PROFIBUS

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Technical Guideline

Installation Guideline
for PROFIBUS-DP/FMS

Version 1.0
September 1998

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1 Introduction

The information contained in this document applies to PROFIBUS-DP and PROFIBUS-FMS systems. It describes common procedures to follow when specifying a PROFIBUS installation which have proven to be effective in practice. However, it is also necessary to observe the specific installation instructions from the suppliers of the fieldbus devices and to comply with the relevant safety guidelines. This manual does not cover PROFIBUS-PA, which is for intrinsically safe systems. Different guidelines apply to installation in areas subject to explosion hazards.

To bridge large distances as well as in wide area applications (galvanic isolation, lightning strikes) the use of fiber optical cables is recommended for data transmission.

The following installation guidelines only apply to data transfer using copper cables (RS 485) to EN 50170. Furthermore, operators of PROFIBUS equipment are strongly recommended only to use fieldbus devices and components which have been certified by the PROFIBUS User Organization e.V. (PNO). Certified products have undergone extensive tests carried out by specialists to demonstrate their compliance to the PROFIBUS standard EN 50170 in combination with PROFIBUS devices from other manufacturers. PROFIBUS data transfer is based on the RS 485 standard[1]. The relevant features for use with PROFIBUS-DP/FMS are described in EN 50170 and reflected in the following practical examples. Data transfer using fiber optical cables is also described briefly for the sake of completeness.

2 Planning a PROFIBUS installation

In addition to installation and constructional factors which are largely determined by the location of each of the machines and fieldbus devices, when planning the installation it is also necessary to observe the physical regulations for PROFIBUS equipment as described in EN 50170.

2.1 General information

Table 2-1, which contains general information on dimensioning a PROFIBUS installation, includes important parameters for plant designers. As described in the PROFIBUS RS485 specification, each bus segment can have a maximum of 32 active devices. In order to be able to connect a larger number of PROFIBUS DP/FMS stations, it is necessary to segment the bus. The segments are then interconnected with repeaters which amplify and refresh the data signals. Repeaters can also be used for galvanic isolation of bus segments or bus sections. Each repeater allows the PROFIBUS system to be extended by an additional bus segment with the maximum admissible cable length and the maximum number of fieldbus devices (see Table 2-1). Repeaters increase the signal propagation times. This should be taken into account during planning.

[1] EIA RS 485 = Electrotechnical Association, multi-point interfaces.

Maximum number of stations participating in the exchange of user data	DP: 126 (addresses from 0 .. 125) FMS: 127 (addresses from 0 .. 126)
Maximum number of stations per segment including repeaters	32
Available data transfer rates in kbit/s	9.6, 19.2, 45.45, 93.75, 187.5, 500, 1500, 3000, 6000, 12000
Max. number of segments in series	According to EN 50170, a maximum of 4 repeaters are allowed between any two stations. Dependent on the repeater type and manufacturer, more than 4 repeaters are allowed in some cases. Refer to the manufacturer's technical specification for details.

