PROFIBUS Installation Guidelines

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1. Introduction

This document provides information on the design, lay-out, installation and testing of PROFIBUS networks. The information contained originates from a number of sources (see bibliography).

> 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.

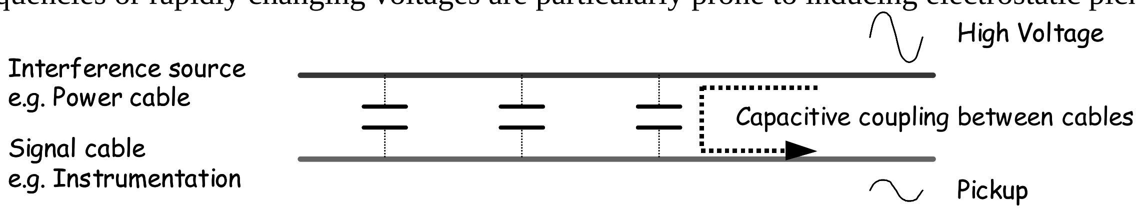
PROFIBUS is an extremely flexible and reliable communication technology, however, like all high-speed digital communications systems, problems can be caused by a number of simple errors. Poor wiring and layout can cause pickup or interference in cables giving corrupted telegrams. Incorrect termination and many other errors can cause reflections to occur in fieldbus cables, resulting in distorted and corrupted telegrams. In order to understand how to avoid some of these problems we must first understand how they occur.

1.1. Pickup in Fieldbus Cables

Pickup 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 pickup of interference from other electrical cables or equipment:

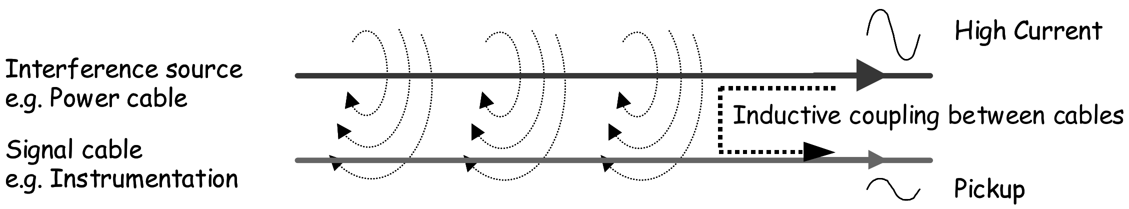
Electrostatic pickup

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 pickup will be. Cables carrying high voltages, high frequencies or rapidly changing voltages are particularly prone to inducing electrostatic pickup.



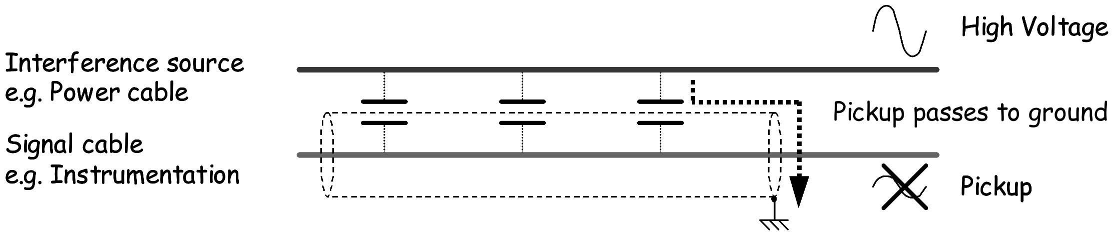
Electromagnetic pickup

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 pickup will be. Cables carrying high current or rapidly changing current are particularly prone to inducing electromagnetic pickup.

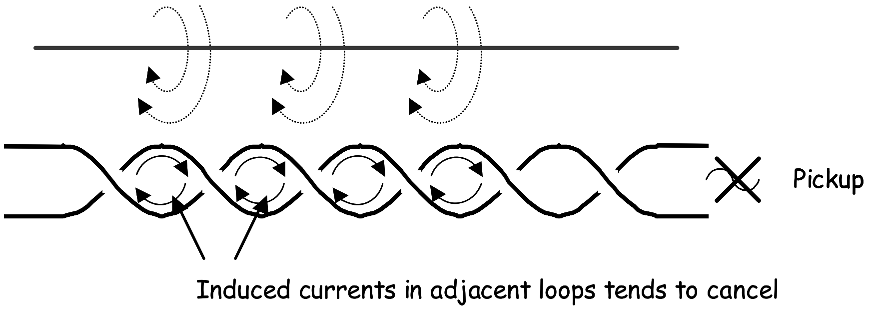


Pickup Reduction

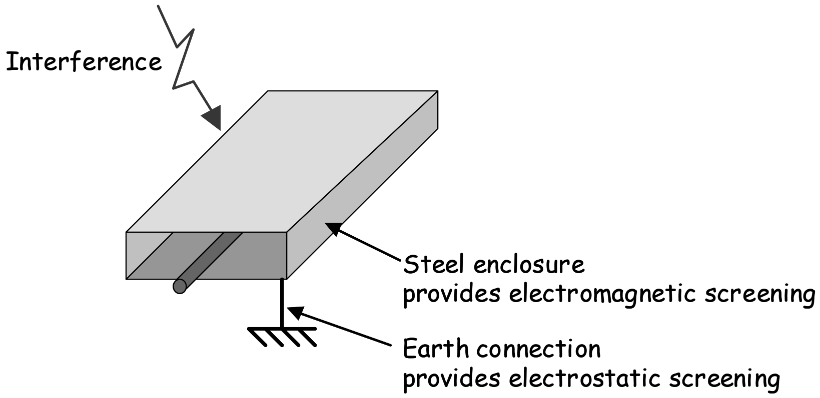
Shielding or screening the signal cable can reduce electrostatic pickup. However, shielding is only effective when the shield is properly connected to earth (ground). Unearthed screening has no effect whatsoever; in fact it can make the pickup worse!



Twisted pair cable significantly reduces electromagnetic pickup. 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.

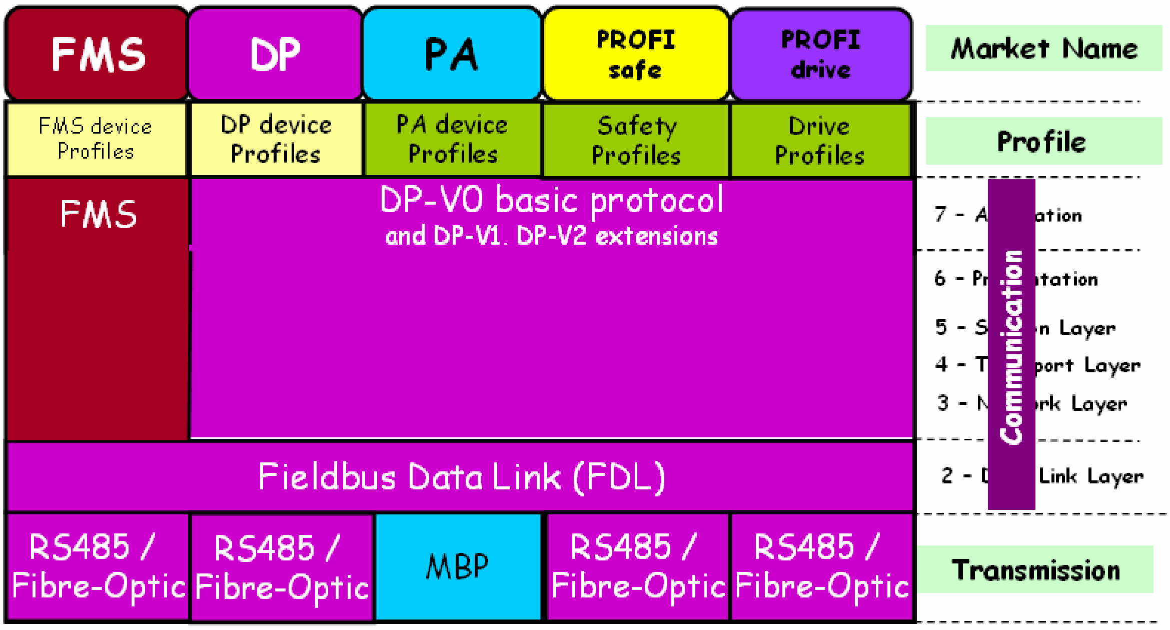


Installation of the fieldbus cable in earthed, magnetically impervious ducting (i.e. steel tray or conduit) can further reduce both electrostatic and electromagnetic pickup. This is because the steel provides magnetic shielding for the magnetic fields that induce electromagnetic pickup and the earthed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



1.2. *PROFIBUS Connection Technology*

PROFIBUS has an extremely wide range of application and therefore utilises several different transmission technologies. PROFIBUS DP and FMS both use RS 485 (also called H2) transmission. In addition fibre optic (FO) transmission can be used. PROFIBUS PA uses Manchester Bus Powered (MBP) transmission as specified in IEC 61158-2 (also called H1).



The PROFIBUS Open System Interconnection model

OSI defines a 7-layer model from Application Layer to Physical Layer. PROFIBUS does not use Layer 3 to 6. So, in PROFIBUS, the basic operation is defined by Layer 2 and the application layer, Layer 7. Layer 2 is called Fieldbus Data Link or FDL, which defines how devices access the bus and how the bits and bytes are presented, i.e. it defines the data format. At the application layer the data are interpreted. So, you have various PROFIBUS applications, i.e. DP-V0, DP-V1 and DP-V2. FDL plus the application specification forms the PROFIBUS protocol.

User Layer is not defined in the OSI model because the variety of applications. While in the Process automation, you can standardise analogue input and output values using device profiles, for example, 4 bytes of data to represent the process value and 1 byte of data to indicate the quality status.

Device profiles are a great way to map data onto communication protocols and hence standardise applications. PROFIsafe and PROFIdrive are other profiles within PROFIBUS. All variations of PROFIBUS (DP, PA, PROFIsafe and PROFdrive) can be on the same network and can talk to each other as they use the exactly same protocol.

PROFIBUS FMS has different application layer so it cannot communicate with other PROFIBUS devices. ROFIBUS FMS masters communicate with PROFIBUS FMS slaves. However, FMS shares RS-485 physical layer with DP and hence can co-exist on the same bus. FMS has become a legacy system and no longer supported by PROFIBUS International.

