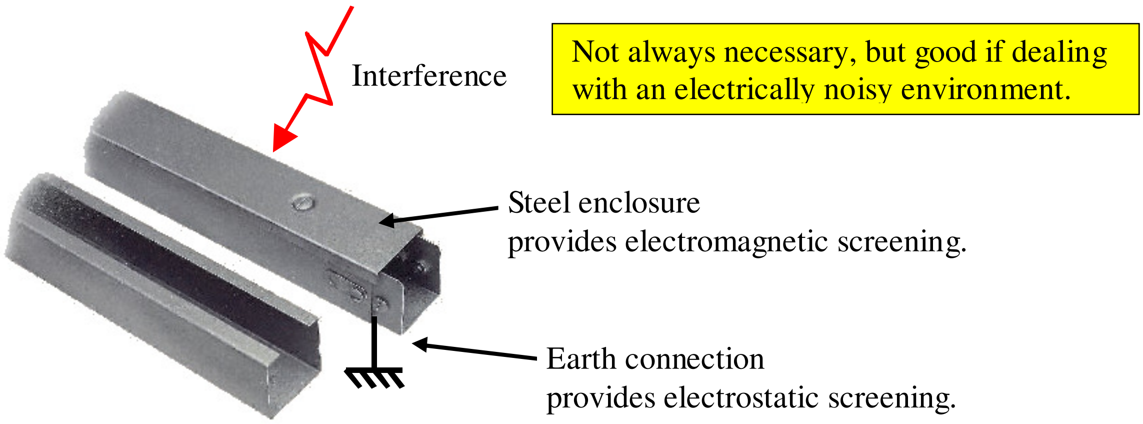
Earthed shielding can reduce electrostatic pick-up

Twisted pair cable significantly reduces electromagnetic pick-up. This is because the induced currents that flow in each loop of the twisted pair cable are flowing in different directions along the wire and hence on average tend to cancel out.



Twisted pair cable can reduce electromagnetic pick-up

Installation of the fieldbus cable in earthed, magnetically impervious ducting (i.e. a closed steel tray or conduit) can further reduce both electrostatic and electromagnetic pick-up. This is because the steel provides magnetic shielding for the magnetic fields that induce electromagnetic pick-up and the earthed enclosure provides additional shielding against electrostatic pick-up.



Solid steel trunking with a lid.

Earthed steel trunking or conduit can reduce both electrostatic and electromagnetic pick-up

6.2. PROFIBUS connection technology

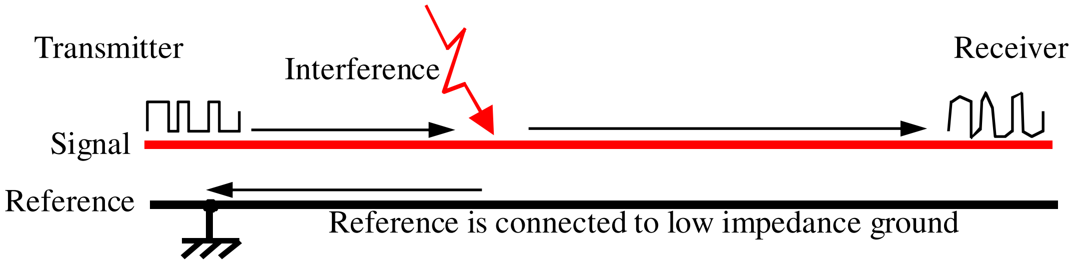
PROFIBUS has an extremely wide range of application and therefore utilises several different transmission technologies. PROFIBUS DP and FMS both use RS485 transmission. In addition fibre-optic (FO) transmission can be used. PROFIBUS PA uses Manchester Bus Powered (MBP) transmission as specified in IEC 61158-2.

Balanced and unbalanced transmission

RS485 and MBP both use balanced two-wire transmission. We need to understand what this means and its implications. Before we explore balanced transmission further, we will first look at unbalanced transmission.

Unbalanced transmission

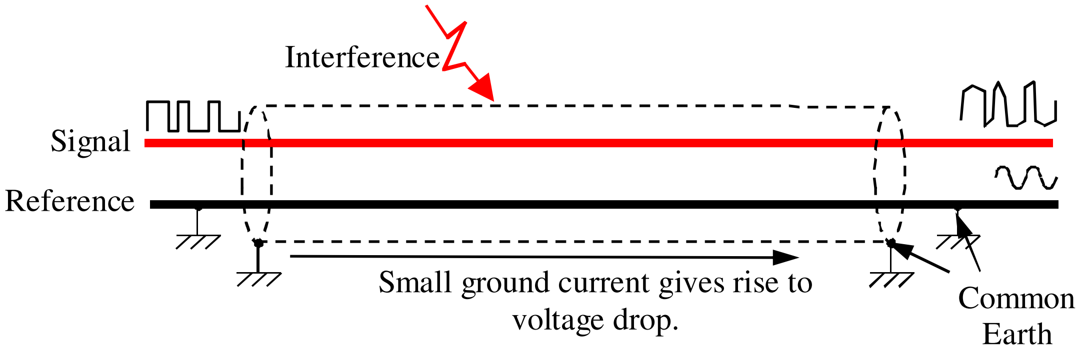
"Unbalanced transmission" is where we use a signal wire and a zero-volt reference wire:



Unbalanced transmission

Electrostatic and electromagnetic interference can be picked up by both the signal and ground wire, however since the ground wire is connected to low resistance earth, the induced voltages and currents pass to earth and have little effect. The signal wire, on the other hand, picks up these induced signals resulting in corrupted transmission. Unbalanced transmission is surprisingly common: RS232, 4-20mA, and many other transmission technologies use unbalanced transmission.

Earthed screening can reduce electrostatic pick-up, but unbalanced transmission can give rise to "Earth Loops" if the reference wire is earthed at both ends. Earth loops cause variations in the reference voltage at the transmitter and receiver:



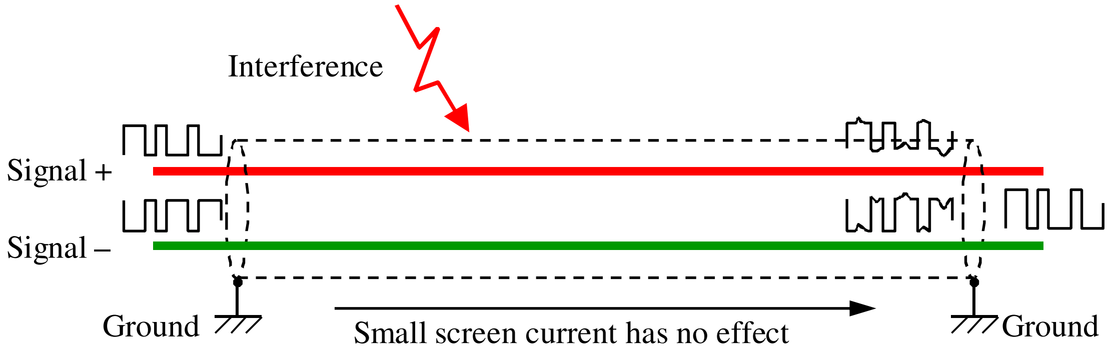
Earth loops on unbalanced transmission

For this reason unbalanced systems are best wired with the reference and shield connected at one end of the cable only (normally at the control room end only).

Balanced transmission

Balanced transmission is where both wires carry the signal, one positive and one negative. The information is carried by difference between the voltages on the two wires (differential). The term "balanced" means that the two wires have identical electrical characteristics and so any interference that is picked up on both wires (common mode signals) tends to cancel out. Balanced transmission is thus much less sensitive to pick-up and interference than single-ended or unbalanced transmission.

In addition, since there is now no reference wire, the screen is totally independent from the signal. Therefore any small currents flowing in the cable shield will have little effect (although larger screed currents and voltages can still cause pick-up):

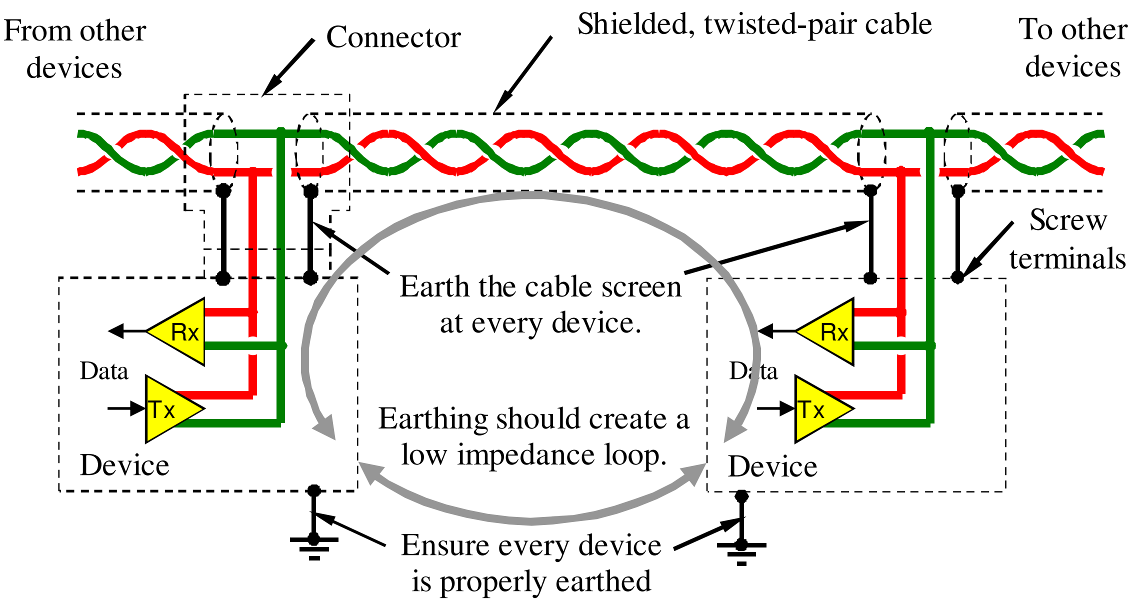


Balanced transmission

Balanced transmission is much less prone to pick-up than unbalanced transmission and because the screen is connected at both ends of the cable it is much more effective than screens that are earthed at one end only.

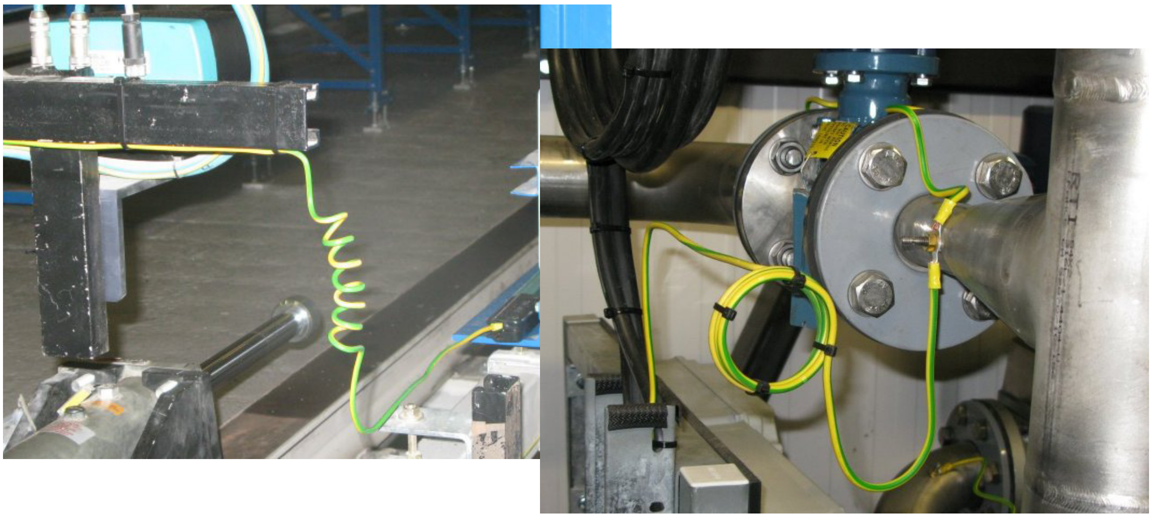
Screening balanced cables

PROFIBUS RS485 and MBP transmission are both balanced to improve noise rejection. Therefore we should earth the cable screen at both ends to ensure that it is effective at high frequencies.



PROFIBUS Earthing

This is normally done by connecting the cable screen to the device earth via the connectors. However, we must make sure that the device is correctly earthed. It is important that the earth wiring is not coiled. If you to leave some spare wire just zig-zag the earth cable. Poor shielding or earthing is a very common wiring error.



Do not coil the earth wire

6.3. RS485 rules

RS485 segmentation

RS485 is a ***multi-drop*** system, which means that many devices can transmit and receive (but not at the same time). In fact only one device can transmit whilst the others receive. An RS485 transmitter can drive the load of 31 receivers, therefore a maximum of 32 RS485 devices can be connected together on a single "segment".

This does not mean that only 32 devices can be connected in a PROFIBUS "network". The RS485 limitation of 32 devices is overcome by splitting larger networks into segments that are electrically isolated but which communicate using repeaters or fibre-optic links. Each segment is a separate piece of copper cable that must adhere to RS485 rules. The overall network can have many more devices and cover a much longer distance than the RS485 rules imply.

Within a segment all PROFIBUS masters, slaves, repeaters, optical link modules, and even telegram analysers count towards the 32-device limit. Thus any repeaters that are connected to a segment contribute towards the 32. It is good practice to leave at least 10% spare capacity per segment for future expansion and/or diagnostic tool connection.

Segment length considerations

RS485 segments can be up to 1.0km in length; however this only applies at lower bit rates. As the data rate increases, the maximum segment length reduces significantly as shown in table 1.

Table 1 – Maximum RS485 segment lengths

Bit rate	Maximum segment length	
9.6 kbit/s	1 000m	Low speed
19.2 kbit/s	1 000m	
45.45 kbit/s	1 000m	
93.75 kbit/s	1 000m	
187.5 kbit/s	1 000m	
500.0 kbit/s	400m	
1.5 Mbit/s	200m	
3.0 Mbit/s	100m	High speed
6.0 Mbit/s	100m	
12.0 Mbit/s	100m	

RS485 repeater limits

The standard says that a maximum of 9 repeaters may be used between any master and slave station. However, many modern repeaters exhibit an increased delay, meaning a maximum of only 4 repeaters giving 5 in-line segments. Old style repeaters had a repeater direction control signal which switched the direction of transmission (requiring an additional wire). Most modern repeaters automatically detect the required transmission direction and automatically switch to the correct direction. However, this introduces a small additional delay thereby restricting the number of in-line repeaters to 4 for modern devices. This implies a maximum of 5 in-line segments from a master to the furthest slave.

6.4. Fibre-optic transmission

Fibre optic transmission is an alternative to copper cable. Two fibre-optic transmission media are available: Plastic fibre, which is low cost but is generally limited to distances of less than 50m and glass fibre which can be used over distances of several kilometres. Fibre optic transmission offers the following advantages over copper:

- Larger distances between stations are possible with fibre-optics than with copper.
- Total immunity to electromagnetic and electrostatic pickup is provided.
- Electrical isolation removes earth potential difference and ground current problems.
- Fibre optic cable has insignificant weight and is largely immune to corrosion.