Table 2-1: General information on planning a PROFIBUS installation

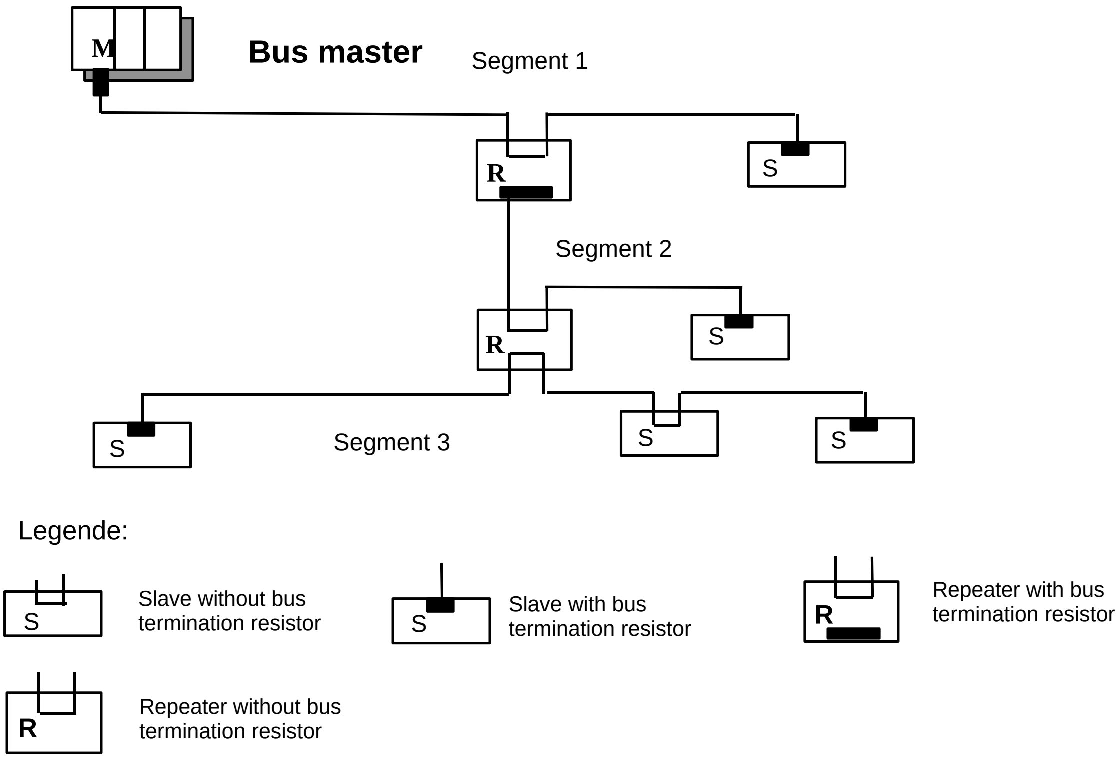


Figure 2-1: Segmenting of a PROFIBUS installation

Figure 2-1 illustrates the layout and segmenting of an example PROFIBUS installation which uses repeaters. Repeaters with galvanic isolation can be used.

2.2 PROFIBUS layer 1 (Physical Layer)

PROFIBUS layer 1 describes the data transmission technology, the pin assignments of the bus connectors and the technical parameters to be complied with. It also contains rules on the design of PROFIBUS-DP/FMS devices with respect to bus physics.

2.2.1 Choice of PROFIBUS data transfer cable type

Depending on the application, the user can choose between electrical and optical fiber data transfer cables. The following types of electrical data cables can be used:

- **Standard bus cable**
- **Standard bus cable with halogen-free sheath (type FRNC)**
- **Cable with PE sheath** for use in the food and drug manufacturing industries (it differs from the standard bus cable solely in the cable sheath).
- **Direct buried cable** with additional protective sheath for laying in the ground.
- **Trailing cable** (this is a special cable type which is used where parts of the machine move occasionally or continuously).
- **Festooned cable**. Compared to a trailing cable, a festooned cable has an additional strain relief element.

The bus cable is specified in EN 50170 part 8-2 as "Cable Type A", and should comply with the parameters in the following table. Cable Type B, which is also described in EN 50170, is outdated and should no longer be used.

Table 2-2 shows the parameters for standard type A bus cables.

Parameter	**Cable type A**
Characteristic impedance in Ω	135 ... 165 at a frequency of (3...20 MHz)
Operating capacity (pF/m)	< 30
Loop resistance (Ω/km)	< =110
Core diameter (mm)	> 0.64 *)
Core cross-section (mm²)	> 0.34 *)

Table 2-2: Bus cable parameters

*) The cable cross-sections used should be compatible with the mechanical specifications of the bus interface connector

The cable parameters specified for standard Type A bus cables result in the maximum length of each bus segment for the respective data transfer rate shown in Table 2-3.

Data transfer rate in kbit/s	9.6	19.2	45.45	93.75	187.5	500	1500	3000	6000	12 000
Max. segment length in m	1200	1200	1200	1200	1000	400	200	100	100	100

Table 2-3: Maximum cable lengths per segment

Important: In a PROFIBUS-DP/FMS installation, you must choose a data transfer rate which is supported by all devices connected to the bus. The chosen data transfer rate then determines the maximum segment lengths as shown above.

The maximum admissible distance between two bus stations in each PROFIBUS network can be calculated as follows:

(NO_REP + 1) * Segment length

NO_REP= The maximum number of repeaters connected in series (depends on repeater type).

Example: *The repeater manufacturer's specifications allow nine repeaters to be connected in series.*

The maximum distance between two bus stations at a data transfer rate of 1500 kbit/s is then as follows:

(9 + 1) * 200 m = 2000 m

2.2.2 Bus stub lines

The use of passive bus stub lines should be avoided.

Programming and diagnostic devices which are attached to the bus e.g. during commissioning are generally connected using their own cable which acts as a bus tap-off cable. In such cases, you should use active bus tap-off devices (e.g. bus terminals, repeaters, active cables etc.).