1.3. RS 485 Transmission

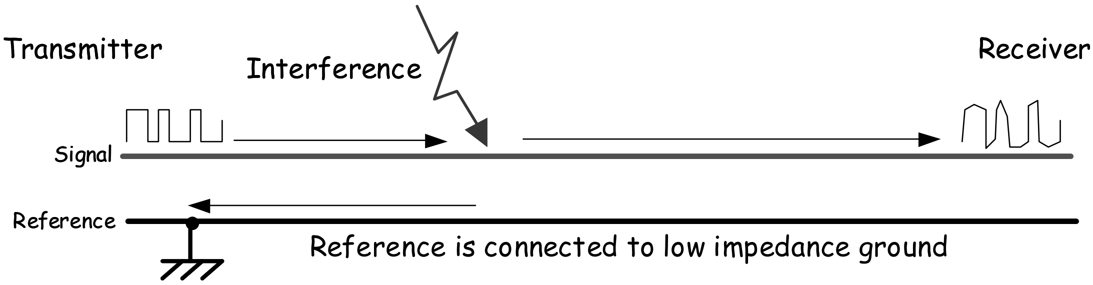
PROFIBUS RS485 uses shielded twisted pair cable allowing communication at up to 12Mbit/s. RS485 can be used to connect up to 32 devices in a single segment (piece of cable). The allowable segment cable length depends upon the bit rate being used. The allowable segment cable length varies from 100m maximum at high speed to 1000m maximum at low speed (see section 4.9).

Balanced Transmission and screening

RS 485 is a ***balanced*** two-wire transmission system, which means that it is the difference in voltage between the two wires that carries the information rather than the voltage relative to ground or earth. Balanced transmission is much less sensitive to pickup and interference than single-ended or unbalanced transmission. Let us see why:

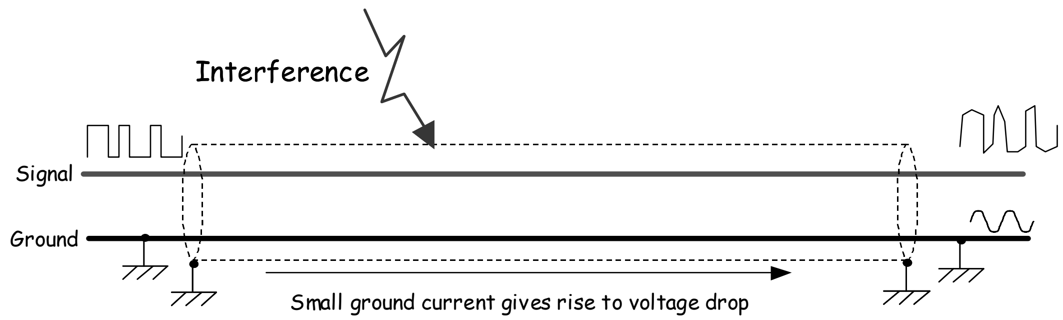
Unbalanced transmission

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



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.

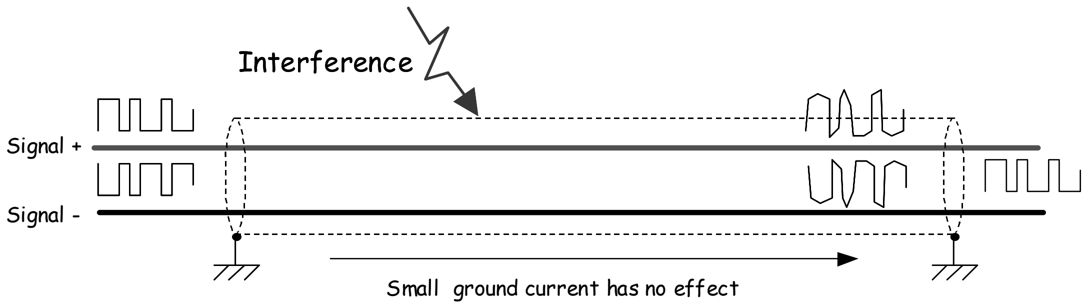
Earthed screening can reduce electrostatic pickup, but, unbalanced transmission can give rise to “Earth Loops” if the reference wire is earthed at both ends. Earth loops cause variations in the reference voltage at the transmitter and receiver:



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

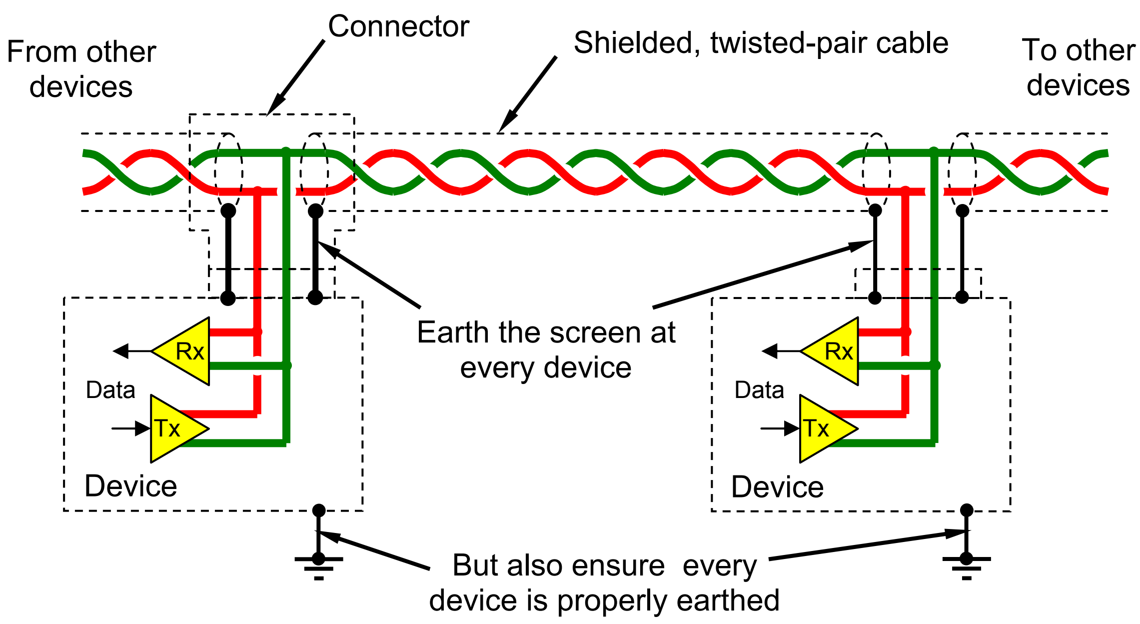
Balanced transmission is where both wires carry the signal, one positive and one negative. The information is carried by difference between the voltages on the two wires (differential). The term “balanced” means that the two wires have the identical electrical characteristics and connections and so any interference that is picked up on both wires (common mode signals) tends to cancel out. 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 pickup):



Balanced transmission is much less prone to pickup 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 transmission is balanced to improve noise rejection. Therefore we should earth the cable screen at both ends to ensure that it is effective at high frequencies. This is normally done by connecting the cable screen to the device earth via the connectors. But we must make sure that the device is correctly earthed. Poor shielding or earthing is a very common wiring error.



PROFIBUS RS 485 transmission

1.4. Segmentation

RS 485 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 32 RS485 devices to be connected together on a single segment (piece of cable). Note that all devices that have an RS 485 driver count towards this 32-device limit, not just PROFIBUS devices.

Does this mean that only 32 devices can be connected in a PROFIBUS network? No, the RS 485 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 RS 485 rules. The overall network can have many more devices and cover a much longer distance than the RS 485 rules imply.

Within a segment all PROFIBUS masters, slaves, repeaters, optical link modules, and even telegram analysers count towards the 32-device limit. This means, for example, that when two repeaters are connected to a segment the maximum number of PROFIBUS stations is reduced to 30. ***It is good practice to leave at least 10% spare capacity per segment for future expansion and/or diagnostic tool connection***; i.e. we should consider including a repeater if the device count approaches 28.

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 so 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.

1.5. 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 interference 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 RS 485 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.

1.6. MBP Transmission

PROFIBUS PA uses Manchester Bus Powered (MBP) transmission (defined in IEC 61158-2). There are several major differences between RS 485 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.

2. 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.

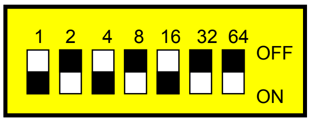
Within a network, every PROFIBUS device or station is given an address through which communication is directed. Every device on a PROFIBUS network must have a unique address. If two devices have the same address then one or the other or perhaps both will fail to operate. This is because the two devices 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 strongest device will override the weaker device and will operate satisfactorily, whilst the weaker device is drowned-out.

2.1. Setting Addresses

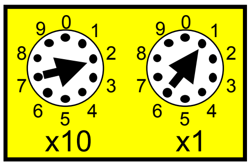
The address of every station must be set by the engineer during commissioning. Station addresses can be set in several ways:

Physical address switch on the device

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 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. Note that an option in the addressing command is to “lock” the address, which means that it cannot be changed again. However, there must always be a method of resetting the device back to the factory default address.

Special software and communication link

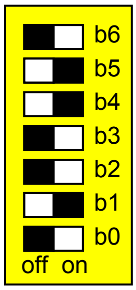
Here the device uses special software which communicates with the device via a serial port or perhaps Ethernet. Devices that use this method of setting the address include Human Machine Interfaces (HMIs) devices or Programmable Logic Controllers (PLCs). This is because these devices need the software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

2.2. 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. For example, to set the decimal address #50, 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.

An alternative way to determine the settings for a binary-weighted switch is to take the decimal address and successively divide by two. Each time we have a remainder from the division then this becomes a digit in the binary result. Here we are working up from the least significant bit. Taking the decimal address #50 as our example again:

50/2 = 25 remainder 0	therefore	bit 0 = off.
25/2 = 12 remainder 1		bit 1 = on.
12/2 = 6 remainder 0		bit 2 = off.
6/2 = 3 remainder 0		bit 3 = off.
3/2 = 1 remainder 1		bit 4 = on.
Leaving a remainder of 1		bit 5 = on.
All remaining bits are 0		bit 6 = off.