Fibre-optic transmission is typically used in conjunction with RS485 wiring to build a network. The copper to fibre-optic interface is accomplished using Optical Link Modules, OLMs (see section 9.1). Like repeaters, OLMs also have the effect of splitting the network into isolated segments.

6.5. MBP transmission

PROFIBUS PA uses Manchester Bus Powered (MBP) transmission (defined in IEC 61158-2). There are several major differences between RS485 and MBP:

- MBP operates using current variations to transmit data.
- It operates at a fixed, data rate (31.25 kbit/s).
- MBP cable can carry both power and data
- MBP segments can be easily implemented for operation in hazardous environments.

Typically, MBP segments are implemented using DP/PA couplers or link modules (see section 5.1). Each PA segment can connect up to 32 PA devices. However, the number of devices is significantly reduced when intrinsically safe operation is required.

Because of the lower bit rate, the allowed cable length on MBP segments is much longer than for RS485 segments. Using best quality (type A) MBP cable, we can use up to 1.9km in a single segment. However, voltage drop limits and intrinsic safety requirements can reduce this significantly.

7. Device addressing

Each PROFIBUS station requires an address through which communications can be directed. Devices such as repeaters and optical link modules simply pass the telegrams on to the next segment and thus do not require an address.

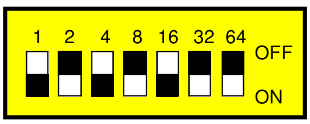
Within a network, every PROFIBUS device must be given a unique address. If two devices have the same address then one or the other or perhaps both will fail to operate. This is because the two devices will both attempt to respond to the master request sent to the common address and each response will be corrupted by the other. Sometimes the stronger device will override a weaker device and will operate satisfactorily, whilst the weaker device is drowned out.

7.1. Setting addresses

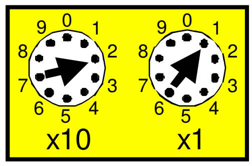
The address of every station must be set by the engineer during commissioning. Station addresses can be set in several ways.

<u>Physical address switch on the device</u>

Here the device address is set by a physical switch on the device. The switch can take a variety of forms. Seven in-line, on-off binary weighted switches, two decimally weighted rotary switches or other forms.



a) Binary-weighted address switch



b) Decimal-weighted address switch

In the binary-weighted switch, each switch is worth a binary digit: 1, 2, 4 … 64. If a switch is on then the digit contributes to the address. For example figure a) shows switches 1, 4 and 16 as on, so the address would be 1+4+16 = 21. Figure b) shows the same address (#21) set on a decimal-weighted switch.

Note that the binary switches can be labelled 0-6 or even 1-7 on different devices. Sometimes we even find an additional switch. The eighth (or perhaps first) switch has some other function, for example hardware or software address selection. Note also that the device power will normally need to be cycled (switched off and then on again) for the new address to be recognised by the device.

Software setting of device address over PROFIBUS

Here the device address is set using a configuration tool (called a class 2 master). The tool uses a “set slave address” command to effect the change. Normally devices are delivered with the address #126, which is a reserved address for this function.

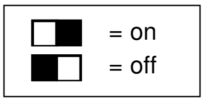
Special software and communication link

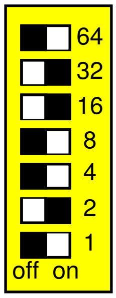
Here the device uses special software which communicates with the device via a serial port or perhaps Ethernet. Devices that use this method of setting the address include Human Machine Interfaces (HMIs) devices or Programmable Logic Controllers (PLCs). This is because these devices need the software and serial cable for downloading the program or configuration, so it is simple to add the PROFIBUS address to this data.

7.2. Setting an address on a binary switch

To set an address on a binary weighted switch we can work down from the most significant switch deciding whether each should be off or on. As an example, we will examine how to set the address #50 (decimal). The procedure starts at the most significant switch (64), since the required address is less that this switch value, we can see that this switch is not required and so should be off. The next switch (32) is required so should be on. This then leaves 50 – 32 = 18 still required. The next switch (16) is required, so is on, leaving 18-16=2 still required. Thus of those switches left only the switch for (2) is required to be on. All the other switches (8, 4 and 1) are not required and should be off.

Example of setting binary switch to address 50





7.3. Reserved addresses

PROFIBUS supports 128 different addresses, numbered 0 to 127. However, some of these addresses are reserved and recommendations should be followed in how these addresses are allocated:

- Address 127 is reserved for global or broadcast messages.
- Address 126 is reserved for off the shelf devices whose address is set over the bus.
- Address 0 should be reserved for an engineering tool (i.e. a class-II master).
- When using a single class-I master it is recommended that its address should be set to 1. Further class 1 masters should be allocated addresses 2, 3 … etc.

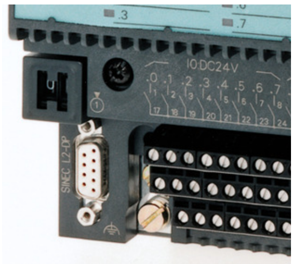
For example, when using a single master, we can have slaves at addresses 2 to 125. There are thus 125-1 = 124 addresses available for slaves.

8. PROFIBUS RS485 wiring

The PROFIBUS RS485 wiring, employed for DP and FMS, uses shielded twisted pair cable. It is highly recommended that only PROFIBUS cable is used with characteristics that are optimised for RS485 transmission.

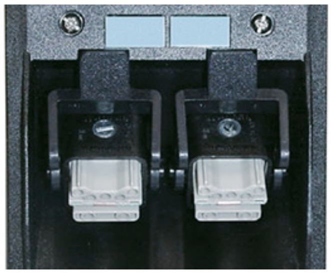
8.1. DP connectors

DP devices can use various types of connector or even screw terminals. However, PROFIBUS International has defined the connections for standard 9-pin sub-D connectors, M12 plugs and sockets (tables 2 and 3) and for hybrid connection system that can be used for fibre-optic or RS485 connection with power supply. Sub-D connectors are designed for use in clean and dry environments; M12 connectors can provide protection up to IP67 and can be used in wet or dusty environments.



9-pin sub-D

M12



Hybrid

RS485 connectors

Table 2 – Pin allocations for Sub-D PROFIBUS connectors

Pin No.	Signal	Function	
1	Shield	Ground connection	Optional
2	M24	Ground for 24V supply	Optional
3	**RxD/TxD-P**	**Data line plus (B-line)**	**Mandatory**
4	CNTR-P	Repeater direction control signal	Optional
5	**DGND**	**Data ground**	**Mandatory**
6	**VP**	**+5V supply for terminating resistors**	**Mandatory**
7	P24	+24V supply	Optional
8	**RxD/TxD-N**	**Data line minus (A-line)**	**Mandatory**
9	CNTR-N	Repeater direction control signal	Optional
Case	Shield	Ground connection	Optional

Table 3 – Pin allocations for M12 connectors

Pin No.	Signal	Function	
1	**VP**	**+5V supply for terminating resistors**	**Mandatory**
2	**RxD/TxD-N**	**Data line minus (A-line)**	**Mandatory**
3	**DGND**	**Data ground**	**Mandatory**
4	**RxD/TxD-P**	**Data line plus (B-line)**	**Mandatory**
5	Shield	Ground connection	Optional
Thread	Shield	Ground connection	Optional

When 9-pin sub-D connectors or M12 connectors are used, the wiring must comply with that set down in the standard. ***Note that the cable shield should always be connected on every device, even though the tables show this as optional***.

The two wires in the twisted-pair cable carry the "Data line plus" (B-line) and "Data line minus" (A-line) signals. The two wires in the PROFIBUS cable usually come colour coded. Normally red and green are used, however other colours may be found. ***When red and green wires are being used the following recommendations apply:***

Red – B-line (RxD/TxD-P) (Aide-memoir: "B to RED" – "**BREAD**")
Green – A-line (RxD/TxD-N) (or "**BLOOD**" is red)

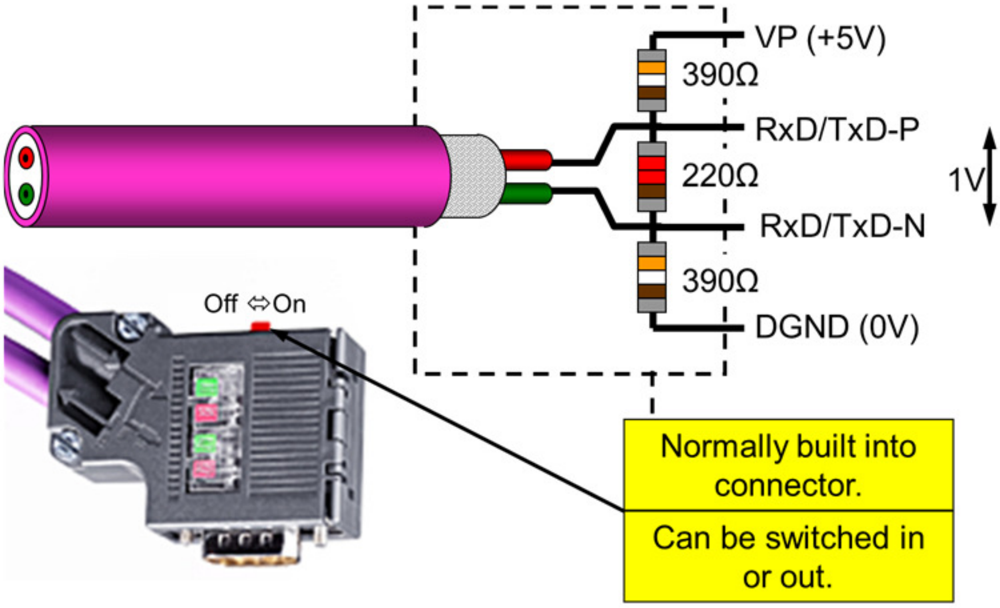
8.2. Reflections and termination

Electrical cables are actually a transmission line in which the signals travel as waves of current and voltage. The cable has a certain inductance and capacitance which depends upon the cable construction and wire size and spacing. When used for low frequency signals, the cable inductance and capacitance can be ignored and only the cable resistance is important. However, when transmitting high frequency signals the inductance and capacitance are important. Every cable has a particular "characteristic impedance" which is measured in Ohms, but this is not the same as the cable resistance. It is a dynamic impedance which is only important at high frequencies. The characteristic impedance of a cable depends upon its inductance and capacitance per meter of length. PROFIBUS DP (RS485) cable has a characteristic impedance of 150Ω which is independent of cable length. Other cables can have significantly different impedance, even though they look quite similar. For example PA (MBP) cable has a characteristic impedance of 100Ω.

When signals travel down a cable, any electrical discontinuity like additional inductance or capacitance can cause reflections to occur. In particular, the end of the cable is a major discontinuity where the impedance suddenly increases to infinity. When the signals reach end of the cable it is just like hitting a brick wall and the signals reflect back from the ends. Just like an echo, the reflected signal can cause multiple signals to appear on the line. Reflections are bad news in high-speed communications because signals are corrupted or distorted by the reflection.

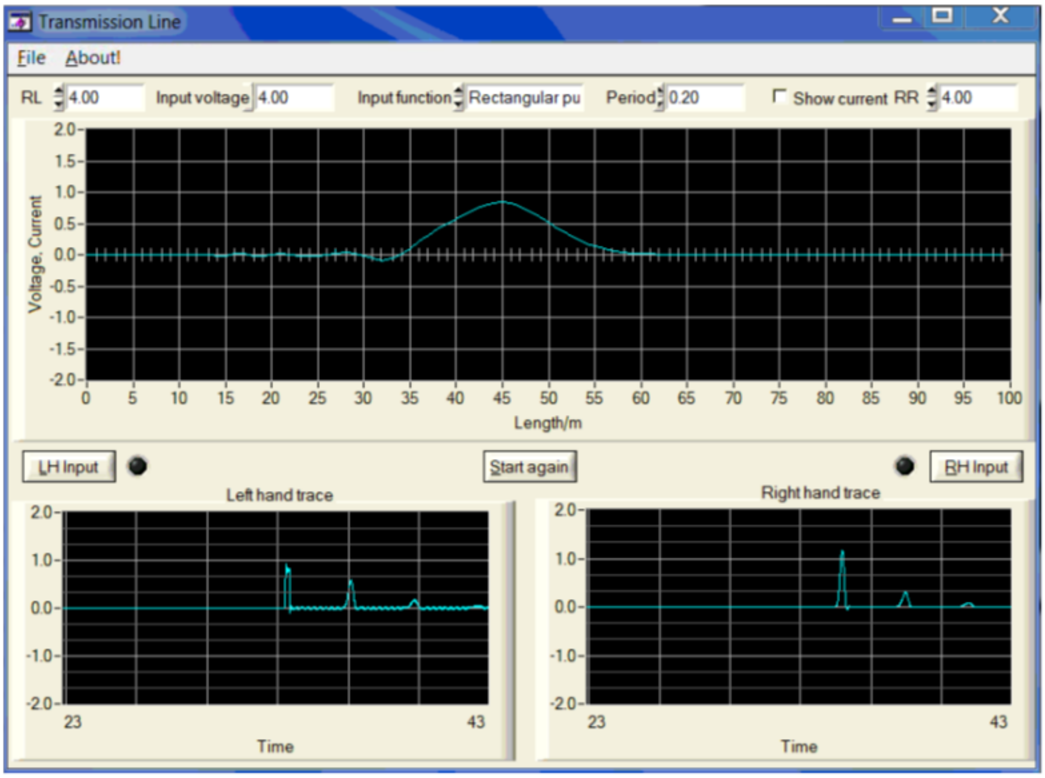
One way of minimising reflections at the ends of a cable is to "terminate" the ends with a specially chosen resistance that matches the cable characteristic impedance. The resistance absorbs the energy of the signal and significantly reduces the reflection (theoretically to zero). The matching termination resistance actually looks to the signal like more cable and so there is no reflection.

PROFIBUS RS485 uses an "active termination" network that must be supplied with 5V. This is why the +5V VP and DGND pins are mandatory on PROFIBUS connectors. The termination network, when powered by 5V, appears as an effective resistance of 150Ω so matching the cable impedance. However, in addition the powered termination network also biases the cable to approximately +2V on the A line and +3V on the B line, so giving a 1V differential when the line is quiet (i.e. when no device transmitting). This bias gives some additional protection from interference because any pick-up which is less than 0.5V peak on each wire cannot possibly cause spurious data bits.



Active termination used in PROFIBUS RS485 wiring

A useful simulation of a high-speed cable is provided by the free package "Transmission Line Simulator", available from the VTC web site at www.VerwerTraining.com/downloads. This can be used to visualise the effect of different termination resistor values at the ends of the cable.