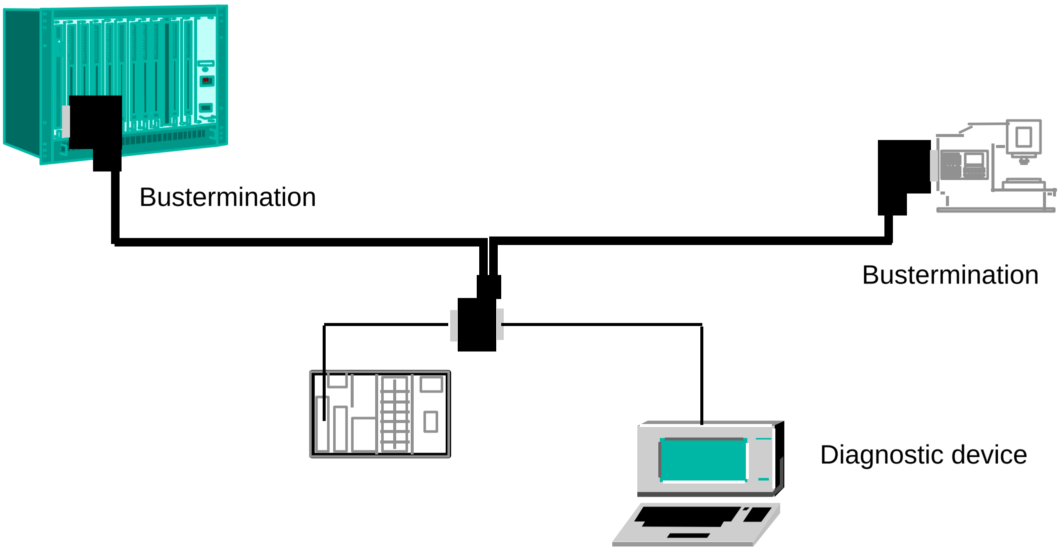


Figure 2-2: Connecting a diagnostic device to the bus using an active bus terminal/repeater

2.2.3 Bus termination to EN 50170 Volume 2

In order to minimize cable reflections and ensure a defined noise level on the data lines, the data transfer cable must be terminated at both ends with a terminating resistor combination as follows.

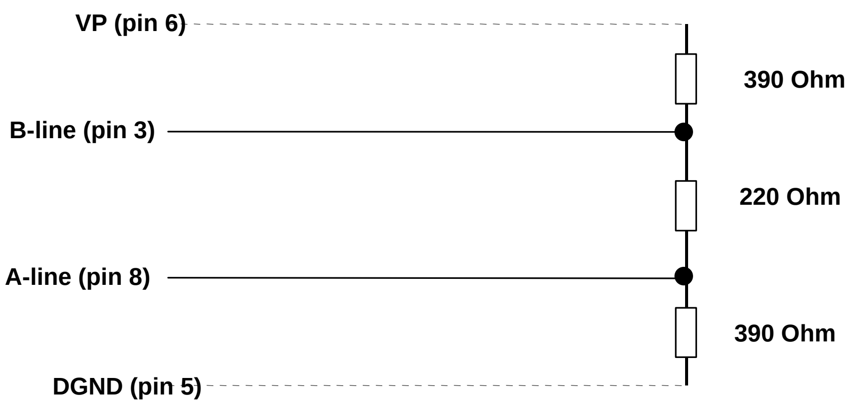


Figure 2-3: Cable termination of the PROFIBUS cable to EN 50170 (pin numbers for a 9-pin SUB-D connector)

2.2.4 Bus connectors and PROFIBUS-DP/FMS interface

A bus connector is used to connect the bus cable to the PROFIBUS device. Bus connectors are available with a variety of protection classes and mechanical designs. The choice of connector is mainly determined by the space available in the vicinity of the PROFIBUS device (i.e. PC interface, PLC or special fieldbus device).

EN 50170 Volume 2 recommends the use of a 9-pin Sub-D connector. Depending on the required protection class and the application of the fieldbus device, other connector designs are also allowed.

Table 2-4 shows the pin assignment if a 9-pin Sub-D connector is used:

Pin no.	**Signal**	**Significance**
1	Shield	Shield/functional ground
2	M24	Ground for +24 V output voltage
3	**RxD/TxD-P *)**	**Receive/Transmit data – plus (B wire)**
4	CNTR-P	Repeater control signal (direction control), RTS signal
5	**DGND *)**	**Data ground (reference potential for VP)**
6	**VP *)**	**Supply voltage - plus (P5V)**
7	P24	Output voltage +24 V
8	**RxD/TxD-N *)**	**Receive/Transmit data – minus (A wire)**
9	CNTR-N	Repeater control signal (direction control)

*) Signals marked in bold and with an asterisk are mandatory and must be provided. Other signals are optional.

Figure 2-4: Pin assignments of a 9-pin Sub-D connector for a fieldbus device

All fieldbus devices which use a standard 9-pin Sub-D connector should provide the
the VP and DGND signals on the bus connector in addition to the receive and transmit signals. With all other connector types, only the receive and transmit signals need to be connected.

Make sure that the connector type used is suitable for the selected baud rate.
If optional signals are provided, they must also comply with EN 50170 Volume 2 and they must be correctly described in the respective GSD file.