PROFIBUS is a multi-master system allowing several master stations to control their allocated slaves in parallel. In many cases, however, a single master will be used.

2.3. 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.

PROFIBUS address range of 0 to 127 (128 addresses available)	
Address 127	**Reserved for broadcast** (i.e. messages that are sent to all devices on the network, cannot be used for a device)
Address 126	**Reserved for new devices whose addresses can only be set over the network** (i.e. no dip switches)
Addresses 0 to 125	**Available for masters and all slaves**
Address 1	**Used for the main controller (Class 1 master)**
Address 0	**Used for an engineering station (Class 2 master) or a diagnostic tool** (reserved even you do not have either of the above)

3. PROFIBUS RS485 Wiring

The PROFIBUS R485 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 RS 485 transmission (see section 6.1). 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 1 and 2) 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.

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.

Table 1 – 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 2 – 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

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:***

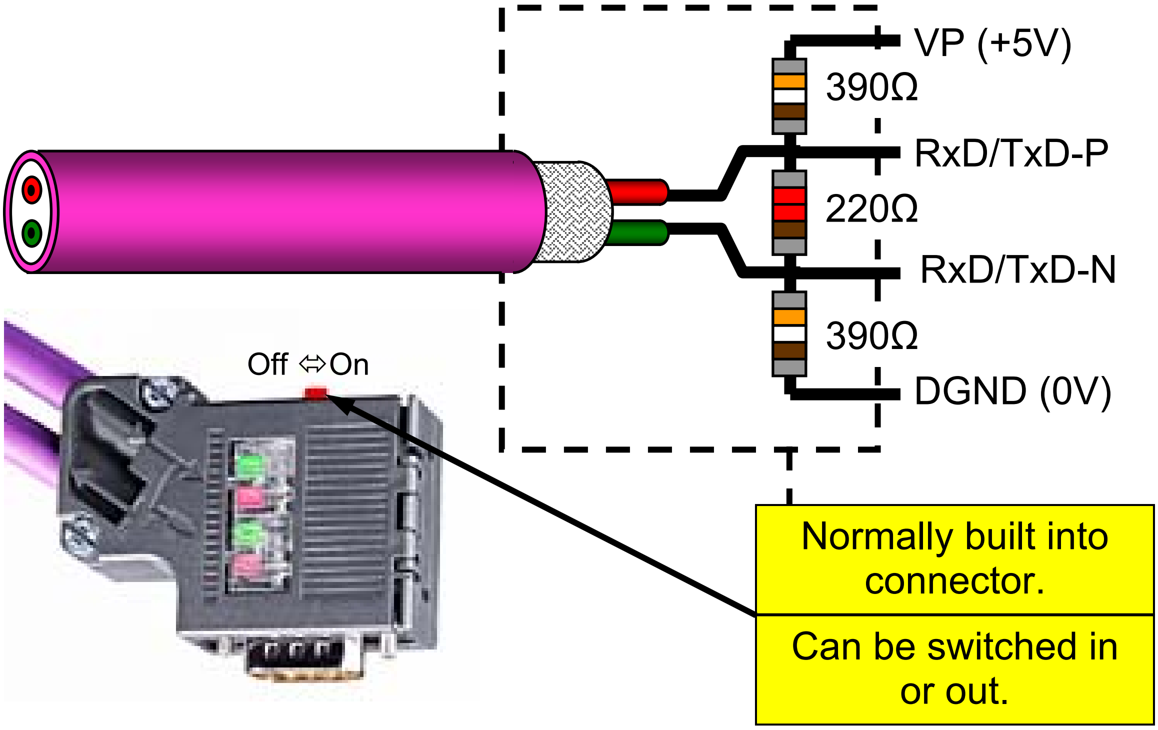
Red – B-line (RxD/TxD-P) (Aide-memoir: “B to RED” – “**BREAD**”)
Green – A-line (RxD/TxD-N)

3.1. Reflections and Termination

When electrical signals travel down a cable, any electrical discontinuity like additional resistance, capacitance or the end of the wire, can cause reflections to occur. In particular, the end of the wire is a major discontinuity where the resistance suddenly increases to infinity.

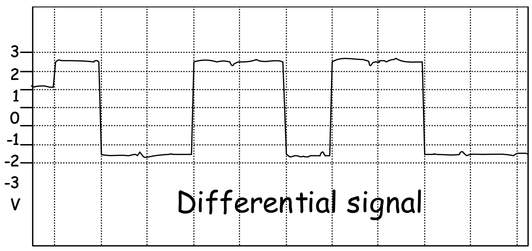
Just like an echo, the reflected signal can cause multiple signals to appear on the line. Reflections are bad news in high-speed communications because signals are corrupted or distorted by the reflection.

One way of minimising reflections at the end of a cable is to terminate the end with a specially chosen resistance that matches the cable properties. The resistance absorbs the energy of the signal and significantly reduces the reflection (theoretically to zero). The matching termination resistance 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 why the +5V VP and DGND pins are mandatory on PROFIBUS connectors.



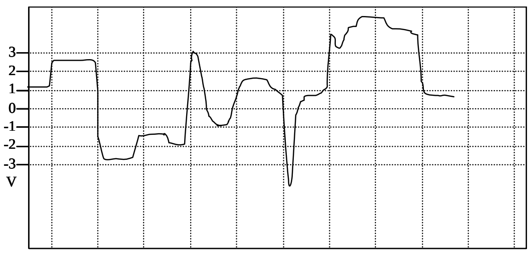
Active termination used in PROFIBUS RS 485 wiring

To avoid reflections from the ends of the cable ***it is essential that each segment is terminated at the two ends and nowhere else***. ***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 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.



A properly 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

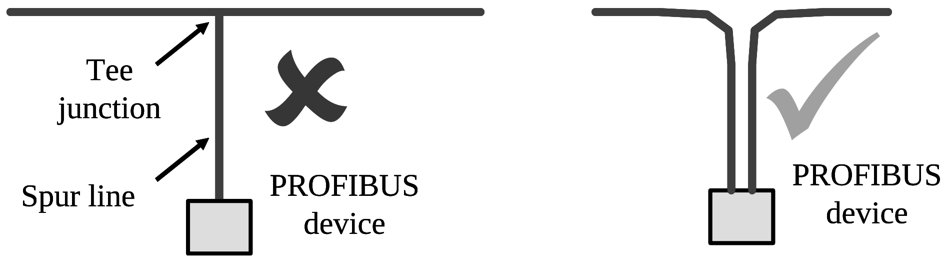
Effect of missing termination on RS485 waveform

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 termination(s) can cause reflections***.

3.2. 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 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:

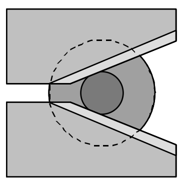


3.3. PROFIBUS RS485 connectors and wiring tools

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:

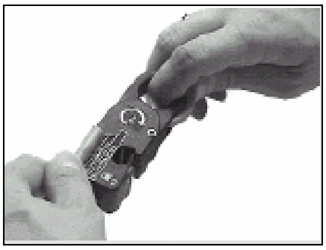
- Built-in termination resistors that can be switched in and out.
- Quick and reliable connection of data wires and shield.
- Connections for incoming and outgoing cables.
- Special inductors built in for operation at over 1.5 Mbit/s
- Outgoing cable isolation when termination switched in.
- Additional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

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” technology, where the core insulation is not removed, but is pierced by a blade in the connector:



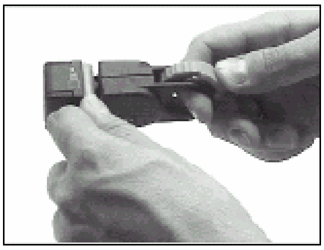
Insulation displacement technology gives a reliable airtight, low-resistance connection to the cable core. ***However this type of insulation displacement connection should not be used with stranded core cable because the individual cable strands can be completely cut by the connector.***

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



1

Measure the length of the cable to be stripped using the template on the side of the stripping tool.

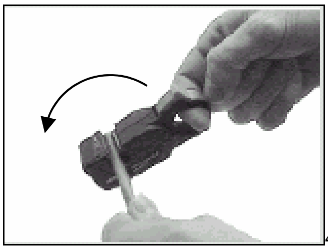


2

Insert the measured cable end into the stripping tool. Use your index finger as a stop.

3

Close the stripping tool gently.
.



4

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

5

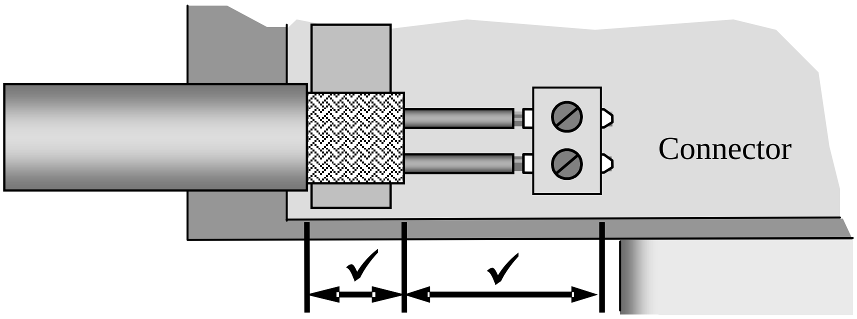
With the stripping tool closed, pull the tool away from the cable removing the cable sheath.

6

Peel away any remaining protective film.