Transmission Line Simulator, available for free download at www.VerwerTraining.com

The RS484 termination rules

To avoid reflections from the ends of the cable it is essential that:

EACH SEGMENT IS TERMINATED AT THE TWO ENDS AND NOWHERE ELSE.

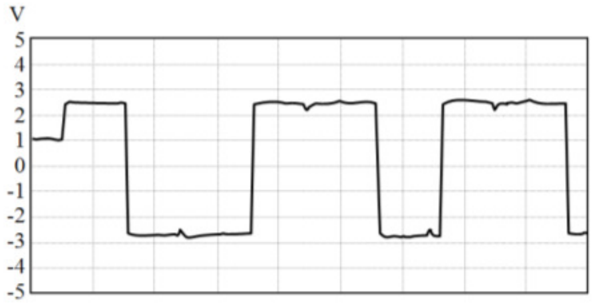
Also:

RS485 TERMINATION NETWORKS MUST BE POWERED AT ALL TIMES (EVEN WHEN DEVICES ARE SWITCHED OFF!)

otherwise reflections can disrupt the remaining devices on the bus.

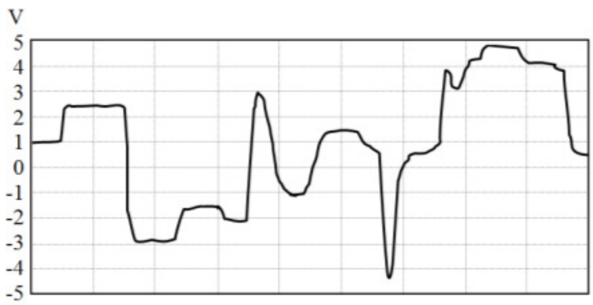
It is suggested that you study and memorise these two important rules. It is very common to find intermittent bus problems caused by incorrect termination. It is also common to find PROFIBUS stations or even whole networks that never work caused by incorrect termination.

So, what can go wrong? Many PROFIBUS devices incorporate built-in termination resistors that can be switched in or out. In such cases it is important that the device termination is switched out when not required. It is common to find the device termination switch mounted on a circuit board, which is hidden inside the device. The switch may be left switched on after pre-delivery tests. A common error is to have these additional termination resistors switched in, giving additional termination in the middle of a segment or double termination at the end of a segment. Any additional or missing termination(s) can cause reflections.



A correctly terminated segment running at 12Mbit/s

Powered termination on at both ends of the segment, normal reflection less than 500mV peak-peak.



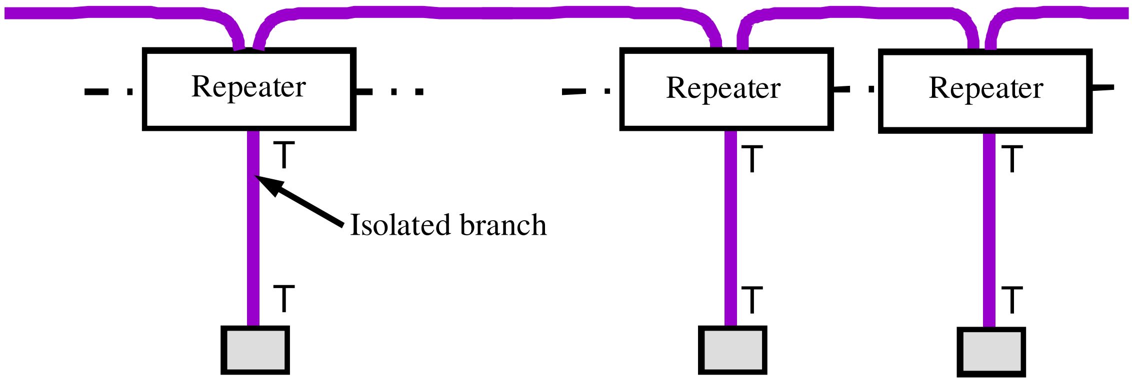
Termination at one end of the segment only

Effect of missing termination on RS485 waveform

8.3. *Spur lines*

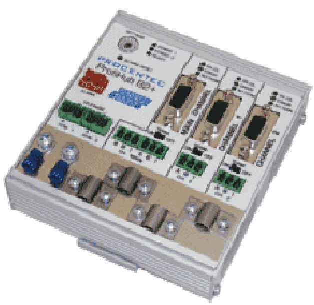
Spur lines (also called stub-lines or drop-lines) should generally be avoided because they can cause reflections. The reason for this is that they introduce additional capacitance on the main trunk line where the spur Tee junction is located. Each segment should ideally be connected as a single linear bus. That is, the cable should daisy chain from device to device:

Repeaters can be used to avoid spur lines, by isolating the branch cable that goes to a device. This idea can be extended to many devices, allowing devices to be connected to the network via isolated branches:



A Hub incorporates several miniature repeaters in a single box. Hubs typically provide connections for trunk in and trunk out and several branch lines, each of which can use the maximum segment length of cable and have up to 31 devices connected. Hubs costs a small fraction of the price for the individual repeaters and provide a cost effective way to connect devices without spur lines.

Profihub B5, IP-20



Profihub B5, IP-20

Profihub A5, IP-65

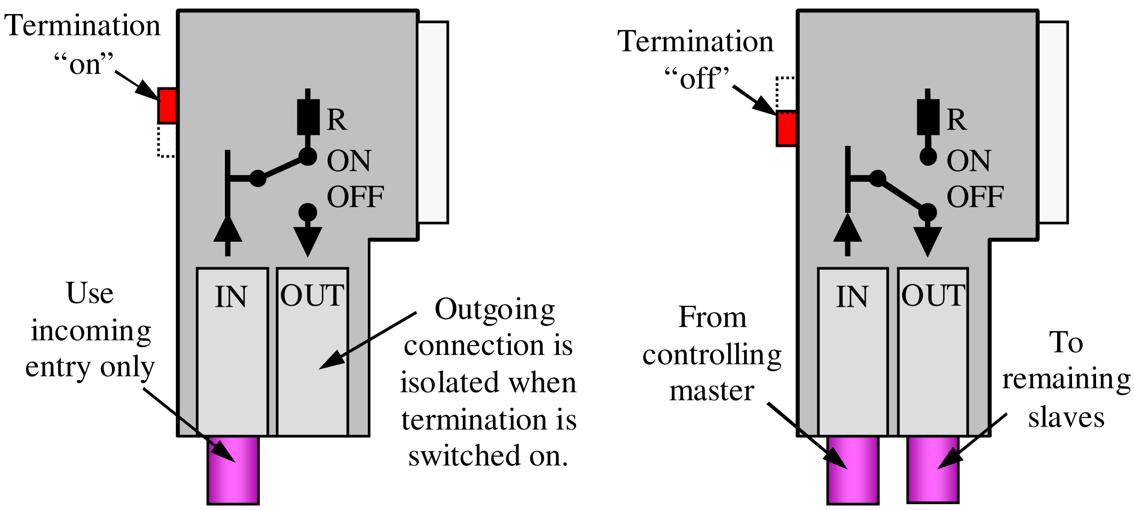
There is no limit to the number of repeaters that can be used in a network. However, we recommend restricting the number of repeaters as each repeater introduces a new segment which makes health checking more time consuming. Never use a repeater without good reason. Hubs are useful for isolating noisy devices (i.e. drives) and providing tree structures without using spurs.

8.4. PROFIBUS RS485 connectors and wiring tools

It is highly recommended that special PROFIBUS connectors are used when wiring a DP/FMS network. These connectors incorporate several features that ensure reliable operation and provide quick and robust connection. These features may include:

- Built-in termination resistors that can be switched in and out.
- Quick and reliable connection of data wires and shield.
- Connections for incoming and outgoing cables.
- Special inductors built in for operation at over 1.5 Mbit/s
- Outgoing cable isolation when termination switched in.
- Additional piggy-back socket for connection of diagnostic/programming tools.

Modern PROFIBUS connectors normally have marked cable entries for “incoming” and “outgoing” cables. This distinction can be important in “isolating connectors” where the outgoing cable is isolated when the termination is switched “in”. Such isolating connectors are useful for commissioning and testing the network. They are also useful for maintenance, where they allow sections of a segment to be isolated whilst retaining correct termination.

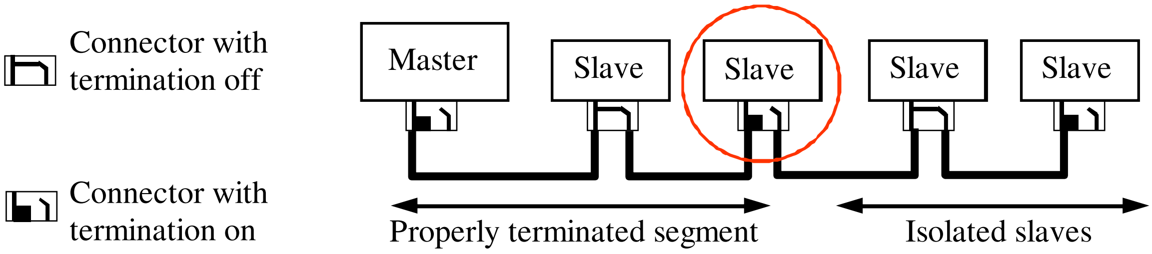


Beginning and end of a segment

All other devices

Correct use of isolating connectors

The first and last connector on a segment should only use the ingoing entry. All other connectors should have the incoming entry connected to the controlling master. In this way any termination can be switched on to isolate the slaves on the outgoing cable.

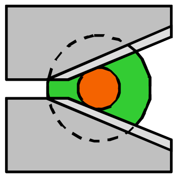


Incremental commissioning and maintenance using isolating connectors

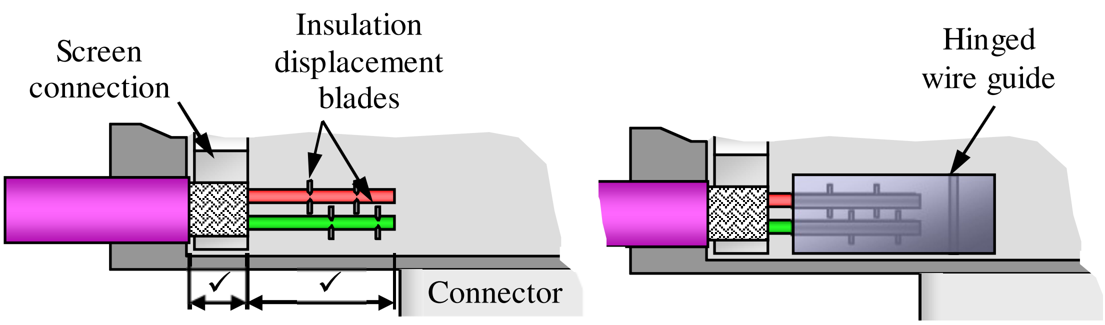
When any such connector has the termination switched "on" all the stations on the outgoing side are disconnected, leaving a properly terminated sub-segment on the ingoing cable.

Many manufacturers produce a PROFIBUS cabling solution with cable, connector and stripping tool. It is important that these items are compatible. One area that can cause problems is the use of stranded and solid core PROFIBUS cable.

Solid core cables are best connected using "insulation displacement" (sometimes called "fast connect") technology, where the core insulation is not removed, but is pierced by a blade in the connector:

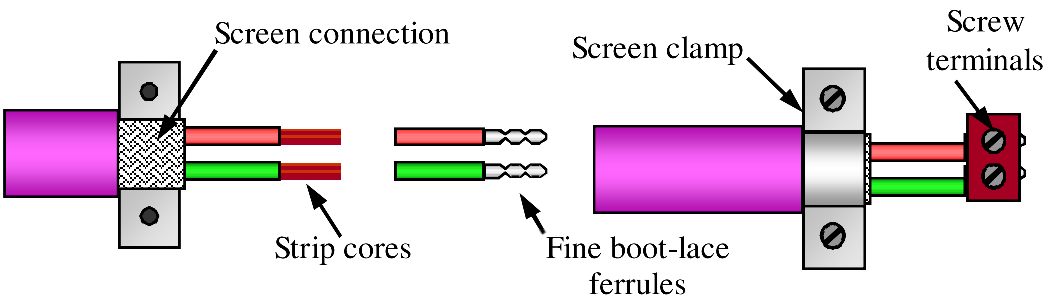


Insulation displacement technology gives a reliable airtight, low-resistance connection to the cable core. However, this type of insulation displacement connection should not be used with stranded core cable because the individual cable strands can be cut by the blades.



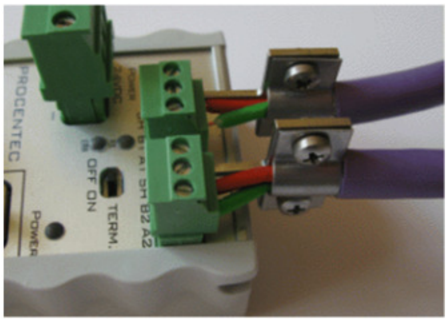
Insulation displacement connector cable preparation

Stranded core cable is best used in conjunction with screwed termination connectors. The wire ends must be stripped of insulation. Ideally a small (0.5mm or 0.75mm) bootlace ferrule should be crimped onto the bare wire using a proper crimp tool (not pliers). Do not twist the strands together.



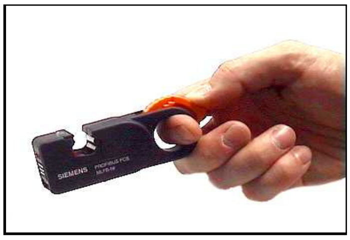
Stranded cable preparation for use with screw connectors

Screen connection into screwed terminals can pose a difficulty. Do not use a “pig-tail” when connecting screens since this introduces an inductance which creates impedance at high frequencies. A 360° connection of the screen is best. Special stainless steel screen clamps are available from Procentec which provide a simple and good quality screen connection to screw terminals.



Procentec screen clamp for screw terminals

Reliable connections can quickly be made using special stripping tools and insulation displacement connectors, as shown below:



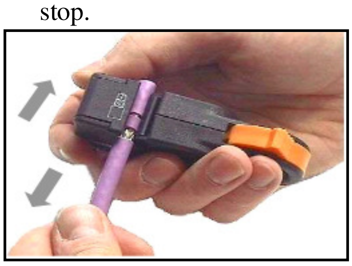
1. Hold the insulation stripper in your right hand and the cable in your left.

2. Match the cable end with the template. Use your left index finger as a guide.

3. Insert the measured cable end into the stripper. Use your index finger as a stop.

4. Clamp the cable gently in the stripper.

5. Rotate the stripper once. Close one more click and rotate again. Repeat until screen is cut.



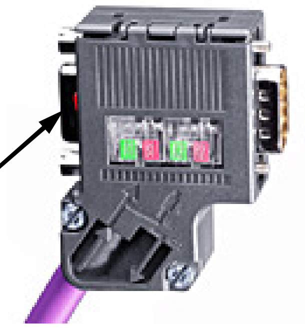
6. Release the clamp and pull off the stripped cable end. Be careful to remove the protective film.