To prevent EMC interference from entering the device, the cable shield should be connected to the functional ground [1)] of the device (generally the electrically conductive case). This is done by connecting the cable shield to the metal case of the Sub-D connector and the functional ground over a large area. The bus connector must have a low-impedance connection to the cable shield.
The data transfer technology of the serial bus system, which uses a shielded twisted pair data cable, is described in the specification of the interference-immune RS 485 interface standard. To allow correct bus termination, each station must connect the signals DGND and VP (5 V) to pins 5 and 6 of the connector, respectively. The 5 V supply for the terminating resistors (VP) should have a minimum current rating of 10 mA (the current load can increase to 12 mA if a NULL signal is sent through the bus).The current rating should be increased to app. 90 mA if you need to be able to supply other types of devices on the bus such as bus terminals and optical fiber cable drivers.

[1)] The electrical equipment in a plant is generally connected to a functional ground. It is used to lead away potential equalization and interference currents and to ensure compliance with EMC regulations and should thus be installed with regard to the requirements of high frequency currents.

Due to the capacitive load of the station and the resulting cable reflections, bus connectors should be provided with built-in series inductors as shown below.

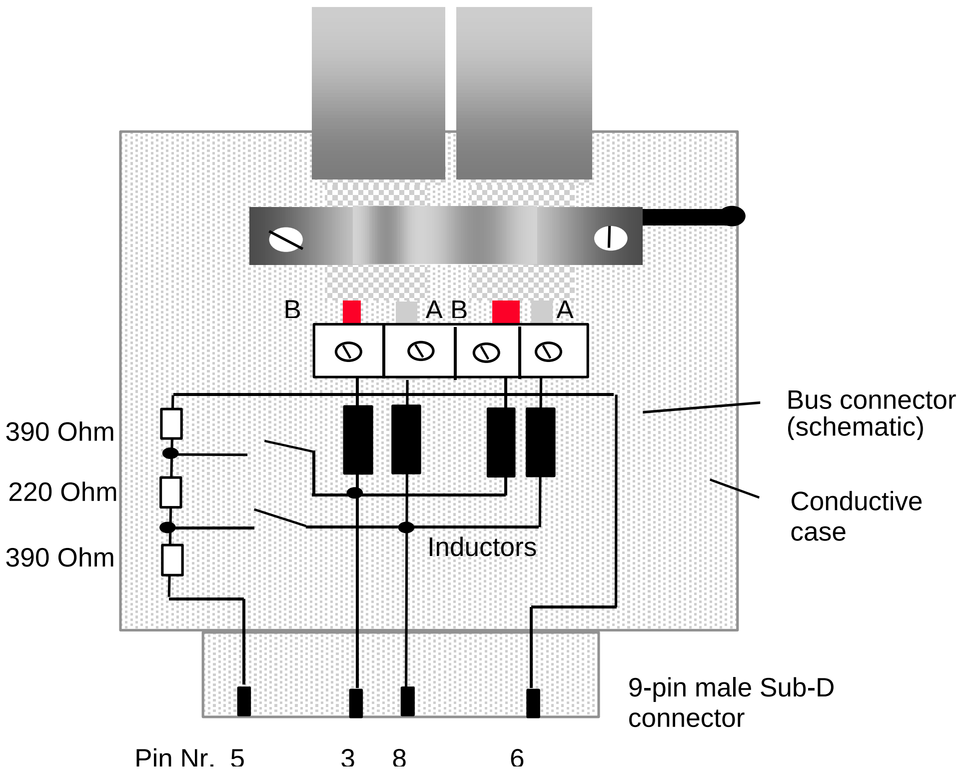


Figure 2-5: Bus connector with built-in terminating resistors and series inductors

Due to the built-in series inductors in the bus connectors, all bus connectors in the network should be attached to fieldbus devices to ensure that the necessary capacitive load is provided by the device input capacitance.

2.2.5 Power supply for the terminating resistors

The active bus termination using a resistor combination avoids signal reflections during data transfer and ensures a defined zero-signal voltage on the data lines when none of the stations on the bus are active. Active termination must be provided at the beginning and end of each RS 485 bus segment.

If the bus termination is missing, this can cause errors during data transfer. Problems can also arise if too many bus terminators are fitted since each bus terminator also represents an electrical load and reduces the signal levels and thus the signal-to-noise ratio. Too many or missing bus terminators can also cause intermittent data transfer errors, particularly if the bus segment is operated close to the specified limits for maximum numbers of stations, maximum bus segment length and maximum data transfer rate.

The power required by the active bus termination is usually obtained through the bus connector from stations connected to the bus. Alternative measures must be taken if there is no guarantee that the power required by the bus termination is permanently provided while the bus is operating. For example, in a particular installation the station providing the power to the bus termination may need to be repeatedly switched off or removed from the bus for operational reasons. In such cases, the bus termination should use an external power supply or a repeater should be used for bus termination instead.