Using the PROFIBUS stripping tool

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

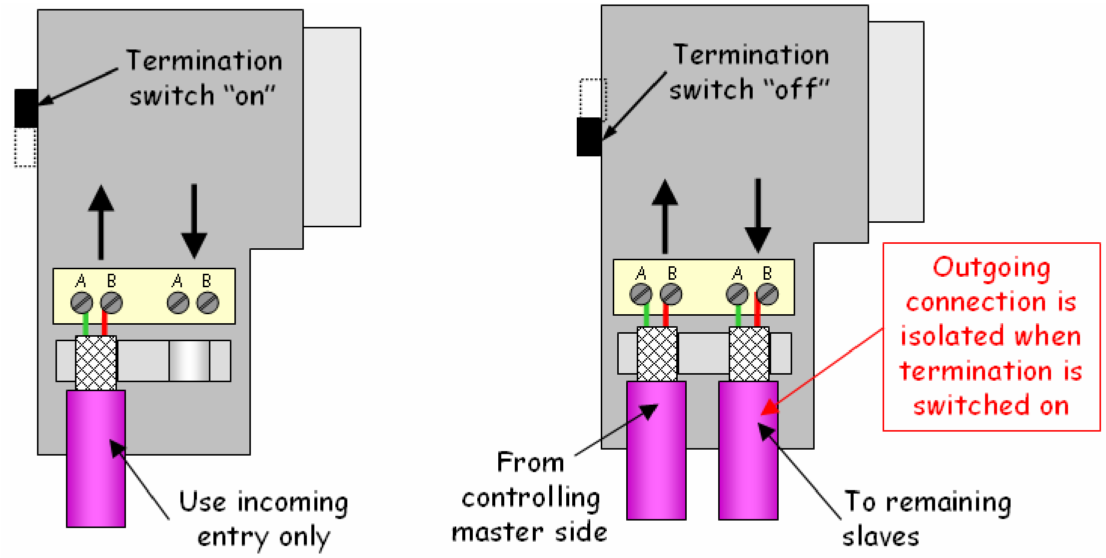


Screwed connectors are best for stranded cable

The bus cable should be daisy-chained from connector to connector. This allows stations to be disconnected without interrupting bus traffic.

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.

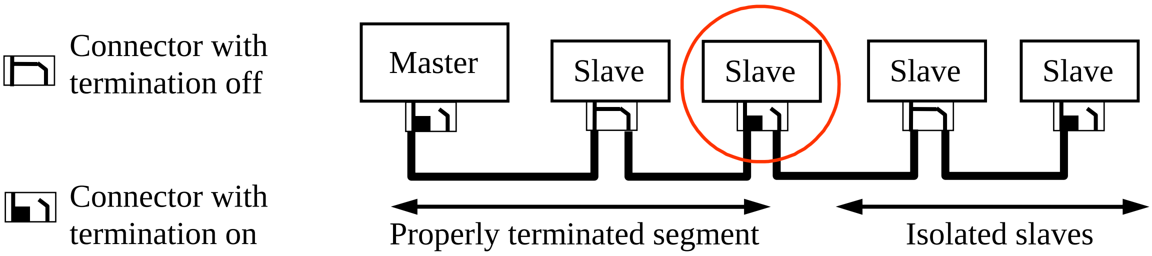
When any such connector has the termination switched “in” all the stations on the outgoing side are disconnected, leaving a properly terminated sub-segment on the ingoing cable. For this reason the first and last connector on a segment should only use the ingoing entry:



a) Connection for first and last stations on the segment.

b) Connections for all other stations on the segment.

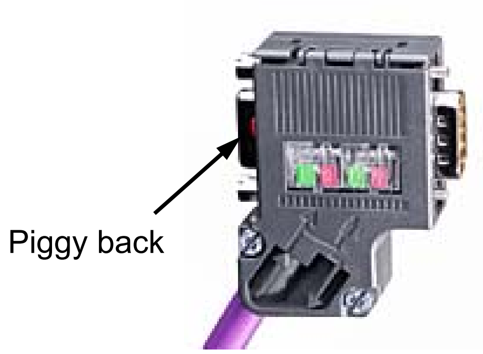
Correct use of isolating connectors



Incremental commissioning and maintenance using isolating connectors

3.4. *Piggy-back sockets*

To allow for network analysis and troubleshooting, each segment should have at least one connector with a "piggyback 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 piggyback socket for adding slaves since it creates a spur line.



At higher baud rates stub-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 to 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.

3.5. *Common RS 485 wiring errors*

It is common to find simple RS 485 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. Un-powered terminations (unplugged or un-powered devices).
e. Incorrectly wired isolating connectors (only becomes a problem when switched on).
2. Pickup 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

3.6. *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 HMS 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 RS 485 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).

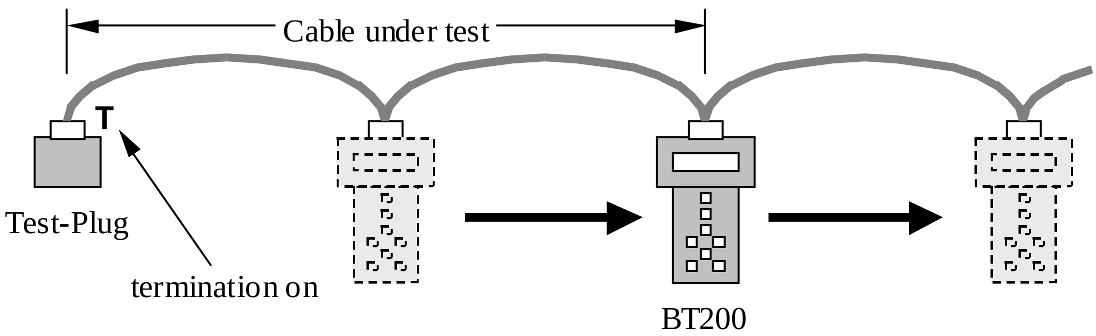
Most hand-held testers have the useful facility of being able to store the test data obtained whilst testing a bus segment. This data can then be downloaded onto a PC and a report generated giving full documentation of the tests performed and the results.

3.7. Wiring Testing using the BT200

Basic cable testing

The wiring test is performed with the BT200 by connecting a special “Test Plug to one end of the segment and switching the terminator on. All devices must be disconnected from the cable. The BT200 is connected to each socket in turn working away from the test plug. 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 form 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.

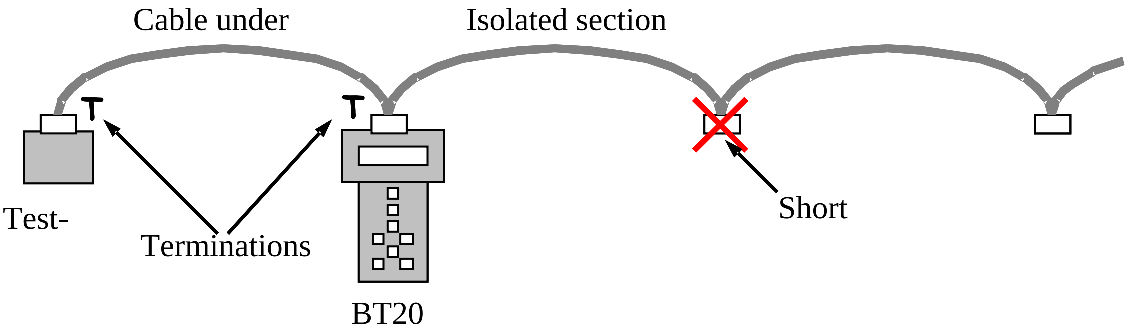
Note that it is important to check every socket since there may be a fault local to a socket that does not affect the rest of the cable. For example: a single socket with the A and B wires crossed over on both the incoming and outgoing cable would not be detectable from the end of the cable.



Principle of the basic BT200 wiring test

Locating a short circuit

If the cable being tested has a short circuit then this will be indicated by the BT200 no matter where the short is located. In such a case the isolating connector can be used to isolate the rest of cable and so locate the short. Simply switch on the termination at the BT200 connector. Always remember to switch it off again afterwards.



Principle of locating a short using BT200

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 “normal” (cable test) mode. You are prompted to press “**TEST**” to perform a 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:

- “Cabeling” – 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 HMS NetTest II

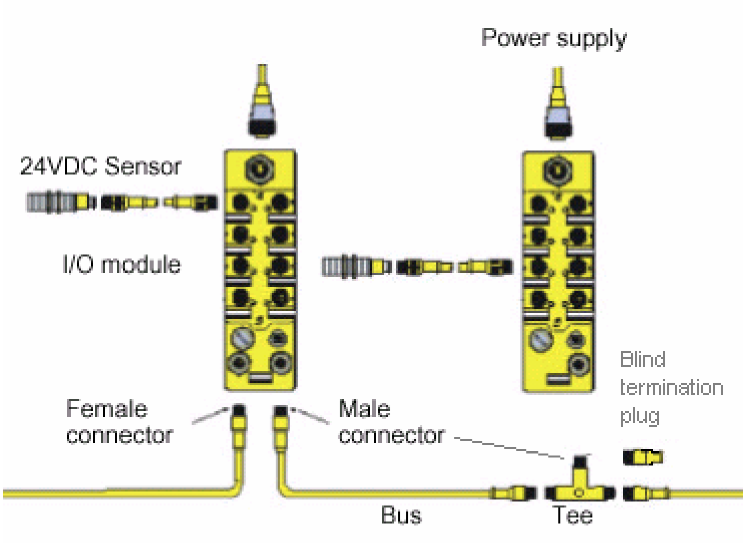
The HMS Bustest II device can also check out cable faults, however this device does not use a separate test plug and used a different procedure based on progressive testing without terminations, with one termination and finally with both terminations. In addition it provides accurate cable impedance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

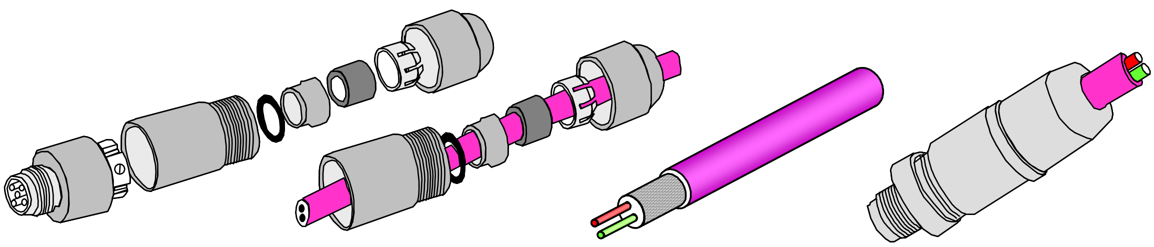
3.8. M12 Connector Systems

M12 screw connectors are used on DP and PA wiring. 5-pin connectors are used for RS485 wiring (DP) and 4-pin connectors may be used for MBP wiring (PA). 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 and that the cable entry is sealed properly against water ingress. You should always refer to manufacturer's instructions.

M12 connectors are more difficult to make up on-site than 9-pin sub-D connectors and so are often supplied pre-wired with cables. 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.