Using the PROFIBUS cable stripping tool

8.5. Piggy-back sockets

To allow for network analysis and troubleshooting, each segment should have at least one connector with a "piggy-back socket". The extra socket allows monitoring or programming devices to be plugged in without disrupting the network. Piggy-backs are best mounted at the end of each segment. Never use a piggy-back socket for adding slaves since it creates a spur line.

At higher bit rates spur lines must not be used so the test tool must be directly connected to the piggy-back. Alternatively, an extra spare socket should be provided for diagnostic tool connection. Note that some diagnostic devices can draw up to 90mA from the socket 5V pin. In such cases you should ensure that the socket is attached to a device which can supply the required current.



8.6. Common RS485 wiring errors

It is common to find simple RS485 wiring and layout errors in the field. The most frequently occurring errors are described below:

1. Termination problems:
    a. Lack of terminations at the end of a segment.
    b. Double termination, caused by devices with inbuilt termination.
    c. Termination in the middle of a segment (can be caused by devices with inbuilt termination).
    d. Unpowered terminations (unplugged or unpowered devices).
    e. Incorrectly wired isolating connectors (only becomes a problem when switched on).
2. Pick-up and interference caused by:
    a. Laying bus cables too close to electrically noisy power cables or equipment.
    b. Lack of proper earthing of the cable screen at every device.
    c. Screen current due to earth potential differences between areas of the network.
3. Power supply problems
    a. Insufficiently rated power supply (check voltage with full load).
4. Wiring problems:
    a. Wrong cable used (e.g. using PA cable for DP segments).
    b. Damaged cable (including squashed, over-bent)
    c. Swapped cores at a device (B-RED rule broken)
    d. Un-earthed screen (not connected at every device, un-earthed devices etc.)
5. Segment rules broken:
    a. Cable too long for the bit rate used.
    b. Too many devices (never more than 32 RS485 drivers on a segment).
    c. Use of spur lines (keep short at lower bit rates and don't use at higher bit rates).
6. Damaged or uncertified devices.
    a. Excessive connection capacitance.
    b. Faulty or poor quality RS485 driver chips

9. Hand-held cable test tools

Hand-held bus test tools are available from several manufacturers. Such tools can quickly and efficiently check PROFIBUS network cabling and slave device connections and can help to minimise wiring faults in PROFIBUS DP networks during installation and start-up. Pre-commissioning wiring, device and address testing can save a lot of time and trouble at the commissioning stage. The Siemens BT200 and COMSOFT NetTEST II are examples of such hand-held tools.

Hand-held testers can typically perform the following checks on PROFIBUS cabling:

- Detection of breaks and short-circuits in wires or screens.
- Checking termination resistor settings.
- Checking the length of the installed cable (based on cable resistance for BT200 – not very accurate; based on reflections on NetTEST II – much more accurate).
- Determining the location of faults.
- Detection of reflection-generating faults.

Hand-held testers may also perform some or all of the following checks on PROFIBUS DP slaves:

- Check the health of the RS485 driver.
- Check the voltage (+5V) for line termination.
- Checking slave addressing (bus scan).
- Cable impedance measurement (NetTEST II only)
- Exercise slave I/O (NetTEST II only).

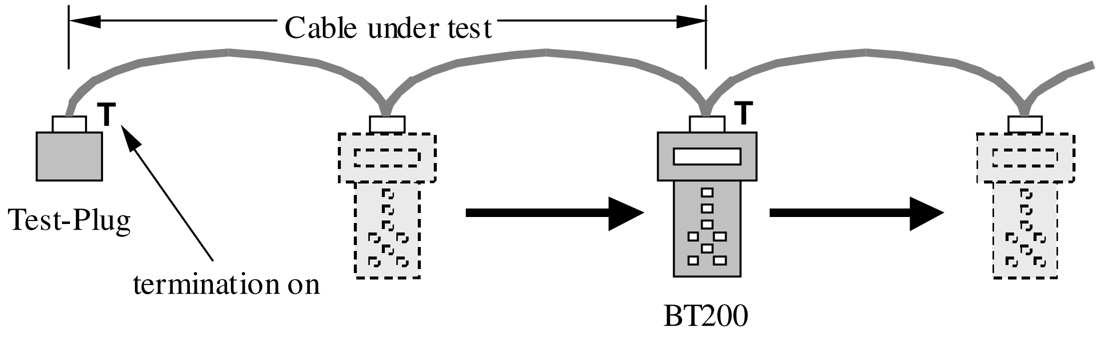
Most hand-held testers have the useful facility of being able to store the test data obtained whilst testing a bus segment. This data can then be downloaded onto a PC and a report generated giving full documentation of the tests performed and the results.

9.1. Wiring testing using the BT200

Basic cable testing

All devices should be disconnected from the cable for the wiring test. A special "Test Plug" is connected to one end of the segment (normally where the master would be) and the termination is switched on. The BT200 is connected to each socket in turn working away from the test plug. Again the termination is switched on at the BT200. It is important to use a systematic procedure in testing cables so that any faults can be accurately determined and located (at least between any two connectors). The test plug should not be moved during testing and every socket should be checked working away from the test plug. The cable is tested from the BT200 back to the test plug, so as soon as a first fault is detected then the fault must be located in the section of cable just added, between the current connector and the previously checked one. You must remember to switch off the termination again on each connector as you move the BT200 along.

Note that it is important to check every socket since there may be a fault local to a socket that does not affect the rest of the cable. For example: a single socket with the A and B wires crossed over on both the incoming and outgoing cable would not be detectable from the end of the cable.



Principle of the basic BT200 wiring test

Use of the BT200 keypad and display

Press ⏻ to power device on. The display then shows Siemens copyright then an automatic battery check is carried out. The bar-graph should extend right across the display indicating a fully charged battery. Note that the charger is not supplied with the BT200 and must be purchased separately.

Normal, cable test mode

After switch on the BT200 enters the "normal" (cable test) mode. You are prompted to press "**TEST**" to perform a cable test.

Battery ■ ■ ■ ■ ■ ■ ■	Start Test →TEST

If the BT200 cannot see the test plug, because of a cable fault, or perhaps because it is not connected, the display will show "**fix all wires**". Should the tested cable section be fault free you will see "**Cabling OK**", followd by "**(1R)**" which means one termination resistor has been detected, or "**(2R)**" indicating two terminations found.

Cabling o.k. (2R) →OK	Fix short circ. B-Shield →TEST

Faults found include short circuit, open circuit, crossed wires etc. together with details of the wires affected.

The BT200 menu

Other functions are available on the BT200 via a menu. To reach the menu, we must press "**Esc**" and "**OK**" simultaneously. The most important of these additional functions are:

- "Cabling" – same as Normal mode.
- "Station Test" – RS485 test and 5V.
- "Bus-scan" – Find slaves on the bus.

The station test is used to check the health of a device RS485 driver and to check the voltage supply for the termination. This test can only be done using a special multi-core cable which is supplied with the BT200. PROFIBUS cable cannot be used since only the two signal wires are connected to the cable.

► **Cabeling** **Station test**	► **Bus scan** **Station test**

Note that the flashing cursor is always on the top line of the display. Thus pressing "OK" will always select the currently showing top-most item.

Performing a bus-scan

After selecting "**Bus scan**" from the menu and pressing "**OK**", you should see confirmation that you are about to do the required test. Press "**TEST**" in response to the prompt and you are then asked for a slave address.

Bus scan **→TEST**	**Slave address** **000 →OK**

The default address is zero, which means the BT200 acts as a master at address 0 and scans all slave addresses from 1 to 126 looking for slaves. (Note that if you enter any other address, it causes the BT200 to scan for that address only.) After a delay of about 1 minute, the display will show a list of found slaves in numerical order.

The other items on the menu include cable length measurement and a reflection test. These measurements are not very accurate and it is recommended not to use these tests. An oscilloscope provides a much more accurate measurement of these characteristics; however this is outside the scope of this document.

Wiring testing using the COMSOFT NetTEST II

The COMSOFT NetTEST II device can also check out cable faults, however this device does not use a separate test plug and uses a different procedure based on progressive testing without terminations, with one termination and finally with both terminations. In addition it provides accurate cable impedance and accurate length measurement.

10. Layout of DP segments

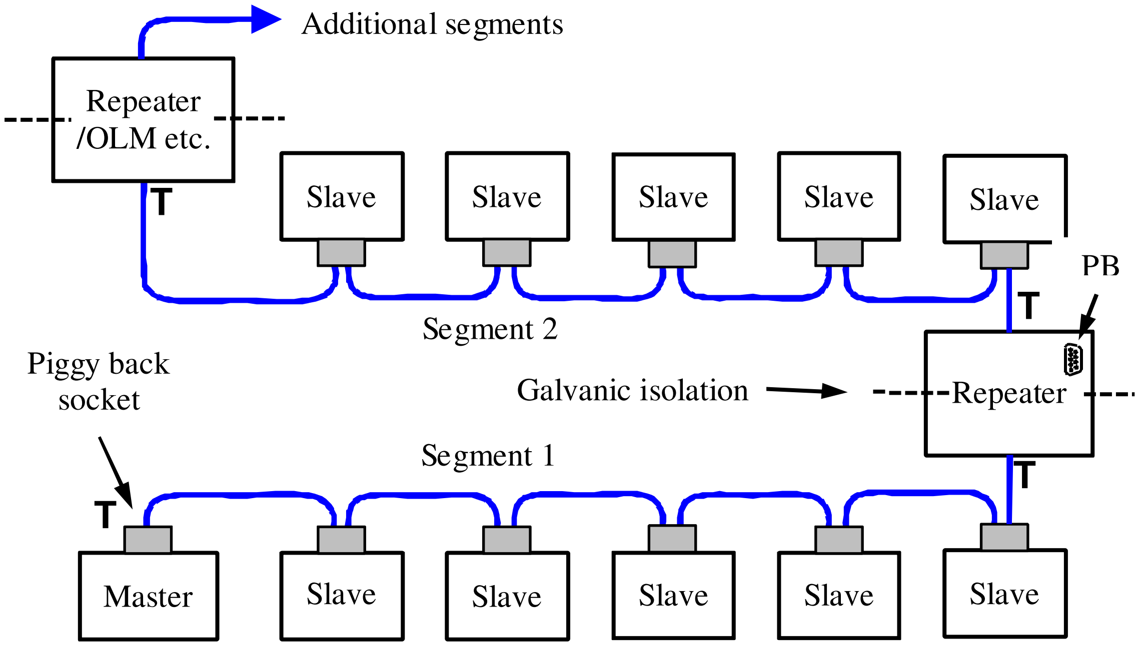
When laying out a PROFIBUS DP network it is important to remember the rules for RS485 segments:

- A maximum of 32 RS484 devices on each segment (10% spare is a good idea).
- Segment length not more than the maximum that is specified for the bit rate used (Table 1)
- RS485 segments should be laid out as a linear bus with the cable daisy chaining from device to device. Spurs should be avoided wherever possible.
- Each RS485 segment must be terminated at the ends of the segment cable and nowhere else.
- RS485 terminations must be powered at all times, even when the end device is unpowered or disconnected.

10.1. Ideal segment layout

During normal operation it possible that devices may fail and require replacing. We must be careful on a working system that we do not unplug a device at the end of a segment that is supplying power to the termination resistors, leaving an unpowered termination. The ideal layout is to keep slaves away from the ends of the segments. I.e. masters, repeaters, couplers OLMs etc are best placed at the ends of the segments. In this way any slave can be replaced without shutting down the network. If you need to replace a master or repeater then the network would have to be shut down in any case.

It is not essential that masters and repeaters are located at the ends of the segment. However, placing slaves at the ends of segments means that care must be exercised to avoid unpowered termination when disconnecting them from the network.

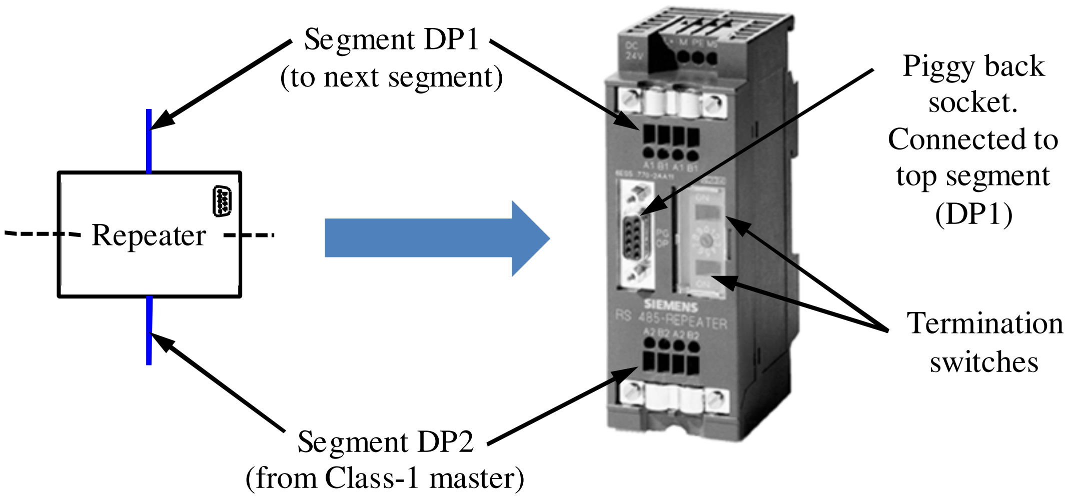


Ideal arrangement for a single master network with repeaters

At the other end of the segment a repeater may be used to extend the network. In this way any station can be removed or replaced without upsetting bus termination. Note that it is essential that power is always supplied to the repeater.

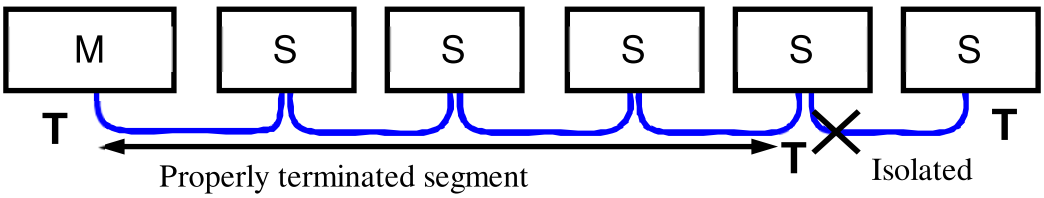
A piggy-back socket should be provided at the start of the segment to allow us to examine the signals and waveforms in the first segment. However, we need to access all segments to check the health of the whole network.

All repeaters provide a built-in piggy-back socket; however, we must be careful because the piggy-back socket is connected to one segment only. The Siemens repeater has a well-known problem in that the piggy-back socket is connected to top segment, which is labelled "DP1". Unfortunately people often connect the incoming segment to DP1 and the outgoing segment to DP2. In order to be able to use the piggy back to examine the outgoing segment to connect the incoming master cable to the bottom segment (DP2) and use the top segment (DP1) for the outgoing cable. In this way we can always connect to the piggy-back socket to examine the signals on the next or outgoing segment. Other repeaters, e.g. Procentec, do not have this problem.