3 Cable laying regulations for PROFIBUS

This chapter aims to promote a general understanding of the requirements to be met during PROFIBUS installation to ensure EMC compliance. In addition, **the user is** still **responsible** for observing the valid safety and accident prevention regulations. Furthermore, the following should be read together with the manufacturer-specific guidelines.

3.1 Laying of copper cable

Data transfer in PROFIBUS systems is based on a interference-immune symmetrical bus system to the RS 485 specification using shielded twisted pair cable. With correct system installation, small external sources of interference are led to ground through the cable shield without causing interference in the data lines. Interference of this type can largely be avoided with appropriate EMC measures such as EMC-compliant system installation, EMC-compliant cable laying and measures that avoid large ground potential differences.

Electromagnetic interference from sources such as switching processes, rectifiers and circuit breakers can cause equipment faults to occur. In addition, overvoltage and lightning strikes can destroy electronic components in fieldbus devices. Correct operation of the plant can then no longer be guaranteed.

Particularly for equipment containing frequency inverters (variable speed drives), the manufacturer's regulations for EMC compliance must be observed for the following components:

- Filters,
- Chokes, and
- Shielding.

In addition, electronic starters should be used if fluorescent lamps are installed within control cabinets.

The following cable laying instructions apply to shielded twisted pair cables. The cable shield is used to improve the immunity to electromagnetic interference. PROFIBUS cables should be shielded with a combination of both conductive braid and conductive foil. In the following, "shield" refers to both types of shields (braid **and** foil). A foil shield should not be used on its own, because it is very thin and can easily be damaged.
The cable shield must be connected to the functional ground at both ends of the cable by making a large-area connection to a grounded conductive surface. When laying the bus cables, particular care should be taken to ensure that the cable shield (braid shield and foil shield, if available) is connected to the shield grounding clamp over a large area.
The two PROFIBUS data lines are designated A and B. There are no regulations on which cable core color should be connected to which of the two data terminals on each fieldbus device; the sole requirement is to ensure that the same core color is connected to the same terminal (A or B) for all stations throughout the entire system (**across all stations and bus segments**). If the data transfer cable has data wires with red and green insulation, then the following assignment should be used:

Data cable wire A - green
Data cable wire B - red

This rule applies to both the incoming and the outgoing data lines.

3.1.1 Laying cables within control cabinets

If a repeater or fieldbus device is installed within a control cabinet, the cable shield of the incoming bus cable should be electrically connected to a grounding rail as close as possible to the cable lead-through using a shield grounding clamp or similar (see Figure 3-1). The cable shield should continue within the cabinet to the fieldbus device and be connected there in accordance with the manufacturer’s instructions. The following installation guidelines should be observed. Ensure that the case of the device and also the control cabinet in which the fieldbus device is mounted have the same ground potential by providing a large-area metallic contact to ground (use e.g. galvanized steel to ensure a good connection). Grounding rails should not be attached to painted surfaces. If the above measures are observed, electromagnetic interference is diverted through the cable’s shield.

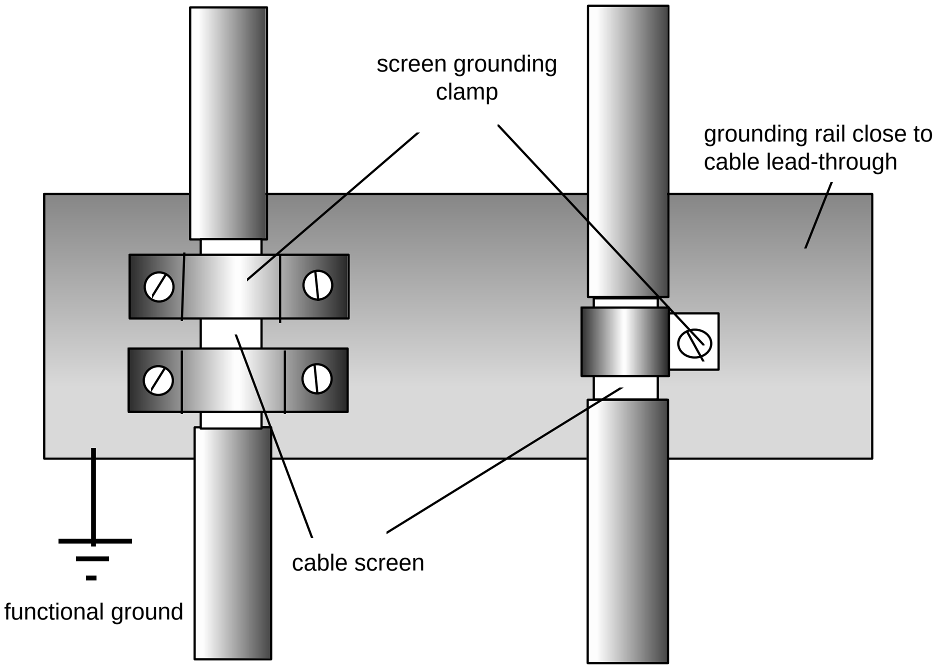


Figure 3-1: Shield connection of PROFIBUS cable to a conductive surface

The following rules should be followed when laying PROFIBUS cables within control cabinets.