Termination is normally provided by a blind termination plug connected to the last device or tee. Power for the termination is normally provided by the device to which it is connected (either directly or through a Tee). This is another reason for always connecting the Tee directly to the slave, rather than via a short cable – the two-core cable cannot carry the +5V termination supply to the terminator plug and we would end with an unpowered termination network, causing reflections.





M12 connector systems

The manufacturer's instructions need to be followed carefully for M12 connectors. In particular, watch for a good screen connection which is distributed all the way around the cable (360°) rather than via a pig-tail or drain wire connection. 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.

4. Layout of DP segments

When laying out a PROFIBUS DP network it is important to remember the rules for RS 485 segments:

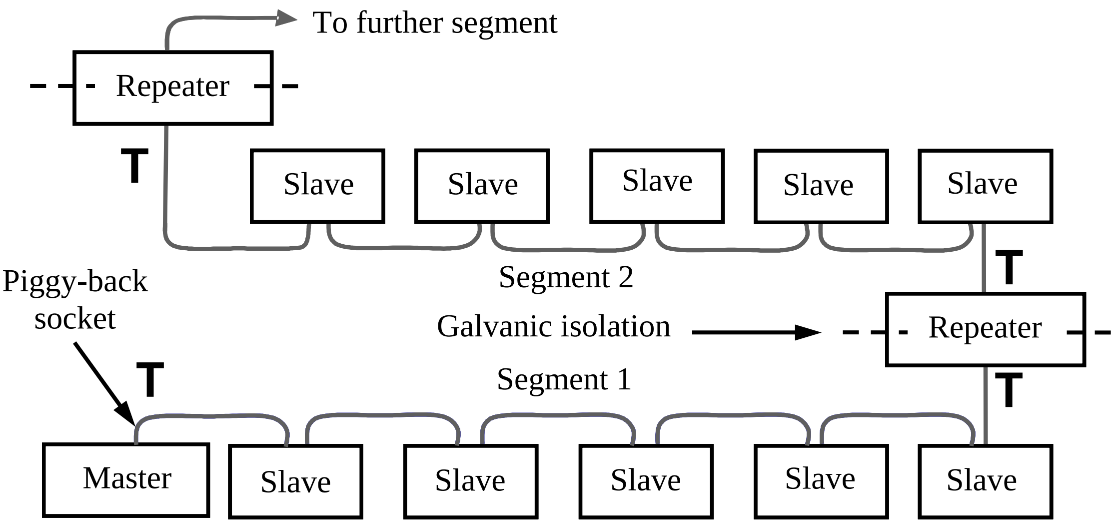
- RS 485 segments should be laid out as a linear bus, with the cable daisy chaining from device to device. Spurs should be avoided where possible)

- Each RS 485 segment must be terminated at the ends of the segment cable and nowhere else.
- RS 485 terminations must be powered at all times, even when the end device looses power or is disconnected.

4.1. Ideal segment layout

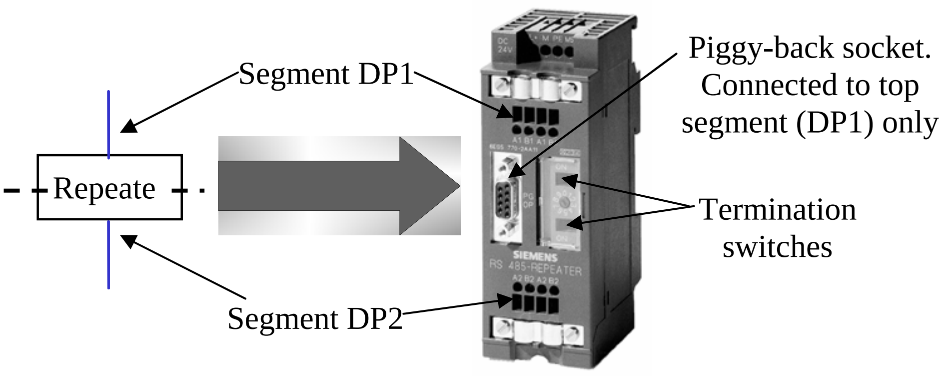
When operating with a single master system, the ideal case is to have the master at one end of the segment with the termination switched “in”. If the Master loses power, for whatever reason, the network will fail anyway so the loss of termination power is immaterial.

At the other end a repeater may be used to extend the network to another segment. 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.



Preferred arrangement for a single master network with repeaters

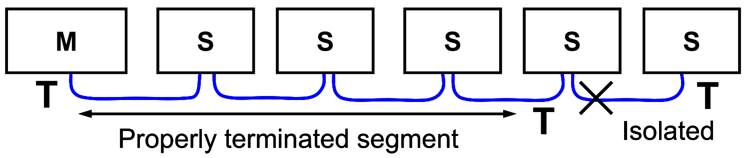
The piggy-back socket provided at the master allows us to examine the signals and waveforms in the first segment. The repeater also provides a built-in piggy-back socket; however, we must be careful because the piggy-back socket is normally connected to one segment only. The piggy-back socket normally allows us to examine the signals on the top segment. Therefore, it is good practice to connect the incoming master cable to the bottom segment (usually called 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.



Correct connection of the repeater and piggy-back socket

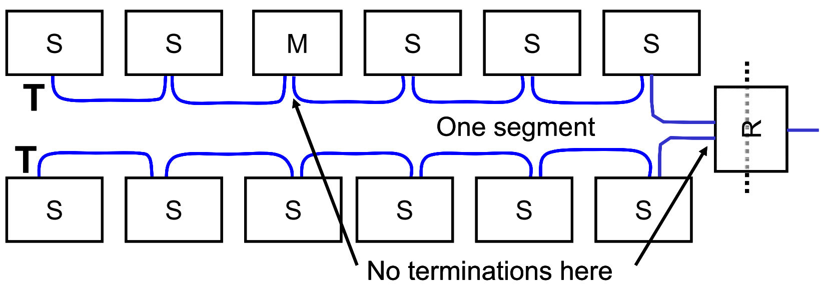
When a repeater is not used at the end of a segment, the termination must be “on” at the last device. This means the last device needs to be powered at all times to maintain the supply to the termination network. If you have to replace the last device, the whole network could become unstable.

If, however, isolating connectors are used (and correctly wired) the above 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:

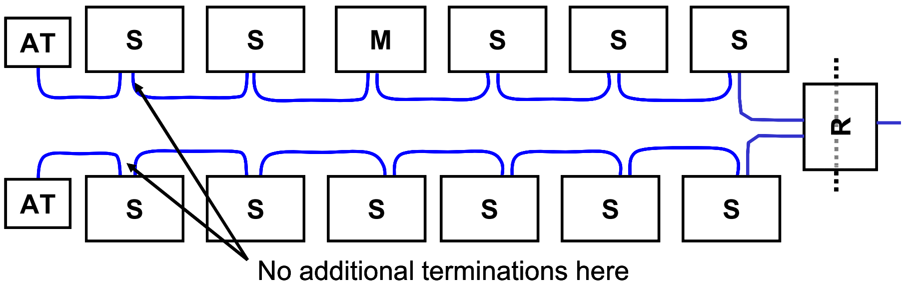


Use of isolating connectors to avoid termination problems when the last slave is removed

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.



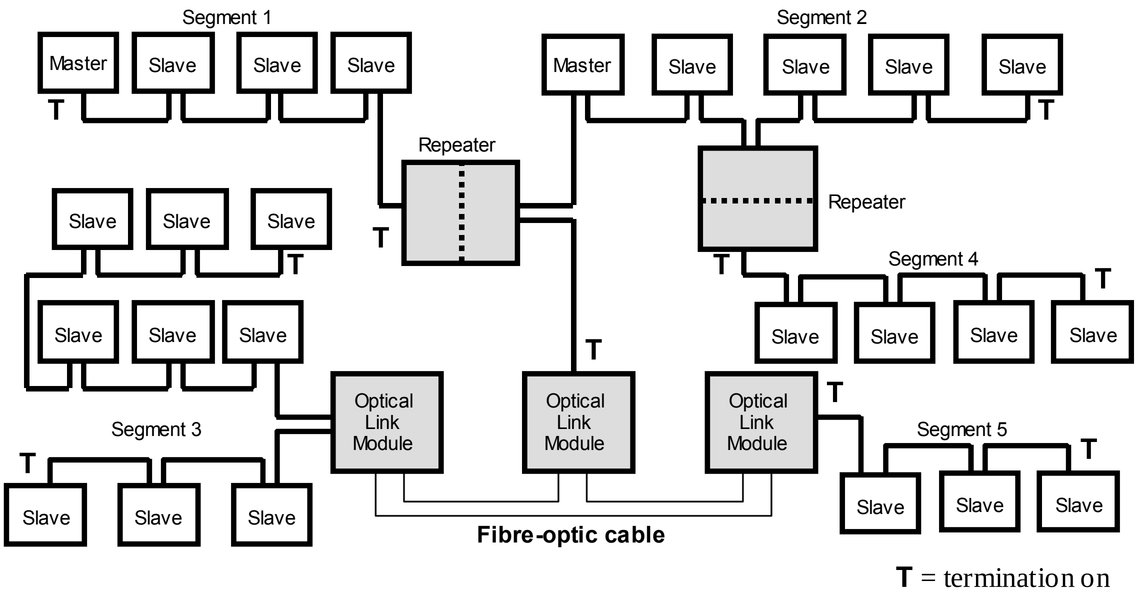
As an alternative to using the terminations in the connector, a separate “active terminator” can be used. An active terminator is simple a termination network that is separately powered. The active terminator is connected to a power supply and needs to be powered at all times. The advantage of this arrangement 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 separate Active Terminators

4.2. 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 must be laid out as a linear bus and must be terminated at each end and nowhere else.



Use of Repeaters and PLMs to produce a complex network structure

4.3. RS485 Cable Length Considerations

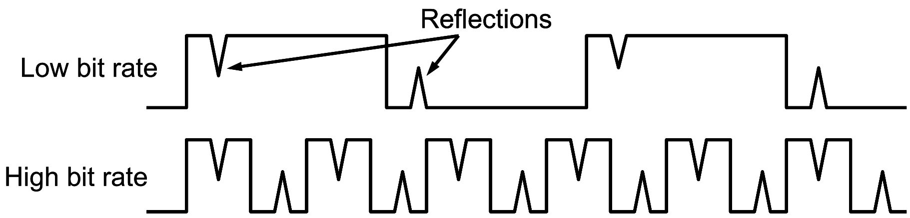
RS 485 segments can be up to 1.0km in length; however this only applies at lower bit rates. As the data rate increases, the maximum segment length reduces significantly as shown in table 3.