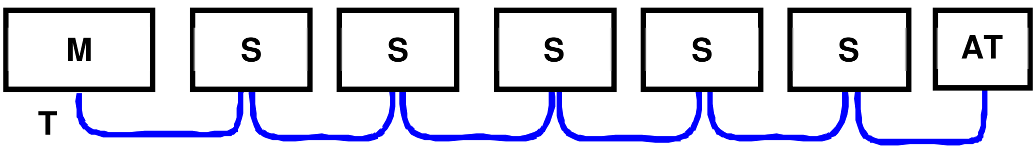
Correct connection of the Siemens repeater and piggy-back socket

When a repeater is not used at the end of a segment the termination must be "on" at the last device. This means the last device needs to be powered at all times to maintain the supply to the termination network. If you have to replace the last device, the whole network could become unstable. However, if isolating connectors are used (and correctly wired) this situation can be avoided by switching on the termination on the penultimate device. This will isolate the last slave but still leave a correctly terminated segment:



Use of isolating connectors to avoid termination problems when the last slave is removed

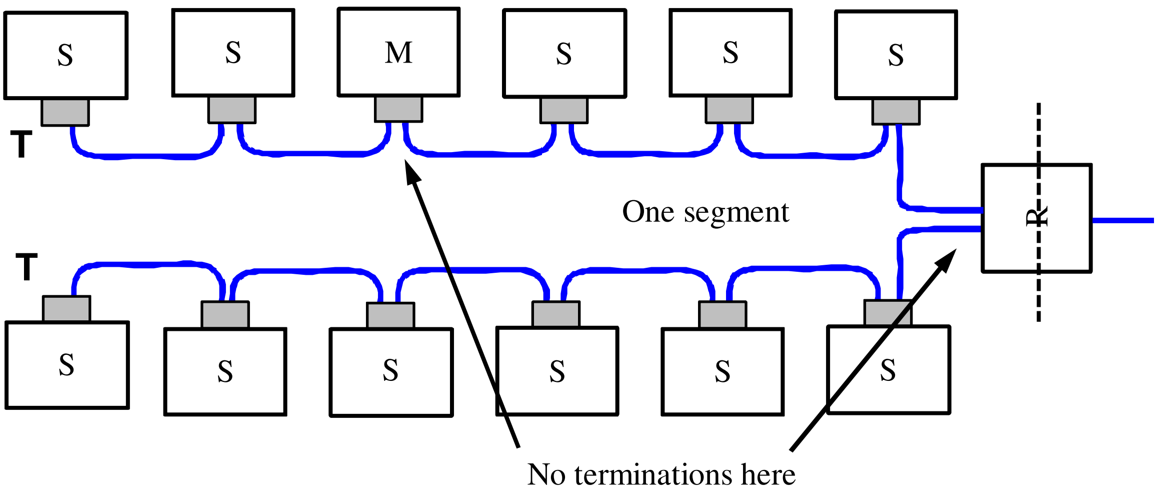
As an alternative to using the terminations in the connector, a separate "active terminator" can be used. An active terminator is simply a termination network that is separately powered. The active terminator is connected to a power supply and needs to be powered at all times. The advantage of this arrangement is that any slave can be disconnected and replaced without disrupting the network. Note that ***additional termination (i.e. on the connector) must not be switched on at the last device since this would result in double termination***.



Use of a separate active terminator

Active terminators from Siemens and Procentec

When construction requirements force the master or repeater to be in the middle of the segment, you need to have the terminations "on" at the first and the last device on the segment only - not at the master or repeater.

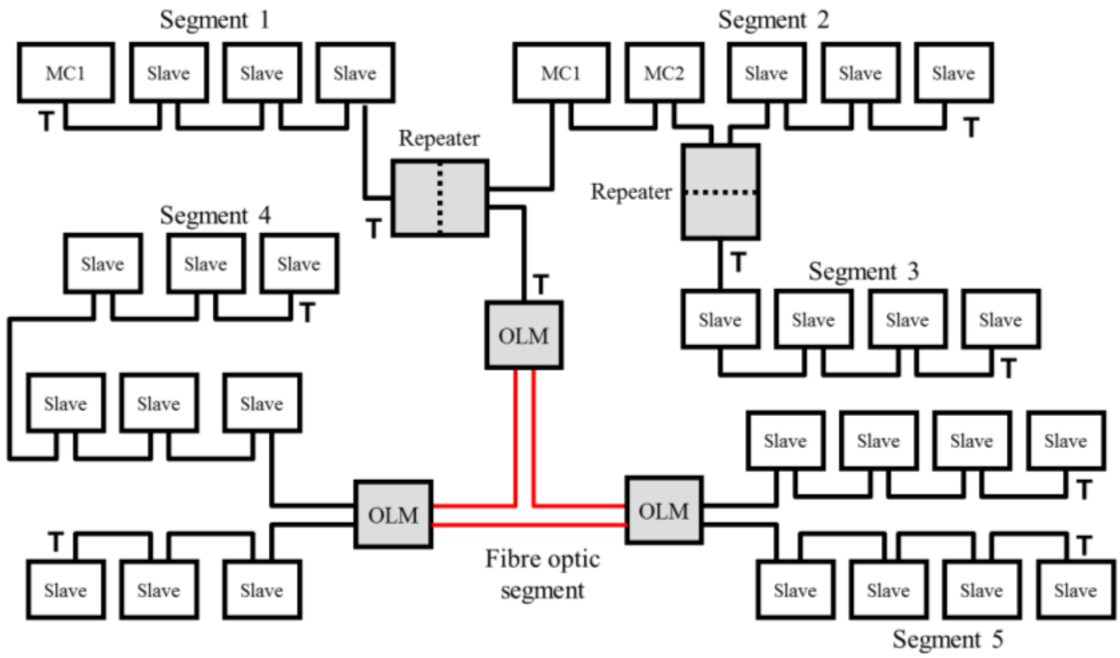


Masters and repeaters do not have to be at the end of the segment,
but terminations should always be at the two ends and nowhere else.

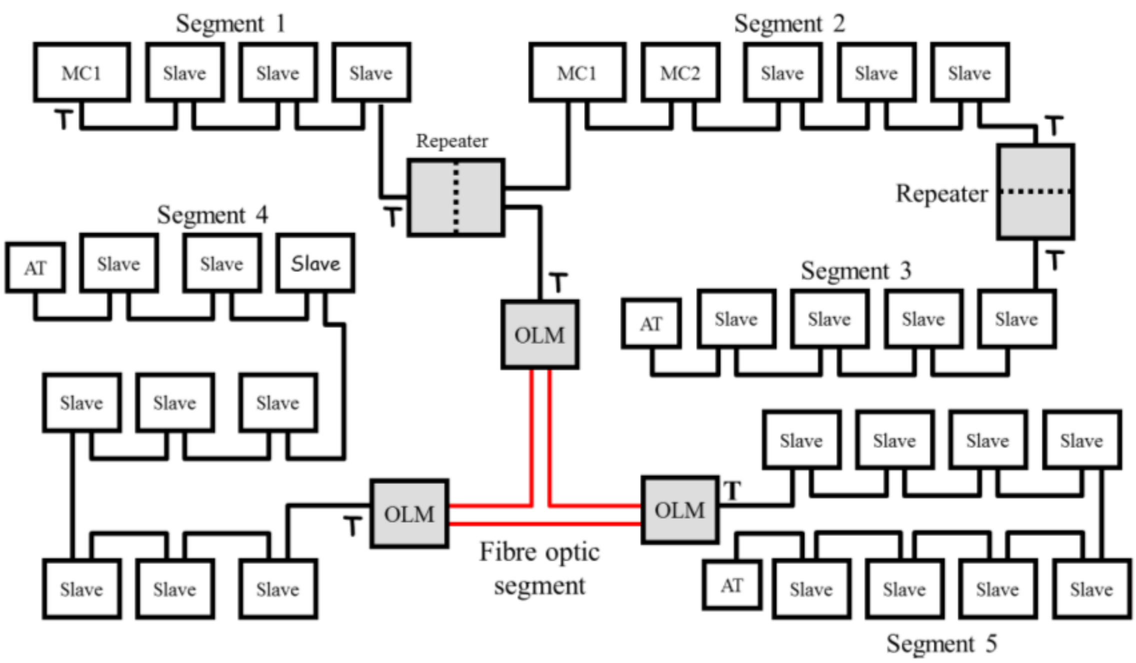
10.2. Network layout with repeaters and OLMs

A single segment must be laid out as a linear bus. However, when using repeaters and/or fibre-optic links to segment a network, much more freedom can be exercised. Every repeater or fibre-optic link introduces another segment, which can itself be a branch of the overall network. BUT, every segment should be laid out as a linear bus and must be terminated at each end and nowhere else.

Ideally, slaves should be kept away from segment ends so that they can be replaced without disrupting the network. Class-2 masters that can be removed or switched off when not in use, should also be kept away from the segment ends Class-1 masters, repeaters, OLMs etc should, if possible, located at the segments. Alternatively separate active terminators should be placed at the segment ends.



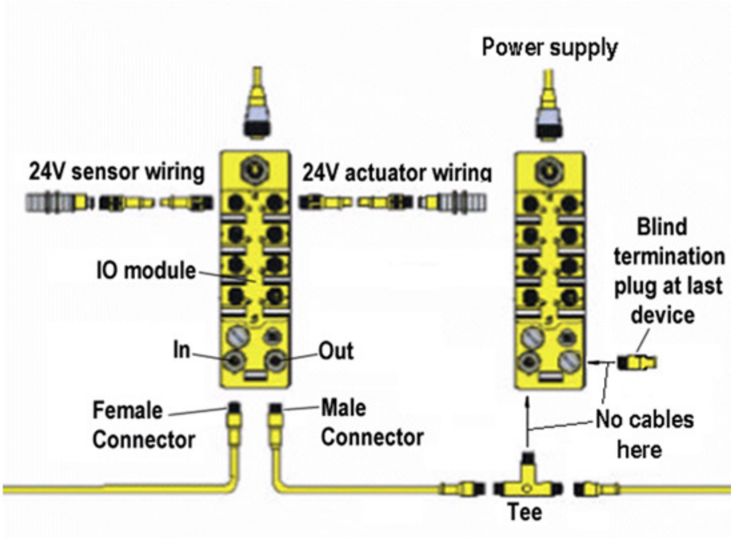
Use of Repeaters and OLMs to produce a complex network structure



Ideal layout for the network keeping class-2 masters and slaves away from segment ends

10.3. M12 connector systems

Devices that are fitted with M12 connectors often have two sockets for incoming and outgoing PROFIBUS cables, however these make it difficult to disconnect a device from a working bus. Tee connectors can be used to connect to devices via a single connection. However, we should not use a spur line to connect to the slave; just plug the tee directly into the slave socket.

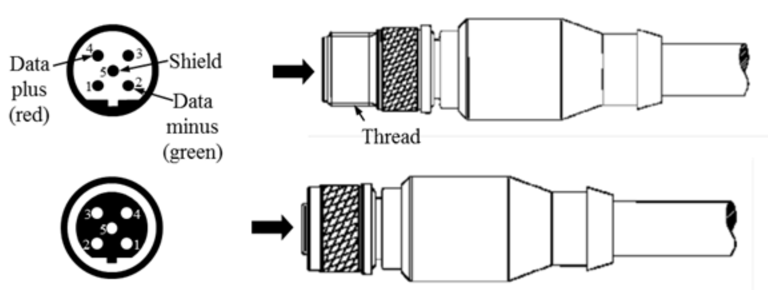


M12 Connector systems

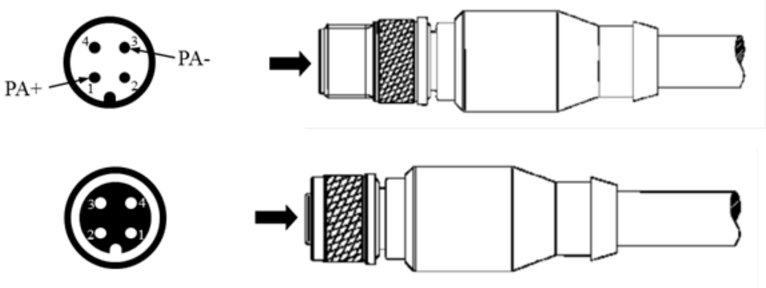
Termination is normally provided by a blind termination plug connected to the last device. Power for the termination is normally provided by the device to which it is connected (either directly or through a Tee). The termination must must never be connected via a cable since the two-core cable cannot carry the +5V termination supply to the terminator plug, and so would result in an unpowered termination which would cause reflections.

M12 connectors are often more difficult to make up on-site than 9-pin sub-D connectors and so are often supplied pre-wired with cables. M12 connectors are available with screw connection or insulation displacement connection options for cable connection. When using M12 connectors, it is most important that the shield is connected properly. You should always refer to the manufacturer's instructions. Also be sure to check the security of the cable seal as it enters the plug. Water ingress through a poorly fitted seal can cause corrosion of the terminals and further, the water can travel along the cable by capillary action to other connectors.

M12 5-pin "B-coded" connectors are used for PROFIBUS DP (RS485) wiring. B-coded connectors have a raised key on the female connector (socket) and a mating slot on the male connector (plug). The incoming cable to a device (i.e. from the master) should have a female connector that pugs into a male socket on the device. The outgoing socket on a device should be female and the cable should be connected with a male plug. PROFIBUS PA (MBP) wiring can use 4-pin A-coded connectors. A-coded connectors have a raised key on the male connector (plug) and a mating slot on the female connector (socket).



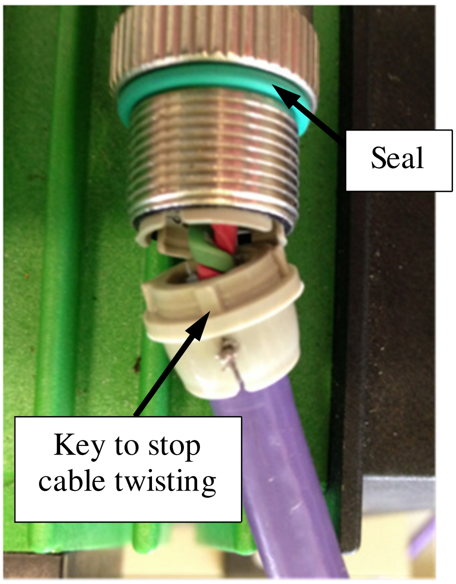
M12 B-coded male and female connectors for PROFIBUS DP



M12 A-coded male and female connectors for PROFIBUS PA

M12 connectors are available for stranded and solid core cables from many different manufacturers. Insulation displacement (fast connect) are best for solid core and screw connectors are best for stranded.

Generally M12 connectors can be more difficult to make up than 9-pin sub-D. Always follow the manufacturer's instructions carefully. Problems commonly occur because of a poor connection between the connector body and the cable screen. Problems are also common in wet or exposed environments when the connector is not watertight. Always make sure that the connector cover is tightened properly against the seal. However, do be careful not to twist the cable cores as the connector cover is tightened. Make sure that the key is engaged on the cable gland Ready-made cables are a good solution.