PROFIBUS cables ...

and cables for ...	**must be laid ...**
• Bus signals, e.g. PROFIBUS • Data signals for PC´s, programming devices, printers etc. • Screened analog inputs • Unscreened DC voltages (<= 60V) • Screened process signals (<= 25 V) • Unscreened AC voltages (<= 25V) • Coaxial cables for monitors	in the same cable loom or cable duct.
• DC voltages from 60 V ... 400 V (unscreened) • AC voltages from 25V ... 400 V (unscreened)	in separate cable looms or cable ducts without minimum spacing requirements
• DC and AC voltages > 400 V (unscreened) • Telephone cables • For areas with explosion hazard	in separate cable looms or cable ducts without minimum spacing requirements

Table 3-1: Laying cables within control cabinets

3.1.2 Laying cables outside of control cabinets

The following rules should be followed when laying PROFIBUS cables outside of control cabinets.

PROFIBUS cables ...

and cables for...	must be laid...
• DC and AC voltages > 400 V (unscreened) • For areas with explosion hazard • Telephone cables	in separate cable runs spaced at least 10 cm apart.

Table 3-2: Laying cables outside of control cabinets

All cable ducts should be constructed of electrically conducting material and connected to functional ground at regular intervals. Bus cables should not be subject to mechanical loads which exceed the manufacturer's specifications. If this cannot be avoided, additional protective measures should be taken, e.g. by laying the cables in a steel pipe or rugged metal duct. The pipe or duct should then be grounded at regular intervals and protected against corrosion.

3.1.3 Laying cables outside of buildings

It is recommended to use fiber optic cables for bus installations which are outside of buildings. In the case of bus cables between buildings which are laid in the ground, you should use a special fiber optic cable type which is suitable for this application. Suitable copper cable types can be used if fiber optic cables cannot be used. Observe the admissible minimum and maximum temperature rating for the type of cable used.