Table 3 – Maximum segment lengths achievable with copper wire

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

When are stub-lines allowed?

Stub-lines (also called “spur-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:



Reflections have a worse effect at higher bit rates

Stubs are not allowed when using higher baud rates (>1.5Mbit/s). At baud rates of 1.5Mbit/s and less, stub-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 on a segment.

Table 4 – Maximum allowable stub-line lengths

Baud rate	Total allowable stub capacitance	Total stub 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

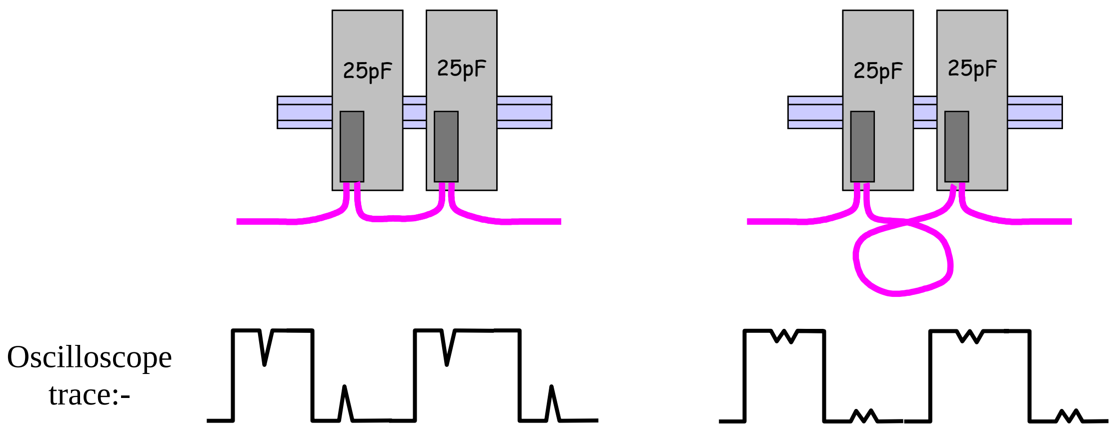
* Calculated for PROFIBUS cable type A at 30pF/m

Note that ***the total stub-line length shown represents the total length of <u>all</u> stubs attached to a segment***. Always try to avoid Spurs on DP segments where possible. Use a repeater to create a branch segment if necessary.
Every PROFIBUS device already has short Spur line within the casing carrying the bus signals between the connector and RS 485 driver chip. Devices are tested for reflections as part of the certification process; however, ***uncertified devices can cause reflections***.

4.4. Special requirements for baud rates >1.5 Mbit/s

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

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 don't add.



<u>Effect of adding 1m of cable between closely spaced devices</u>

5. 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.

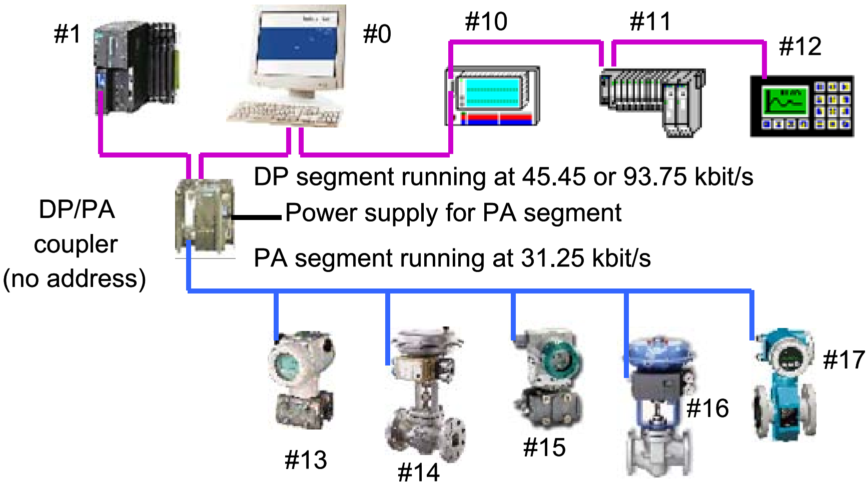
Up to 32 devices can be connected to a PA segment; however the particular characteristics of the segment power supply and/or requirements for intrinsic safety can again reduce this significantly.

5.1. *Coupler and link technology*

Simple DP/PA couplers

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.

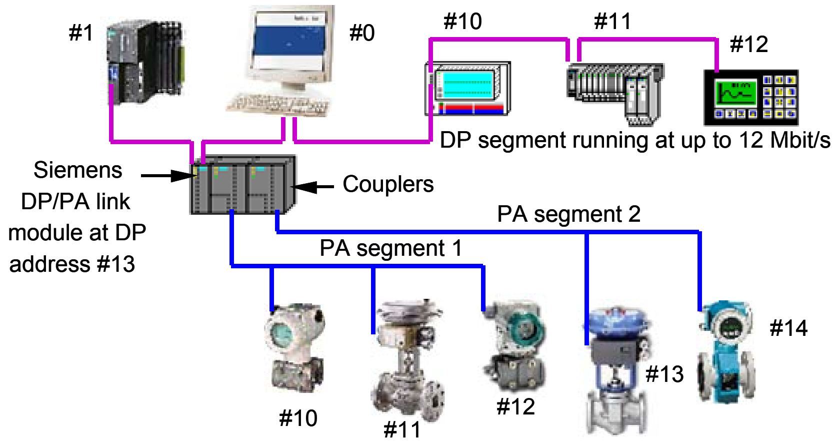
Up to 32 devices can be connected to a PA segment, however power supply limitations or intrinsically safe requirements may reduce this number significantly. Simple couplers, when used on their own, do not have a PROFIBUS address; telegrams are simply translated and passed through from segment to segment. When using a simple coupler, each PA slave is allocated an address which is unique on the network, however, the DP segment must run at low speed (45.45 or 93.75 kbit/s - depending on the coupler manufacturer).



Use of a simple DP/PA coupler

Siemens DP/PA Link Module

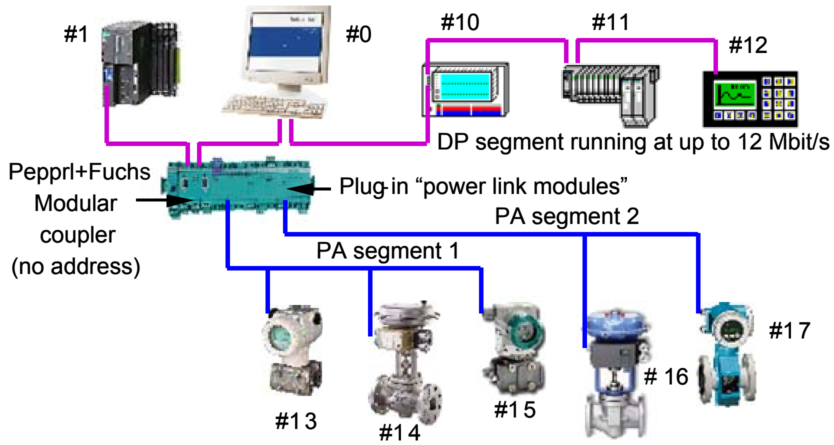
A Siemens DP/PA link module acts like a slave on the DP side and a master on the PA side. Thus a link module must have a slave address through which the DP master can access the PA segment. The PA devices are therefore strictly a new network. So the addressing of the PA devices can overlap the addresses 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.



Use of a Siemens Link Module with Couplers

Pepperl+Fuchs Modular Coupler

Pepperl+Fuchs offer a modular coupler that behaves in a similar way to the Siemens link module. Like a link module, the P+F Modular coupler allows the DP segment to run at up to 12Mbit/s, however it 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. Unfortunately the nomenclature is rather confusing: The P+F modular coupler consists of a "head station" plus a number of "power-link" modules, each of which can drive a PA segment.



Use of a P+F Modular Coupler with Power Link Modules

Company	Product Name	Baud rate on DP side (kbit/s)	Comments
Siemens	DP/PA Coupler	Fixed at 45.45	PA side uses the same address space as DP side
Siemens	DP/PA Link Module	Any baud rate	PA side uses a different address space than on the DP side
ABB	DP/PA Link Device	Any baud rate	PA side uses the same address space as DP side
Pepperl + Fuchs	Segment Coupler for PA (SK1)	Fixed at 93.75	PA side uses the same address space as DP side
Pepperl + Fuchs	PROFIBUS Power Hub System (SK3)	Any baud rate	PA side uses the same address space as DP side

5.2. *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 stub-line length.

Table 5 – Recommended IEC61158-2 stub-line lengths

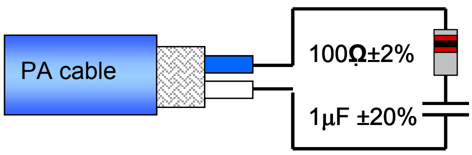
Number of spur-lines	Maximum spur length non-intrinsically safe installation	Maximum spur length intrinsically safe installation
25 to 32	1 m	1 m
19 to 24	30 m	30 m
15 to 18	60 m	60 m
13 to 14	90 m	60 m
1 to 12	120 m	60 m

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

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 and hubs can be useful to avoid such problems.

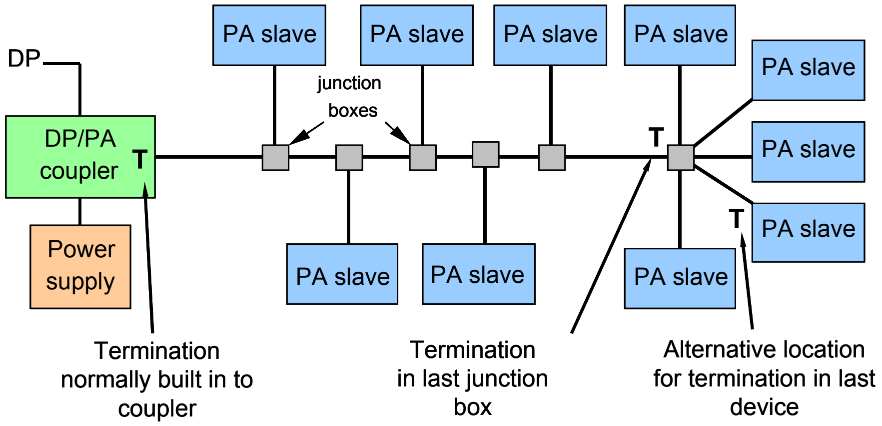
5.3. *MBP termination*

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 RS 485 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.