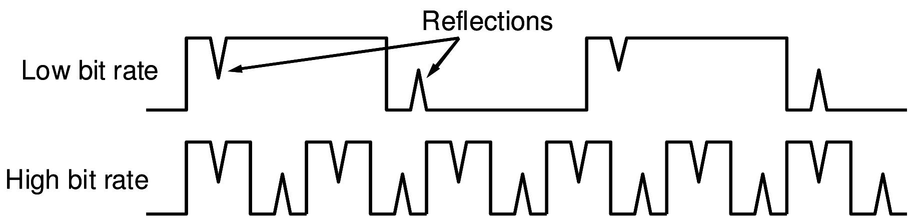
Twisted cores as connector is tightened

Poor screen connection

10.4. When are spur lines allowed?

Spur-lines (also called "stub lines" or "drop-lines") are branches from the main segment cable. Stub-lines can cause reflections to occur because of the additional capacitance introduced by the spur line cable. At low bit rates these reflections have only a small effect, but at higher bit rates spur lines can cause problems.

Spur lines are not allowed when using higher bit rates (>1.5Mbit/s). At bit rates of 1.5Mbit/s and less, spur lines are allowed up to the maximum capacitance shown in table 4. ***Note that additional termination at the end of a stub-line should <u>not</u> be used.*** That is, we should never have more than two terminations per segment.



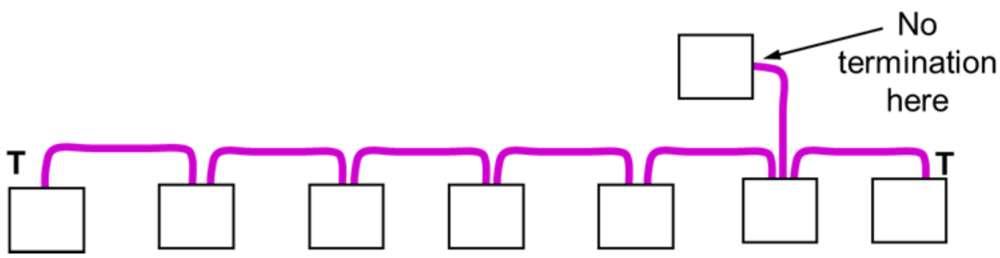
Spur line reflections have a worse effect at higher bit rates

Table 4 – Maximum allowable spur line lengths

Bit rate	Total allowable stub capacitance	Total spur cable length*
>1.5Mbit/s	None	None
1.5Mbit/s	0.2 nF	6.7m
500kbit/s	0.6 nF	20m
187.5kbit/s	1.0 nF	33m
93.75kbit/s	3.0 nF	100m
19.2kbit/s	15 nF	500m

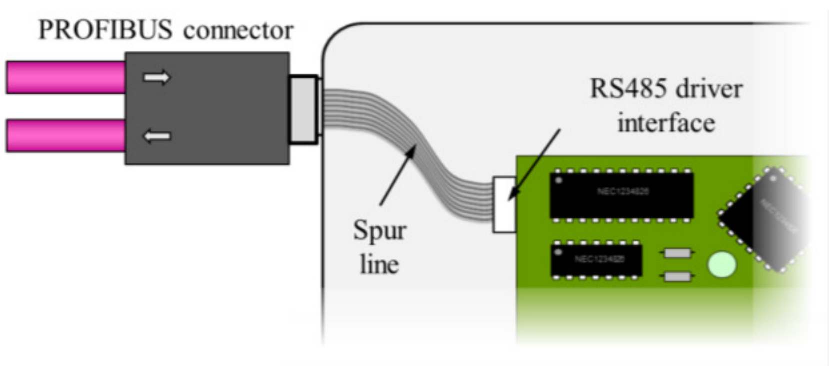
* Calculated for PROFIBUS cable type A at 30pF/m

Note that ***the total stub-line length shown represents the total length of all spurs attached to a segment***. Always try to avoid spurs on DP segments where possible. Use a repeater to create a branch segment if necessary. If spur lines are used, the end of the spur should never be terminated. That is a segment must never have more than two terminations, even if using spurs.



Never exceed two terminations on a segment even if using spurs

Every PROFIBUS device already has short spur line within the casing carrying the bus signals between the connector and the RS485 driver chip. Devices are tested for reflections as part of the certification process; however, ***uncertified devices can cause reflections***. Certified devices will have a connection capacitance of less than 30pF.

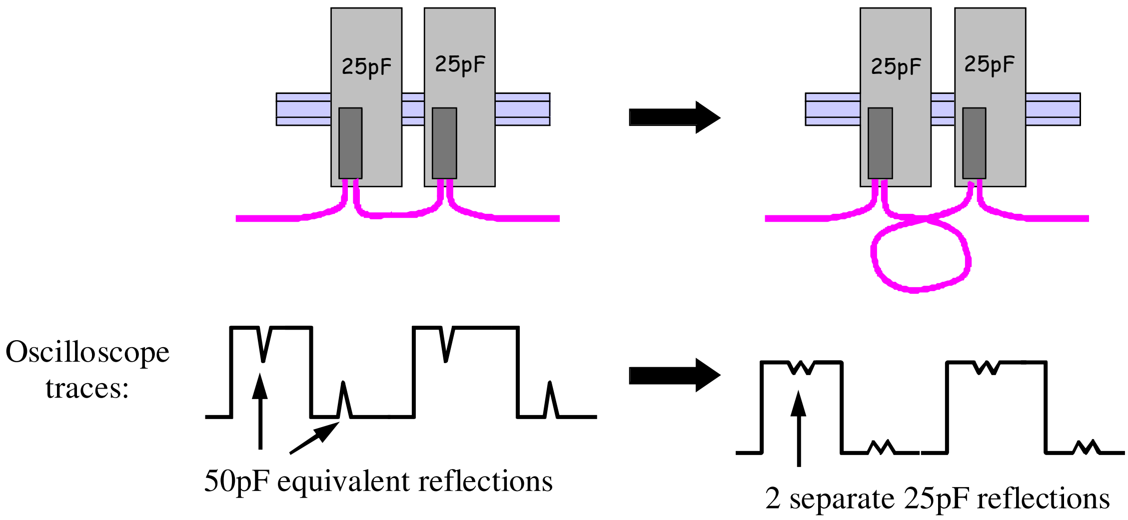


Uncertified devices can incorporate an internal spur line connecting the PROFIBUS interface to the outside world

10.5. *Special requirements for bit rates >1.5 Mbit/s*

- Use of bit-rate greater than 1.5 Mbit/s requires special connectors with built in inductors.
- Spur lines are not allowed when using bit rates greater than 1.5 Mbit/s.
- The maximum segment length is 100m.
- A minimum cable length of 1m is recommended between any two stations.

This minimum cable length requirement is because stations that are closely connected can together cause reflections even though they individually meet the PROFIBUS certification requirements. Separating stations with 1m of cable introduces a small delay between the devices, so the reflections do not add together.



Effect of adding 1m of cable between closely spaced devices

11. Layout of PA segments

Manchester Bus Powered (MBP) transmission, which is defined in IEC61158-2, is used for PROFIBUS PA. This is identical to the transmission system used for Foundation Fieldbus (FF), however, PROFIBUS and FF devices cannot share the same cable.

Spur lines are common in MBP segments where field-mounted junction boxes are often used to route cable branches to individual devices. There are, however, limitations on the length/number of spurs. A total of up to 1900m of cable can be used in a MBP segment, however the characteristics of the cable (see section 6.2) and/or requirements for intrinsic safety (see section 5.4) can reduce this significantly.

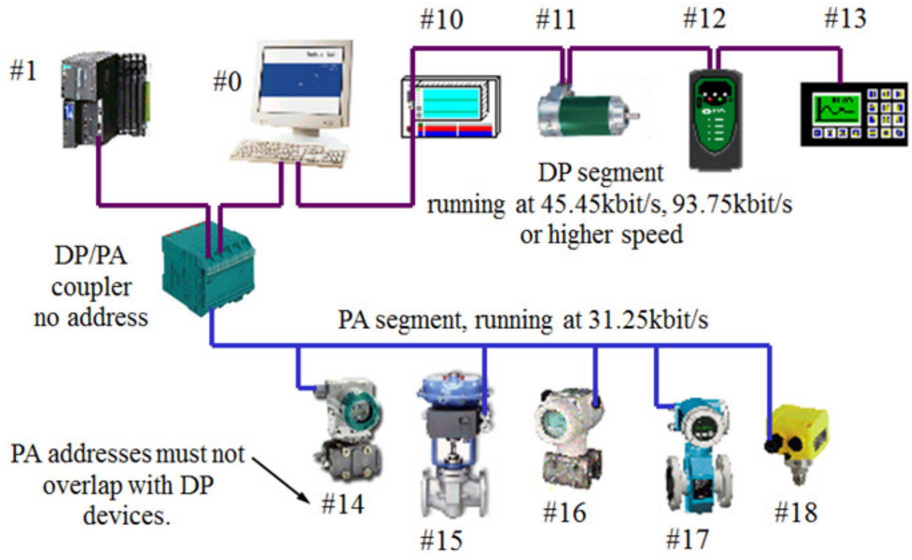
Up to 32 devices can be connected to a PA segment; however the particular characteristics of the segment power supply and/or requirements for intrinsic safety can again reduce this significantly.

11.1. *Coupler and link technology*

PA slaves are controlled by DP masters and so we must use a DP/PA coupler to connect PA segments to DP segments. The coupler converts between RS485 and MBP signals, in addition it provides power for the PA segment. Intrinsically safe couplers also incorporate a protection barrier (Zenner barrier) to limit the current and voltage supplied to intrinsically safe segments. Up to 32 devices can be connected to a PA segment. However power supply limitations or intrinsically safe requirements may reduce this number significantly.

Simple DP/PA couplers

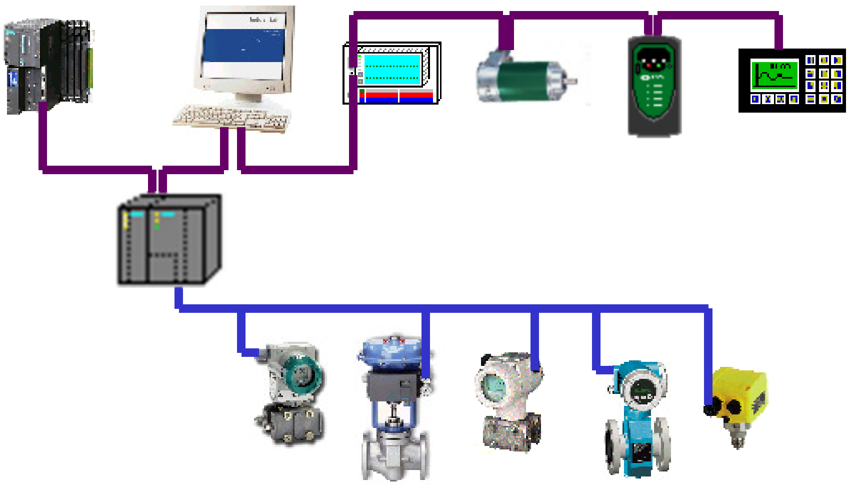
A simple coupler, when used on its own, does not have an address, the telegrams are simply translated and passed through from segment to segment. Simple couplers are therefore transparent. When using a simple coupler, each PA slave is allocated an address which is unique on the network. I.e. PA addresses must not overlap DP addresses. Some simple couplers require the DP segment to run at low speed (45.45 for Siemens or 93.75 kbit/s for other manufacturers), but high speed simple couplers are also available.



Use of a simple DP/PA coupler

Siemens DP/PA link module

A Siemens DP/PA link module acts like a slave on the DP side and a master on the PA side. Thus a link module must have a slave address through which the DP master can access the PA segment. The PA devices are therefore strictly a new network. So the addressing of the PA devices can overlap the addresses on the rest of the network. A link module allows the DP segment to run at high speed (up to 12 Mbit/s), independently of the PA bit rate. Typically a link module will incorporate several plug-in couplers to drive PA segments. Link modules have the advantage that more than 126 devices can be used on a network (since addresses can overlap). However, a link module is not transparent and the PA devices cannot be seen from the DP segment.



Use of a Siemens Link Module with Coupler

Higher speed transparent couplers

Many manufacturers such as Pepperl+Fuchs, ABB and Procentec offer a high speed transparent coupler that behaves in a similar way to the Siemens link module. Like a link module, these couplers allow the DP segment to run at higher speed. However, the coupler does not take a DP address and appears transparent on the network. Like a simple coupler, the PA addresses must not overlap the DP addresses.

11.2. MBP spur lines

The length of the individual spur lines on a PA segment depends upon the total number of spurs used. Table 5 shows the recommended length of individual MBP spur lines. Notice that intrinsically safe installation requirements provide an additional restriction on spur line length. Devices can be installed and removed with power applied to the cable, however care must be exercised to ensure that the leads do not short which would mean loss of power to the other devices on the segment. Fused spurs or segment protectors can be useful to avoid such problems.

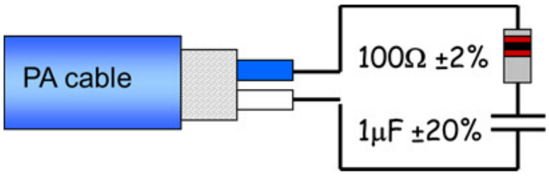
Table 5 – Recommended IEC61158-2 spur line lengths

Number of spur lines	Maximum spur length non-intrinsically safe installation	Maximum spur length intrinsically safe installation
25 to 32	1 m	1 m
19 to 24	30 m	30 m
15 to 18	60 m	60 m
13 to 14	90 m	60 m
1 to 12	120 m	60 m

Note that the maximum cable length of 1900m includes cable used for spurs.

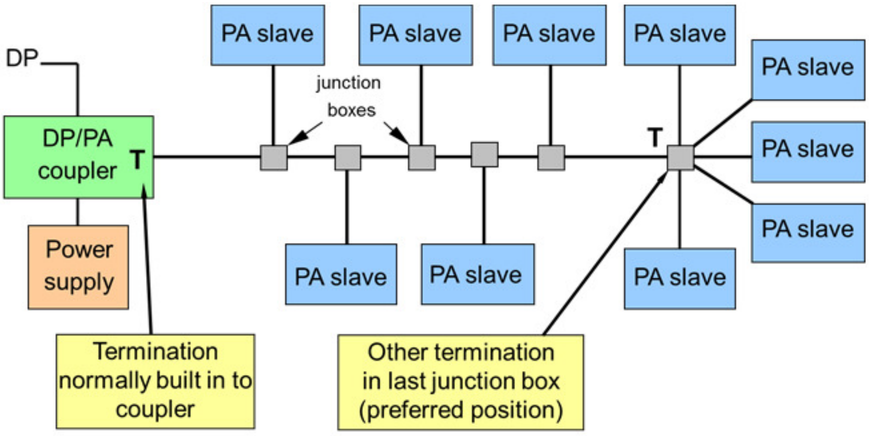
11.3. MBP termination

Terminations should be used on PA segments for the same reasons as described for DP segments, that is to stop reflections from the end of the main trunk line. However the termination network for MBP segments is very different to that for RS485 wiring. An MBP termination consists of a capacitor and resistor in series connected between the two wires. The resistor matches the characteristic impedance of PA cable and the capacitor is included to block DC, otherwise significant current would flow through the resistor from the power supply. Note that MBP terminators are not powered.