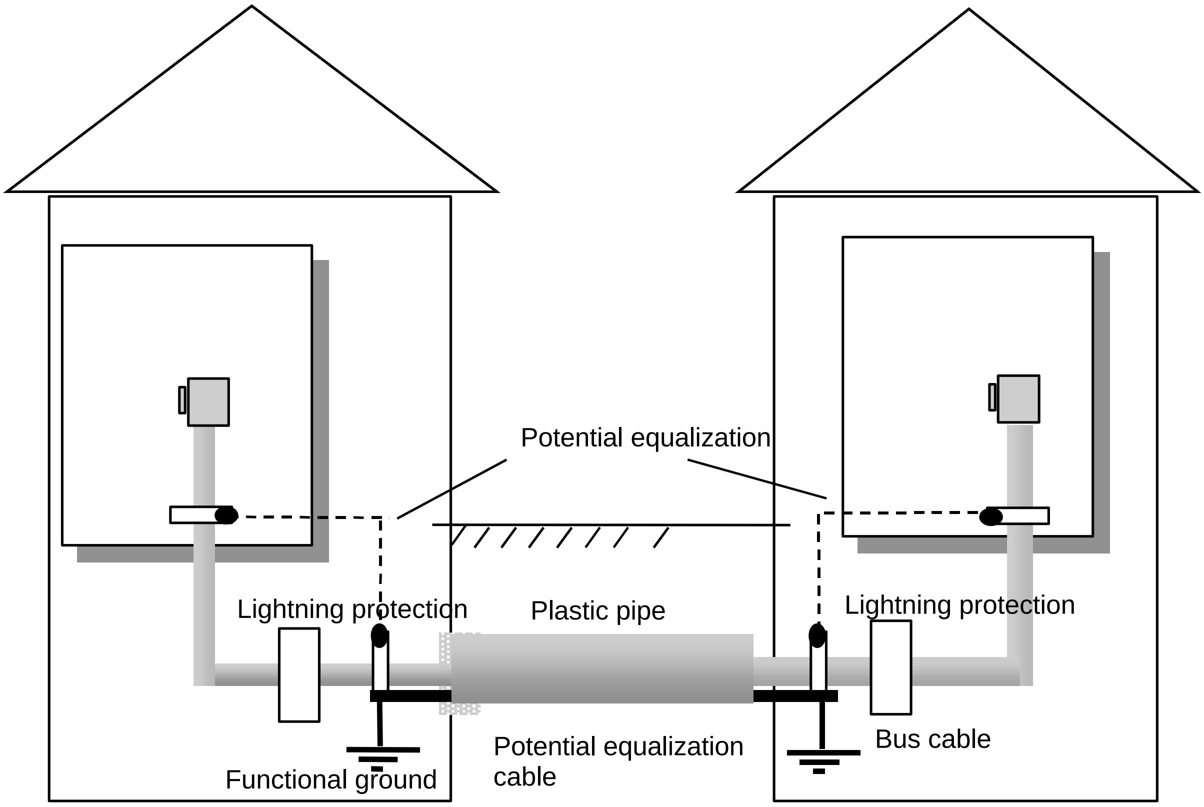


Figure 3-2: Laying bus cables outside of buildings

In principle, the same rules apply to laying cables outside of buildings as within buildings. However, for outside installation, the cables should be provided with additional protection by laying them inside a suitable plastic pipe.

The transition from external to internal cables should always use an auxiliary terminal block. It is used to interconnect the cable for burial in the ground with the standard bus cable. Lightning arrestors should be installed directly where the cable enters the building. In addition, the auxiliary terminal block should contain appropriate circuits to protect against overvoltages (lightning protection).

3.1.4 Potential equalization and screening

The cable screen should be connected to ground at both ends of the cable. The use of fiber optic cable is recommended if problems are experienced with interference. A low impedance potential equalization cable should be used if this is not possible.

Situations where interference can present a problem include:

- Plant which extends over a large area
- Power is fed to the plant from different power sources
- Networking extends over several buildings

If one of these situation apply, the following should be observed when installing the potential equalization system:

- The circuit through which interference signals flow must be closed, and
- Each part of the plant must be electrically connected to the potential equalization system/functional ground at as many places as possible. Electrically conducting pipes, parts of machines or supporting structures should be integrated in the potential equalization system. In order to ensure long-term reliability, appropriate measures should be undertaken to protect against corrosion.
- The potential equalization cable must be protected against corrosion.
- The cross-section of the potential equalization cable should be chosen with regard to the maximum potential equalization currents which can flow.

Special care should be taken when installing potential equalization cables to maximize the interference immunity of the data cables. If possible, the potential equalization cable should be laid parallel to and as close as possible to the data cable (preferably in the same plastic pipe). The cable screen should never be used for potential equalization. The potential equalization cable should be finely stranded to ensure that it is also effective at high frequencies as a result of the large surface area.

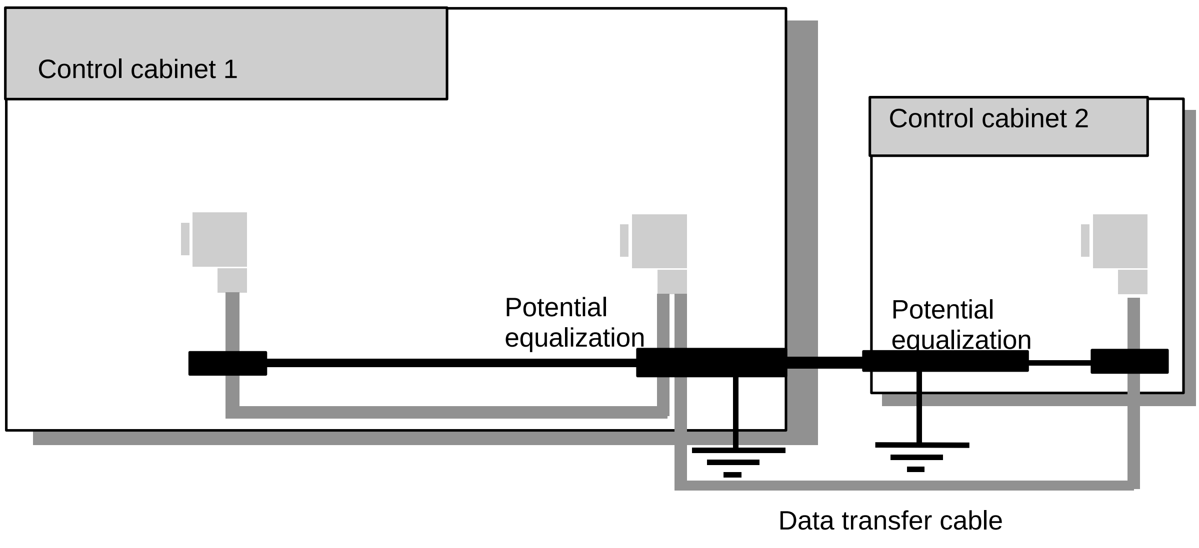


Figure 3-3: EMC-compliant installation of a plant with grounded reference voltage

3.2 Choice of cables and bus connectors

Choice of the appropriate cable and connector types (material, admissible temperature range, protection class, etc.) is dependent on the application. The regularly updated PROFIBUS Product

Catalog which is available from the PROFIBUS User Organization contains details of approved cable and connector types.