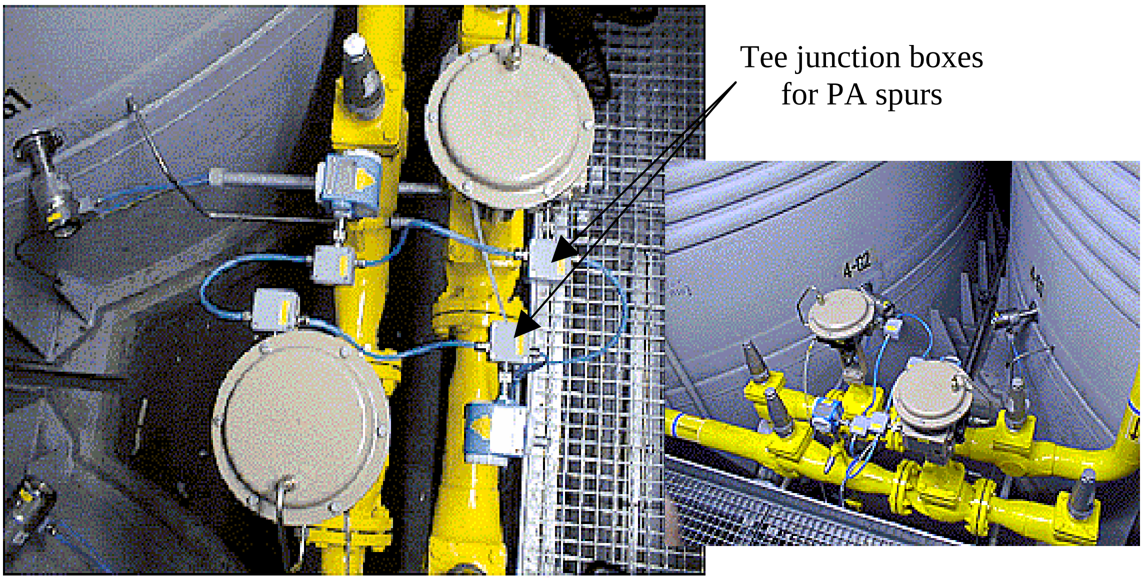
MBP Termination

Note that MBP terminators are not powered. Terminators are mounted at the 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

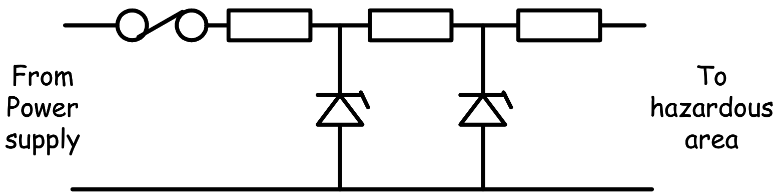
Note that the position of the terminator determines how many spurs we have. For example when the terminator is in the last junction box then we have one more spur then if the terminator is mounted in the last device. Terminators in junction boxes are preferred because of the availability of off-the-shelf solutions. These junction boxes can be obtained with a single spur, or with multiple spurs, with and without terminations and protection.



Typical PA Installation using junction boxes

5.4. *Intrinsic Safety Considerations*

When electrical equipment operates in a potentially explosive atmosphere (a hazardous environment) 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 (and hence power) available to the field-mounted device. Capacitance and inductance are also controlled to limit the stored energy available for a spark. Different classes of protection are provided: EEx ib which is safe in the event of a single fault and EEx ia which remains safe in the event of a double fault. EEx ia equipment can be used in a “zone 0” application where the threat of explosion is permanent or sustained. The gas group is considered since some gasses are easier to ignite than others. Gas group IIC has the most stringent requirements. Finally the surface temperature must be limited to below the gas or vapour ignition temperature. Temperature class T4 has the lowest requirement.



Typical protection barrier circuit limits current and voltage even in the presence of faults

Special "barriers" that incorporate voltage and current limiting devices are placed in the circuit. Certified devices must be used that meet the capacitance and inductance requirements for the protection category. Also the cable length and spur lengths must be limited. This means that when used to protect a PA segment, the number of devices and maximum cable length are significantly less than the IEC61158-2 specification would allow for non-hazardous applications.

PROFIBUS PA segments can be designed to be intrinsically safe by ensuring all devices are certified for intrinsic safety and that the cable and terminations meet the requirements. Traditionally the "entity concept" was used for designing intrinsically safe applications, however a relatively new method called the "Fieldbus Intrinsically Safe Concept", FISCO, has been introduced to simplify system design. FISCO power supplies for intrinsic safety limit the available output power to a segment, however, in addition, the voltage is limited. This allows greater current to be delivered to the segment (hence more devices). Intrinsically safe DP/PA couplers incorporate barriers that provide current and voltage limiting. A typical coupler certified for EEx ia gas group IIC might provide 110mA at a voltage of 13V which would limit the number of devices to 7 or 8 per segment (compared to 32 devices for a non-hazardous application).

The FISCO model enforces the following restrictions:

- Each segment has only one source of power.
- Every field device consumes a constant basic current.
- The field devices act as passive current sinks.
- Device capacitance and inductance limited to Ci < 5nF, Li < 10µH.
- ***Total cable length limited to 1000m maximum***. (including spurs)
- ***Individual spur line lengths limited to 60m maximum***.

The detailed design of an intrinsically safe PA segment is beyond the scope of this document and the reader is referred to the PROFIBUS – MSB Technical Guideline.

6. Cables for PROFIBUS

6.1. Cables for PROFIBUS RS485 segments

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

Parameter	
Impedance	135 to 165 Ω at a frequency of 3 to 20 MHz
Capacitance	< 30 pF / m
Resistance	≤ 110 Ω/ km
Wire diameter	> 0.64 mm
Conductor area	> 0.34 mm^2

In order to fit the cable into standard connectors, the cable needs to have a sheath diameter of 8.0 +/- 0.5 mm.

The term “Type-A” is rather confusing because it really means “Quality-A”, i.e. “best quality”. Several different forms of 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.

All can be obtained as “Type-A” cable.

6.2. *Cable for PROFIBUS PA*

IEC 61158-2 specifies four different types of cable for use in PA 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.

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

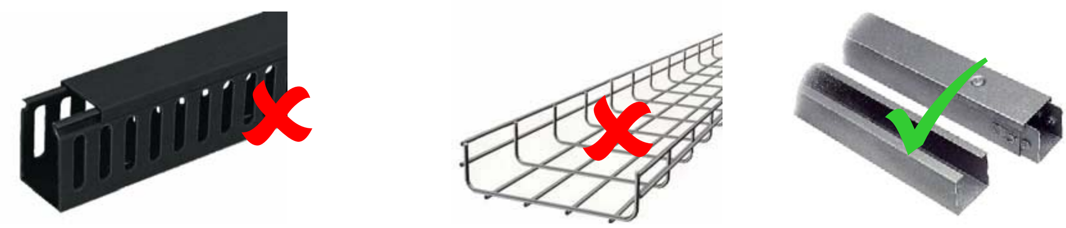
When using IEC61158-2 type A cable, the total segment length can be up to 1.9km including all branches or stub-lines. Intrinsically safe requirements will give significantly reduced segment length (see section 5.4).

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.

7. Installing PROFIBUS cables

7.1. 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 pickup and to avoid accidental damage.

When installing, it is important not to distort or damage bus cables since this can cause reflections to occur in the network. ***In particular, 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).

Use cable pulleys to avoid damage and excessive bending during installation

7.2. Cable Segregation

To reduce the chances of interference pickup, 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:

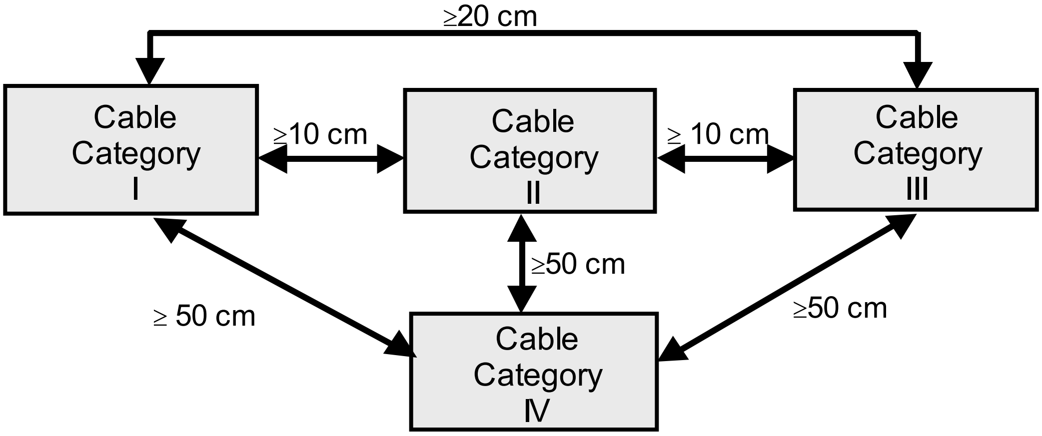
- Cables carrying DC voltages >60V and ≤400 V
- Cables carrying AC voltages >25V and ≤400 V

<u>Category III:</u>

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

<u>Category IV:</u>

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

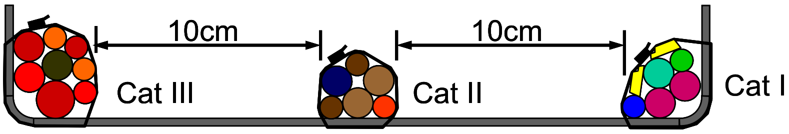


<u>Separation distances for cables of different category</u>

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.