MBP Termination

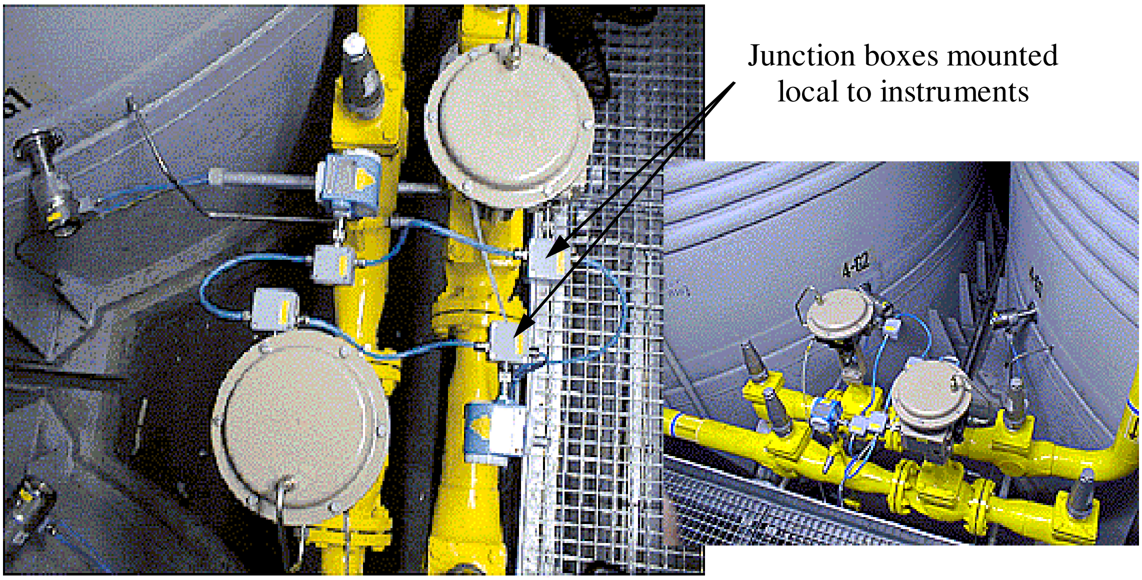
The rule for positioning the terminators on MBP segments is the same as for RS485, i.e. terminators are mounted at the two ends of the main cable run only (i.e. not at the ends of spur lines). Most segment couplers incorporate a built-in terminator, which should be at one end of the line. The other terminator is normally mounted on the last or furthest device, or sometimes in the last junction box.



PA segments can use spurs and tree structures

Junction box systems are available from many manufacturers with a single spur, or with multiple spurs and with and without terminations. These junction boxes can incorporate sophisticated electronic solutions for short circuit protection, operation in hazardous environments and even redundancy.

Junction box systems for MBP wiring are available from many manufacturers



Typical PA Installation using junction boxes

11.4. Intrinsic safety considerations

When electrical equipment operates in a potentially explosive atmosphere (a hazardous environment) by law, special precautions must be taken to ensure that it will not cause an explosion. Several protection methods are available, however “intrinsically safe protection”, EEx i, has many advantages for instrumentation. Intrinsically safe protection is based upon limiting the current and voltage available to the field-mounted device. Capacitance and inductance are also controlled to limit the energy available for a spark.

The design and implementation of intrinsically safe systems is outside the scope of this document and the reader is referred to the appropriate Technical Guideline for intrinsically safe MBP or RS485 segments. However the installer should understand that special limitations apply. We must use special certified DP/PA couplers that limit the current and voltage supplied to the field devices. All devices that are connected to the IS segment must be individually certified (even when mounted in the safe area). The total cable length and spur lengths must be limited.

Warning

We must be very careful when working in potentially explosive environments. Non-intrinsically safe equipment must never be connected to any Intrinsically Safe segment, even if the connection is made in the safe area.

Only certified Intrinsically Safe test equipment can be connected to an Intrinsically Safe cable.

12. Cables for PROFIBUS

12.1. *Cables for PROFIBUS RS485 (DP)*

The standard IEC61158 specifies a "type A" cable for use with PROFIBUS RS485 as shown in table 6.

Table 6 – Cable specification for PROFIBUS RS485 type A cable

Construction	Shielded, twisted pair
Conductor area	> 0.34 mm^2
Impedance	150Ω ±10% at a frequency of 3 to 20 MHz
Capacitance	< 30 pF / m
Resistance	≤ 110 Ω/ km

The term "Type-A" is rather confusing because it really means "Quality-A" or "Grade-A", i.e. "best quality". Several different forms of RS485 Type A cable are available:

- Standard PROFIBUS solid-core cable.
- Stranded-core cables for flexibility.
- Cables with special sheaths for use in the food and chemical industries.
- Armoured cables for protection against rodent and other damage.
- Zero Halogen (Low Smoke) cables for use in confined spaces.

12.2. *Cables for PROFIBUS MBP (PA)*

IEC 61158-2 specifies four different types of cable for use in MBP segments (table 7). PA type A cable (not the same as RS485 Type A cable) is a two-core shielded twisted pair cable which gives the best performance in terms of signal attenuation and hence cable length. Notice that the thicker, Type D, cable has a lower resistance but its characteriscic impedance and high frequency loss restrict the cable length.

Table 7 – Cable specification for PROFIBUS PA cables

	Pairs	Shield	Conductor area	Max DC loop resistance	Max total cable length
Type A	Single	Yes (90%)	0.8 mm^2	44 Ω/km	1900 m
Type B	Multi	Overall shield	0.32 mm^2	112 Ω/km	1200 m
Type C	Multi	None	0.13 mm^2	264 Ω/km	400 m
Type D	Multi	None	1.25 mm^2	40 Ω/km	200 m

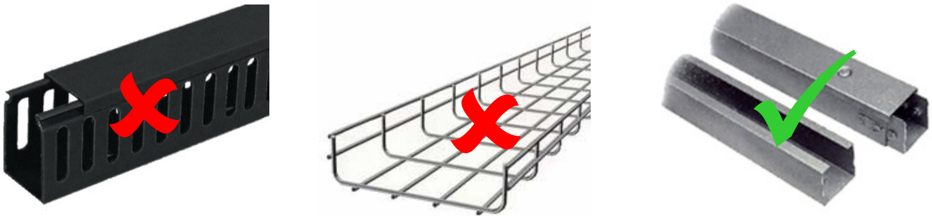
When using MBP type A cable, the total segment length can be up to 1.9km including all branches or spur lines. However, voltage drop and intrinsically safe requirements will give significantly reduced segment length.

The recommendation is to use type A cable for new installations. However, the ability to use other types of cable is useful when fieldbus devices are being fitted to an existing plant which already has cable installed.

13. Installing PROFIBUS cables

13.1. General guidelines

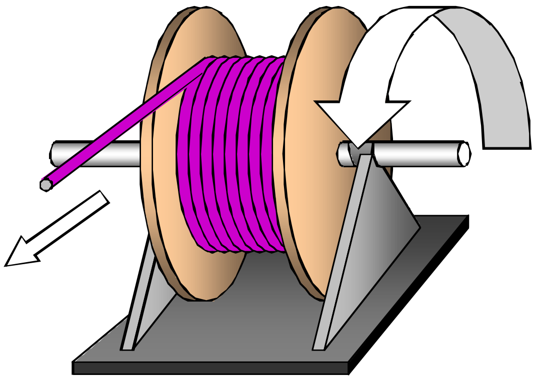
Bus cables should ideally be installed in their own steel cable channels or conduits. Plastic trunking provides no screening whatsoever: it is just a cable tidy. Basket type cable trays also do not provide screening.



Solid steel channelling with a lid or steel conduit
provides electrostatic and electromagnetic screening

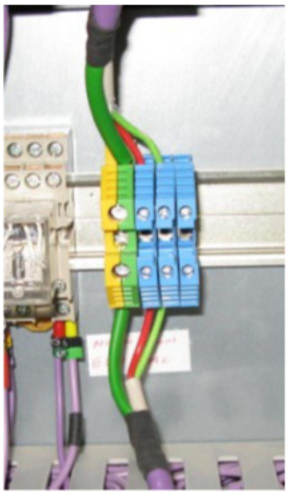
If not installed in conduit bus cables should be brightly coloured and installed where they are clearly visible and separate from all other cables in order to improve any interference pick-up and to avoid accidental damage.

When installing bus cables, it is important not to distort or damage them since this can change the characteristic impedance and so cause reflections to occur. ***In particular, do not squash cables by allowing people to walk on them or vehicles to drive over them. Do not twist or stretch bus cables, do not squash or crimp them and adhere to the recommended minimum bend radius*** (typically for solid core: 75mm minimum. For stranded cables: 45mm for a single bend and 65mm for repeated bending). Be careful not to untwist the twisted-pair construction. Always unwind cables from the drum by rolling the drum or allowing it to rotate on a pole.



13.2. Joining cables

Sometimes we need to join cables, for example when cables are damaged, or provide a means to disconnect cables, for example when wiring cabinets off-site. The temptation is just to use standard rail-mounted screw connectors. However such connectors can have significant inter-terminal capacitance which can cause reflections on RS485 segments.

Do not use screw terminals to join DP cables

Screw terminals are OK for PA (MBP) cables because of the low speed. However M12 connectors are best if you need to join or disconnect DP (RS485) cables. As an alternative, a spare sub-D connector can be used to join a cut cable by using the IN/OUT cable entries. The connector does not need to be plugged in to a device, but should be protected from shorted pins or water ingress.

13.3. Cable segregation

To reduce the chances of interference pick-up, it is important that bus cables are run separately from other types of cable. It is useful to categorise various cable applications as follows:

Category I:

- Fieldbus and LAN cables (e.g. PROFIBUS, ASi, Ethernet etc.).
- Shielded cables for digital data (e.g. printer, RS232 etc.).
- Shielded cables for low voltage (≤25V) analogue and digital signals.
- Low voltage power supply cables (≤60V).
- Coaxial signal cables

Category II:

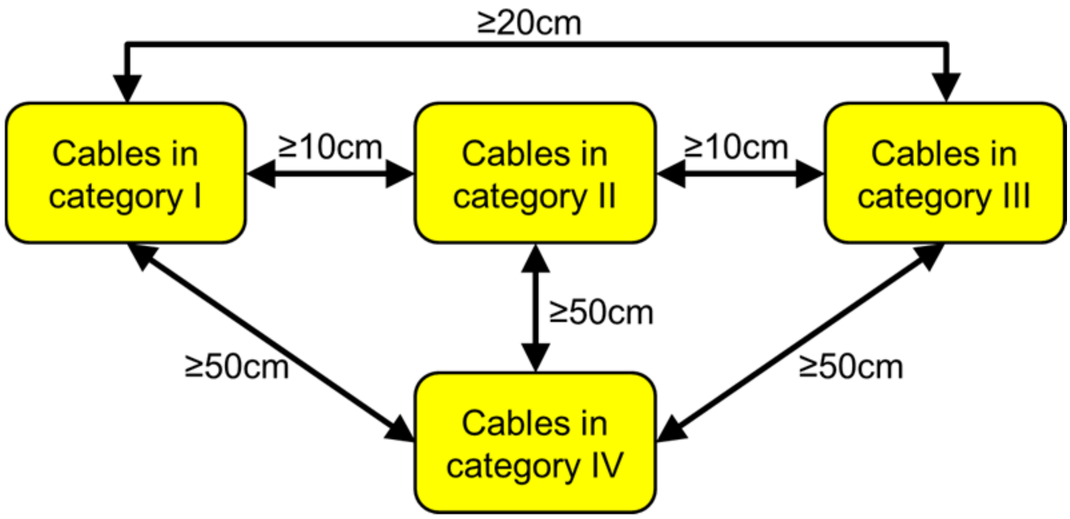
- Cables carrying DC voltages >60V and ≤400 V
- Cables carrying AC voltages >25V and ≤400 V

Category III:

- Cables carrying DC or AC voltages >400 V
- Cables with heavy currents.
- Motor/drive/inverter cables.
- Telephone cables (can have transients >2000V).

Category IV:

- Cables of categories I to III at risk from direct lightning strikes (e.g. connections between components in different buildings)

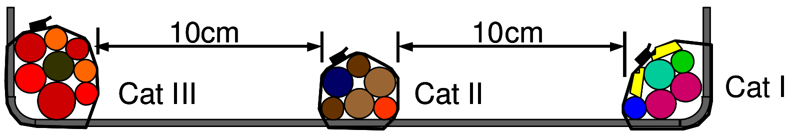


Separation distances for cables of different category

Sometimes it is impossible to adhere to the separation distances. Where cables have to cross, they should cross at right angles and should never run in parallel even for short distances.

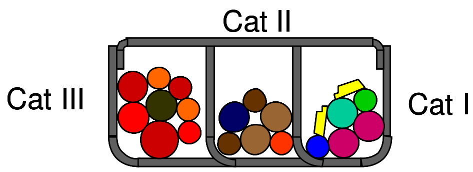
13.4. Use of cable trays and channels

Cables from the same category can be bundled together or laid directly beside each other in the same cable trays. Cables of different category must be separated by at least the distances shown.



Cables mounted on a cable tray, rack or ladder
must be separated by the recommended clearances

When separated by earthed steel partitions with a steel lid, the bundles can be placed next to each other. All channels and partitions must be properly earthed using flexible bonding links protected against corrosion. Note that braided straps are better than solid metal for high-frequency EMC protection.



Cable groups separated in steel compartments can be placed next to each other

14. Earthing considerations

14.1. Protective and Functional Earths

Earthing or bonding of equipment is essential for safety reasons. Such earthing systems are often called the Safety Earth or Protective Earth (PE). Protective earthing is designed to protect people from electric shocks due to wiring faults which would otherwise cause equipment or structures to become “live”. The protective earth will divert the dangerous current to ground and cause a fuse to blow or contact breaker to trip in the case of a fault.

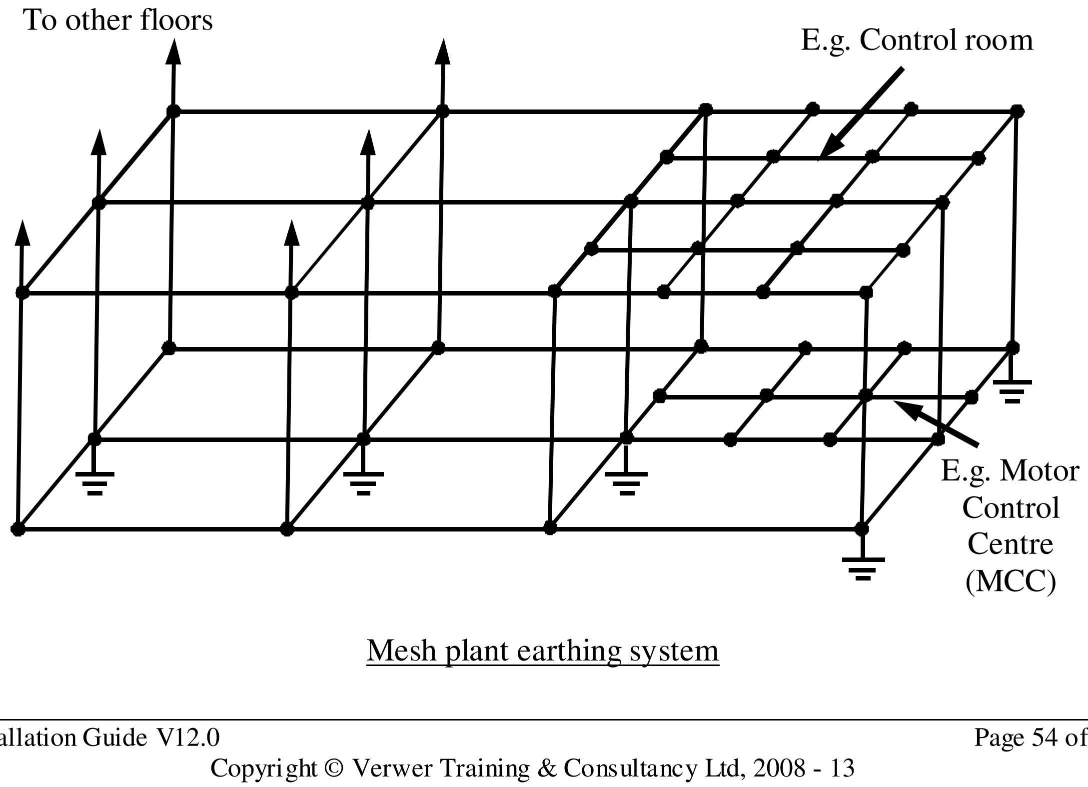
However, we also sometimes see a separate Functional Earth (FE) on equipment. The Functional Earth is provided as a clean reference voltage for unbalanced analogue or digital signals. The FE wiring should generally be separate from the PE but should be connected at just one point, which is used as the zero-volt reference.

Modern systems such as PROFIBUS DP and PA use balanced transmission, which does not require a reference earth. But we quite often see a FE connection on PROFIBUS equipment. This is used to provide a zero volt reference for unbalanced input and output signals, for example with 24V digital signals or 0 to 5V or 4-20 mA analogue signals. The FE should be considered as a zero-volt reference for these signals and should be connected to the PE at one point only.

A third reason for earthing is to provide a grounding of the cable screen to guard against electrostatic pickup. For balanced transmission systems like PROFIBUS the screen should be connected to the earthing system at both ends and further, the screen and earth wiring should produce a low-impedance loop (see section 6.2).

14.2. Plant Earthing Systems

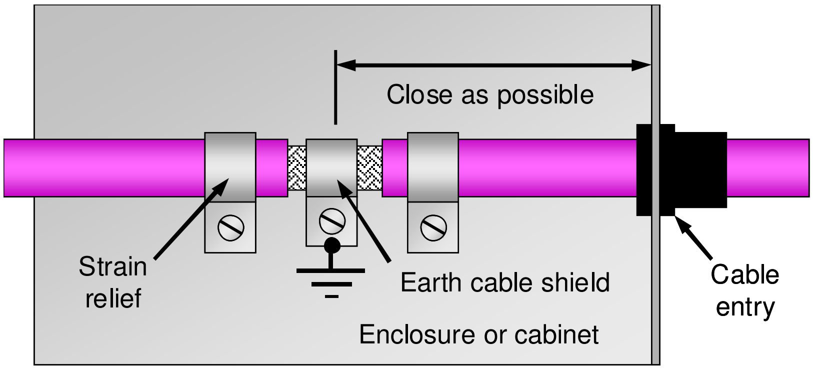
The plant earthing system should be laid out to carry the earth currents that naturally flow between the parts of the plant. A mesh earthing system is best where multiple paths exist for the earth currents.



Mesh plant earthing system

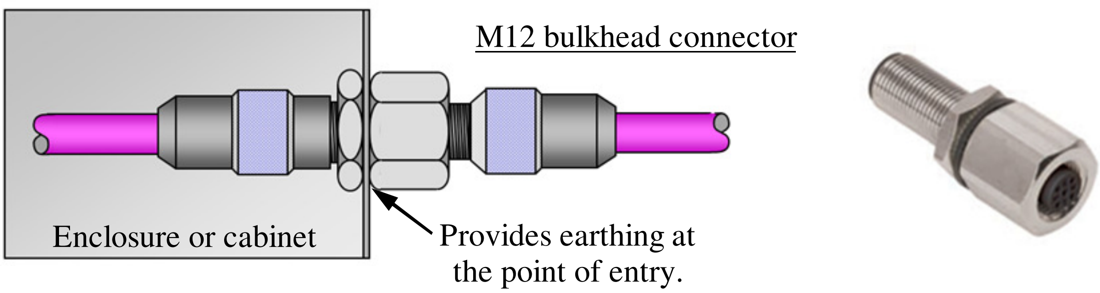
14.3. Cabling within wiring cabinets

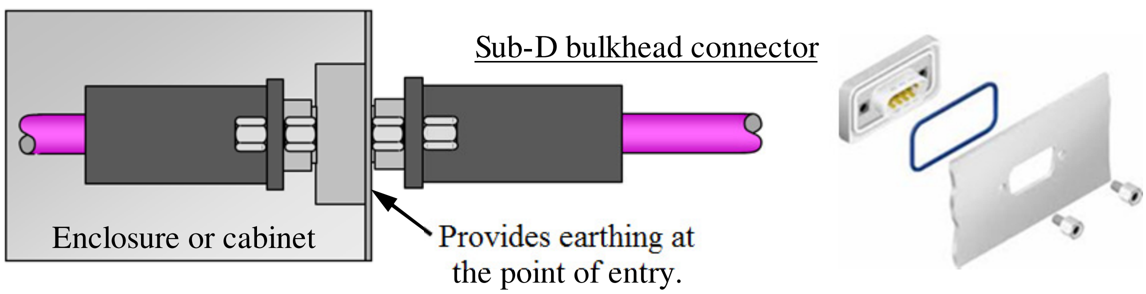
For safety reasons all metal electrical cabinets must be connected to the plant earthing system. In addition the braided shields of all PROFIBUS cables entering the every cabinet should be earthed with metal clamps as close as possible to the point of entry to the cabinet. This is because the cable screen can carry pick-up into a cabinet where it can disrupt sensitive electronic equipment. Earthing the screen close to the point of entry minimises this problem.



Earthing the cable screen close to the pint of cabinet entry

A more robust solution is to use a bulkhead adaptor or connector. These provide earthing of the cable screen at the point of entry to the cabinet. They also have the additional advantage that they also allow the cabinet internal wiring to be completed by the panel builder and tested off-site.





M12 or Sub-D bulkhead connectors provide screen earthing at the point of entry

Try to avoid parallel routing of PROFIBUS cables and internal cabinet wiring, even with cables of the same category. Try to maintain separation distances, but where cables of different categories must cross, they should do so right angles. If the separation distances cannot be maintained, use earthed metallic channels with bonded partitions to separate cables.

Remember to observe the minimum cable length requirement of 1m between devices for networks running at over 1.5 Mbit/s. The excess cable can be easily looped out of the way, but do remember the minimum bend radius requirement for the cable being used. Even when using rates of 1.5 Mbit/s or less, it is good practice to observe this 1m cable length between devices. You may wish to upgrade the bus speed at some later date.

14.4. Potential equalisation

In order for the screen to be effective at high frequencies, ***the screen must be earthed at both ends of the cable***. Sometimes, however the local earth at different parts of the plant can be at significantly different potential, which can lead to current passing along the cable screen. ***Such screen current is to be avoided since it can lead to interference pick-up.***

Earth potential problems are common where:

- The network cable covers a large area or extends over a long distance.
- Power is supplied to different sites from different sources (i.e. sub stations).
- Heavy electrical currents are present (e.g. arc furnaces, power stations etc).

One solution is to install a ***potential equalisation cable*** between the different earth potentials. The potential equalisation cable can carry significant current and should be sized accordingly (16 mm^2 is not uncommon). Finely stranded cable, with a large surface area, should be used to ensure that effectiveness at high frequencies. Potential equalisation cable should be laid parallel to and as close as possible to the network cable to minimise the area enclosed between the two. The potential equalisation cable actually becomes part of the plant mesh earthing system.

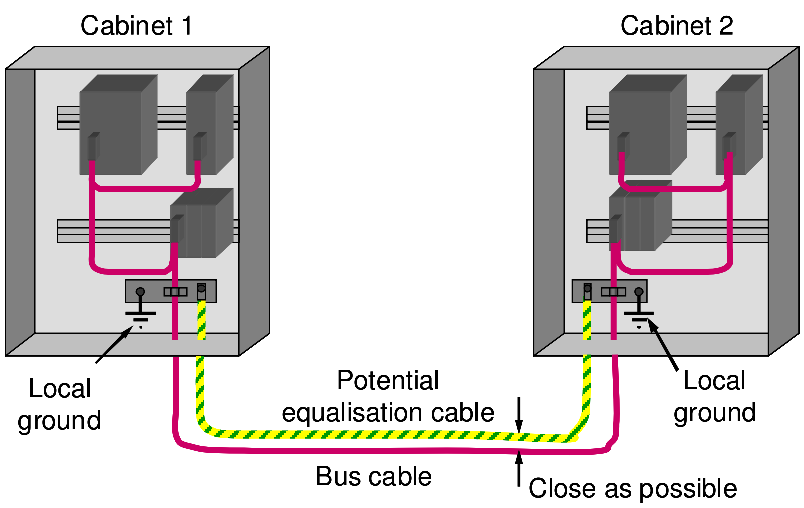
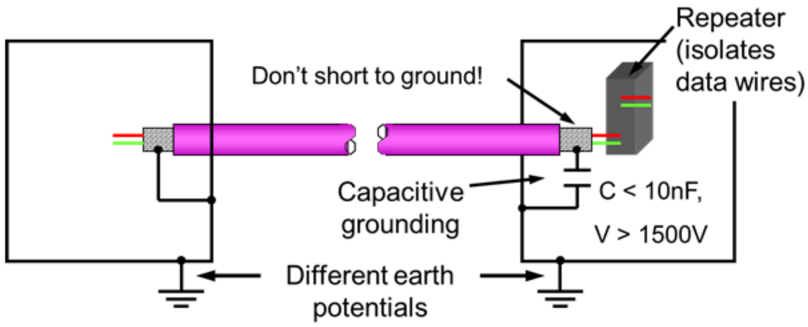


Figure 20 – Installation of a potential equalisation line

NOTE: The network cable screen must never be used for potential equalisation.

An alternative to running heavy potential equalisation cables is to use capacitive shield grounding at one end of the cable. This technique provides a good path to ground for high frequency signals that can cause pick-up, yet will not allow DC current to pass along the PROFIBUS cable shield. A repeater should be used in such cases to also isolate the data lines (A and B):



Capacitive grounding

Remember that optical-fibre segments provide total isolation from one end to the other. They also are totally immune to any electrical interference and can be used over long distances.

14.5. Measuring Screen Current and Earth Loop Impedance

PROFIBUS cable screen current can be measured using a clip-on Ammeter. Because PROFIBUS cables use balanced transmission, the signal currents cancel out and the measurement shows just the screen current. The screen current should generally be between 5 and 50mA.

Earth-Loop impedance can also be measured with special clip-on devices that induce voltage in the screen and measure the resulting current. Earth loop impedance should be typically be less than 1Ω.

Clip-on Ammeter for measuring network screen currents

Earth-loop impedance measurement (Indu Sol)

15. Fibre-optic components

An optical fibre cable transfers data signals using light which travels along a glass or plastic fibre. Several types of fibre-optic transmission media are available:

- Plastic fibre which is low cost, simple to make up, but is generally limited to distances of less than 50m.

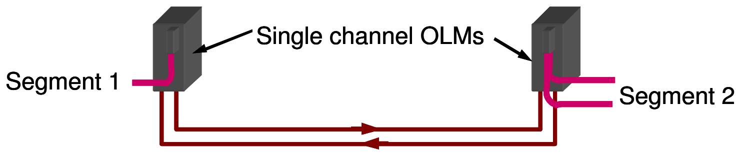
- Multi-mode glass fibre which can be used over distances of up to 2km.
- Single-mode glass fibre which can be used over distances of up to 50km.

Glass-fibre cable requires special techniques and tools for making up and testing. Plastic fibre transmission is less expensive and can easily be made up on-site.

15.1. Optical link modules

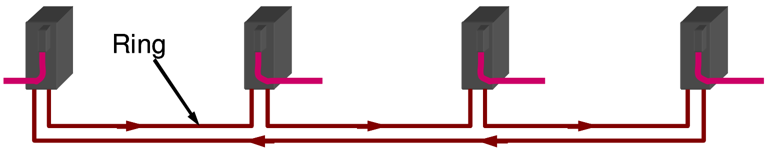
Fibre-optic PROFIBUS transmission requires the use of RS485 to fibre-optic conversion called Optical Link Modules (OLMs). OLMs are available from various manufacturers. Each optical channel on an OLM requires two optical connections: one for transmission and one for reception. Some OLMs have duplicate optical channels (i.e. 2 in plus 2 out) allowing two optical segments or redundant fibre-optic paths to be implemented. Like repeaters, OLMs also have the effect of splitting the network into isolated segments.

When using OLMs to connect two segments, two fibre-optic cables are required; one for the signal in each direction. Other, more complex topologies are possible using more OLMs.



OLMs connecting two segments

Optical segments are normally arranged as a ring using multiple single-channel OLMs:



OLMs can be used to give tree, star and even redundancy:

Redundant fibre-optic connection using two channel OLMs

16. Bibliography

Documents available from PROFIBUS International (www.profibus.com)

PROFIBUS Standard - DP Specification
Implementation Guideline IEC 61158/61784, Type 3, PROFIBUS
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Handbook PROFIBUS Installation Guideline
Installation Guideline for PROFIBUS DP/FMS
Installation Guideline PROFINET Part 2: Network Components
PROFIBUS Interconnection Technology
PROFIBUS PA User and Installation Guideline
PROFIBUS RS485-IS User and Installation Guideline
PROFIsafe - Environmental Requirements
PROFIBUS Installation Guideline for Planning, Order No.: 8.012
PROFIBUS Installation Guideline for Cabling and Assembly,Order No.: 8.042
PROFIBUS Installation Guideline for Commissioning Order No.: 8.022

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IEC61000-5-2: 1997: Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines, Section 2: Earthing and cabling.

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