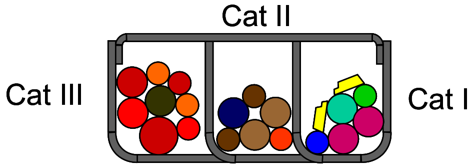
7.3. Use of cable trays and channels

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.



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

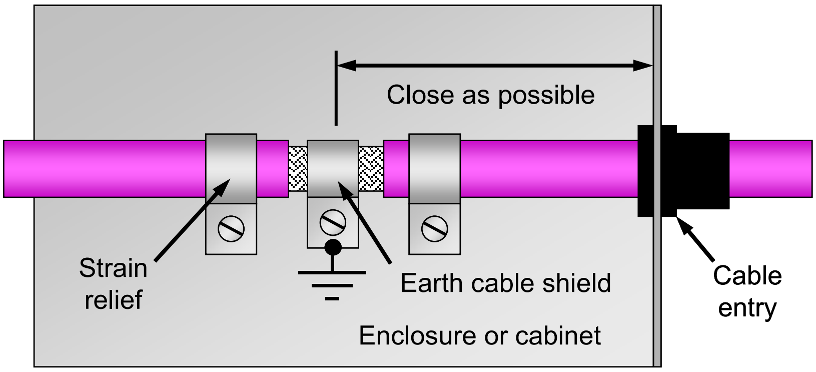
When separated by earthed steel partitions with a steel lid, the bundles can be placed next to each other. All channels and partitions must be properly earthed using flexible bonding links protected against corrosion. Note that braided straps are better than solid metal for high-frequency EMC protection.



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

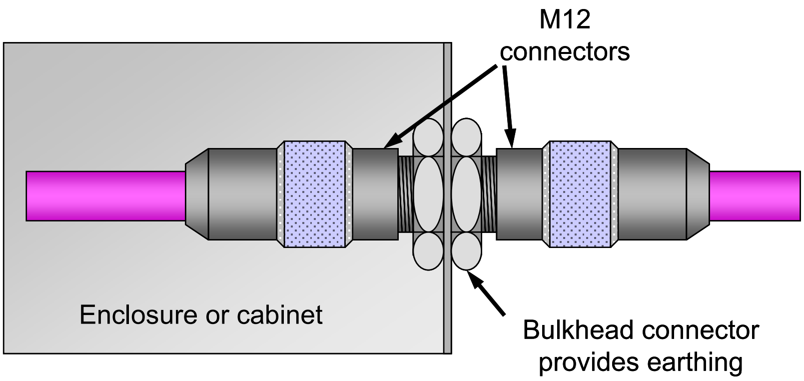
7.4. *Cabling Within Wiring Cabinets*

The braided shields of all PROFIBUS cables entering the wiring closet 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 M12 bulkhead adaptor. These have the additional advantage that they also allow the internal wiring to be completed and tested off-site.



A more robust solution using earthed bulkhead connectors

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.

7.5. 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 pickup.***

Earth potential problems are common where:

a) The network cable covers a large area or extends over a long distance.
b) Power is supplied to different sites from different sources (i.e. sub stations).
c) 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.

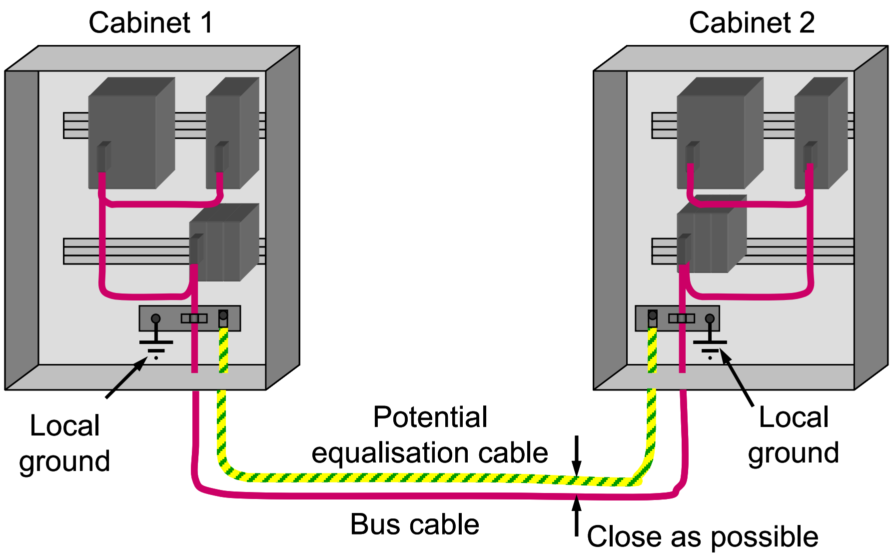
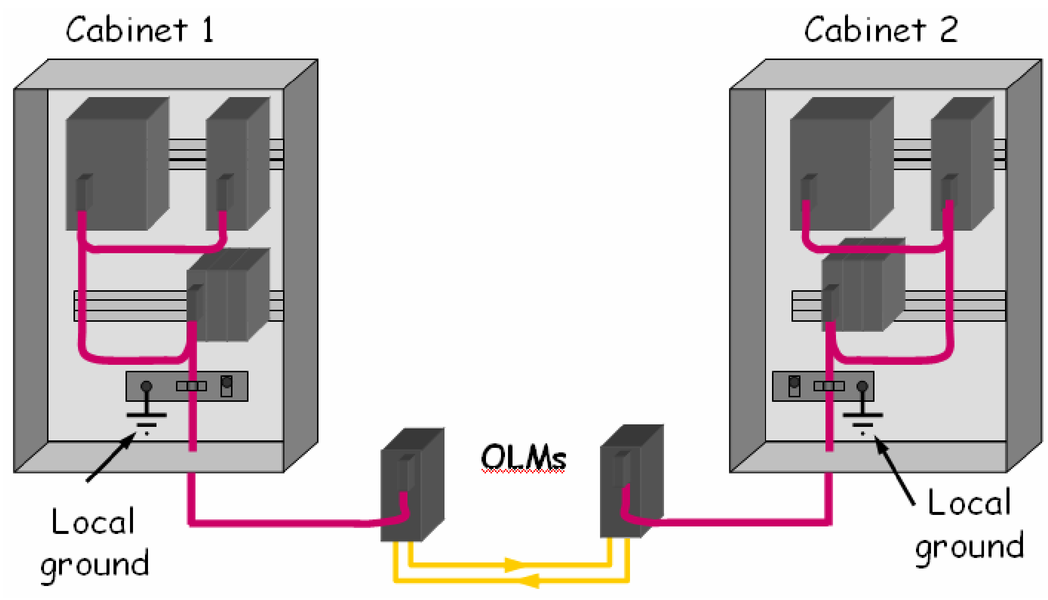


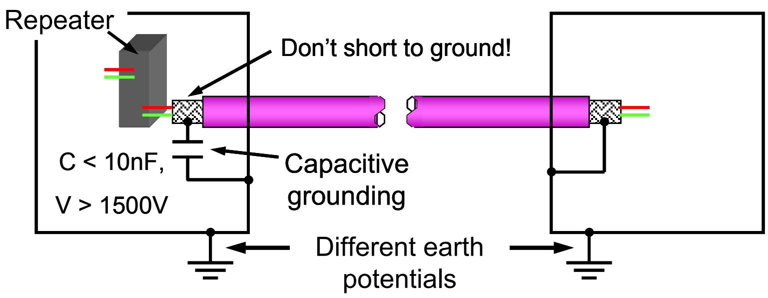
Figure 20 – Installation of a potential equalisation line

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

An alternative running heavy potential equalisation cables is to use fibre optic link modules between the different earth potentials.



Another 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 pickup, 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.

8. Repeaters

An RS 485 repeater amplifies the data signals on bus lines and provides isolation between individual bus segments. A repeater is required, when:

a) there is a need to connect more than 32 devices to the bus, or
b) there is a need to isolate sections of the bus, or
c) the segment exceeds the maximum permissible cable length for the bit-rate used.

Repeaters can also be useful to create branch segments in your network.

Some older repeaters do not incorporate automatic bit-rate detection and hence the baud rate must be explicitly set using a switch provided on the device.

9. 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:

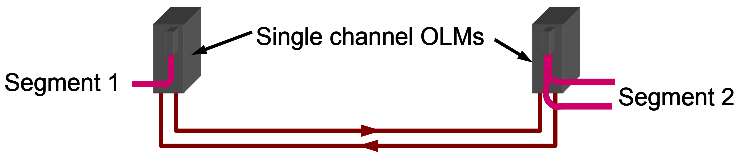
- Plastic fibre which is low cost, simple to make up, but is generally limited to distances of less than 50m.
- Multi-mode glass fibre which can be used over distances of up to 2km.
- Single-mode glass fibre which can be used over distances of up to 50km.

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.

9.1. Optical Link Modules

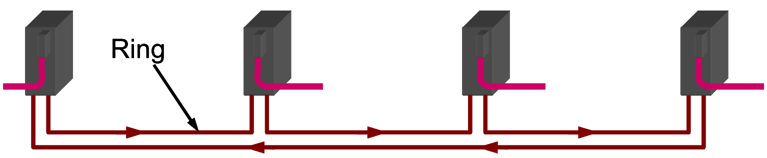
Fibre-optic PROFIBUS transmission requires the use of RS 485 to fibre optic conversion called Optical Link Modules (OLMs). OLMs are available from various manufacturers. Each optical channel on an OLM requires two optical connections: one for transmission and one for reception. Some OLMs have duplicate 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.

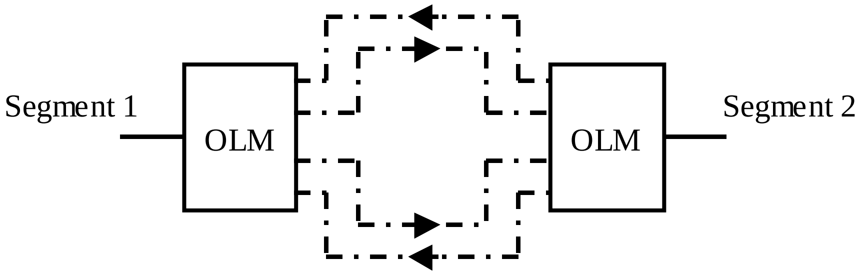


OLMs connecting two segments

Optical segments are normally arranged as 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

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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

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