In order to be able to connect to fieldbus devices during commissioning and diagnostics through the bus (remote function), it is recommended to provide at least one bus connector per bus segment which has an interface for a programming device.
Before attaching the bus connectors to the bus cable, installation personnel should get information on the mechanical design and function of the connectors. Generally speaking, the data wires are labeled A and B within the connector. Ensure that the same wire color is connected to the same terminal (A or B) for all stations throughout the entire system, both for incoming and outgoing wires (see section 3.1). The cable shield should be electrically connected to the shield grounding clamp over a large area. The shield grounding clamp should be electrically connected to the connector cover. It is recommended to check the resistance between the shield grounding clamp and the connector cover with an ohmmeter. Terminating resistors must be provided at the beginning and end of each bus segment (and only at these positions). Ensure that the signal wires do not contact the braided shield.

The correct method should be used to strip the insulation from a PROFIBUS cable. Ensure that the braided cable shield makes contact over a large area and that the strain relief is fitted correctly. Observe the manufacturer's recommendations.

3.3 Design of an installation with grounded reference voltage

Equipment is normally arranged as a grounded system, whereby the ground of the power feed is connected to the functional ground over a large area (Figure 3-4). As shown in Figure 3-3, the shield of the bus cable is connected to the potential equalization system over a large area where it enters the control cabinet. The potential equalization rail is grounded in each control cabinet and connected to the potential equalization rails of the other control cabinets.

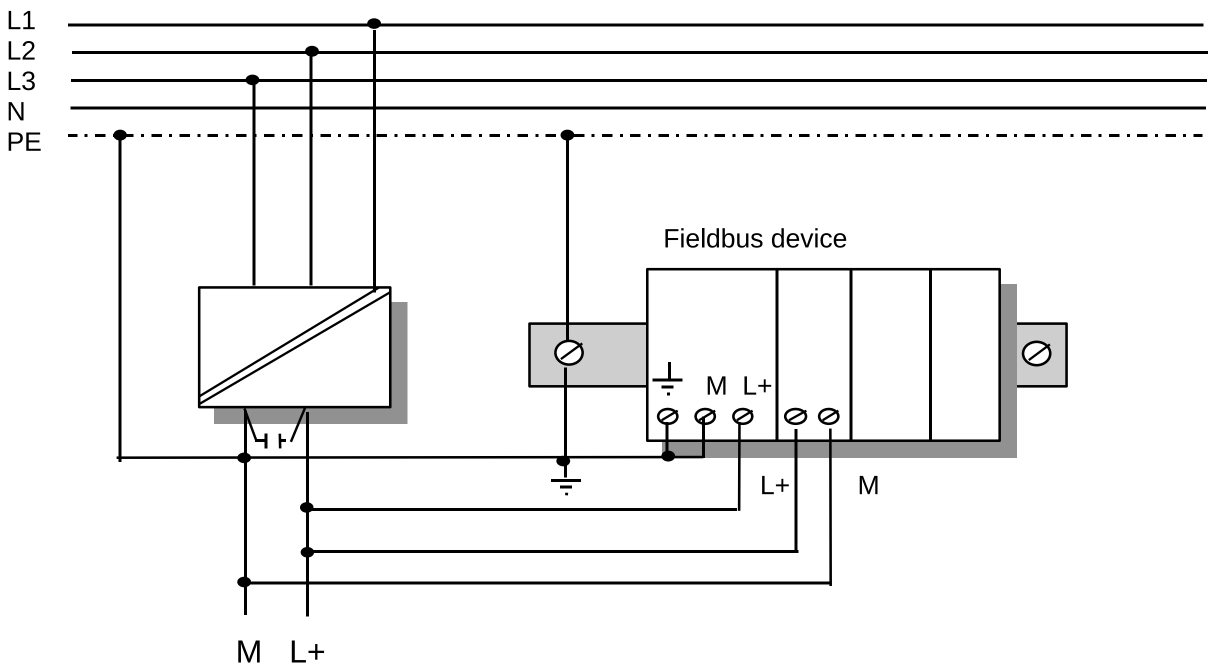


Figure 3-4: Schematic diagram of a plant with grounded reference voltage

3.4 Design of an installation with non-grounded reference voltage

In exceptional circumstances, equipment can be arranged as a non-grounded system. This can be necessary if high short-circuit currents can occur (induction furnaces, etc.). In a non-grounded system, it is necessary to provide an insulation monitoring device with a voltage limiter (Figure 3-5). The term "non-grounded" is also used if an R/C circuit is fitted between ground and PE. Many devices are fitted with an R/C circuit of this type to improve the interference immunity. This should be considered when choosing the earth-leakage monitor. In addition, the non-grounded arrangement ensures that uncontrolled equalization currents do not destroy devices on the bus. The relevant safety regulations must be observed.

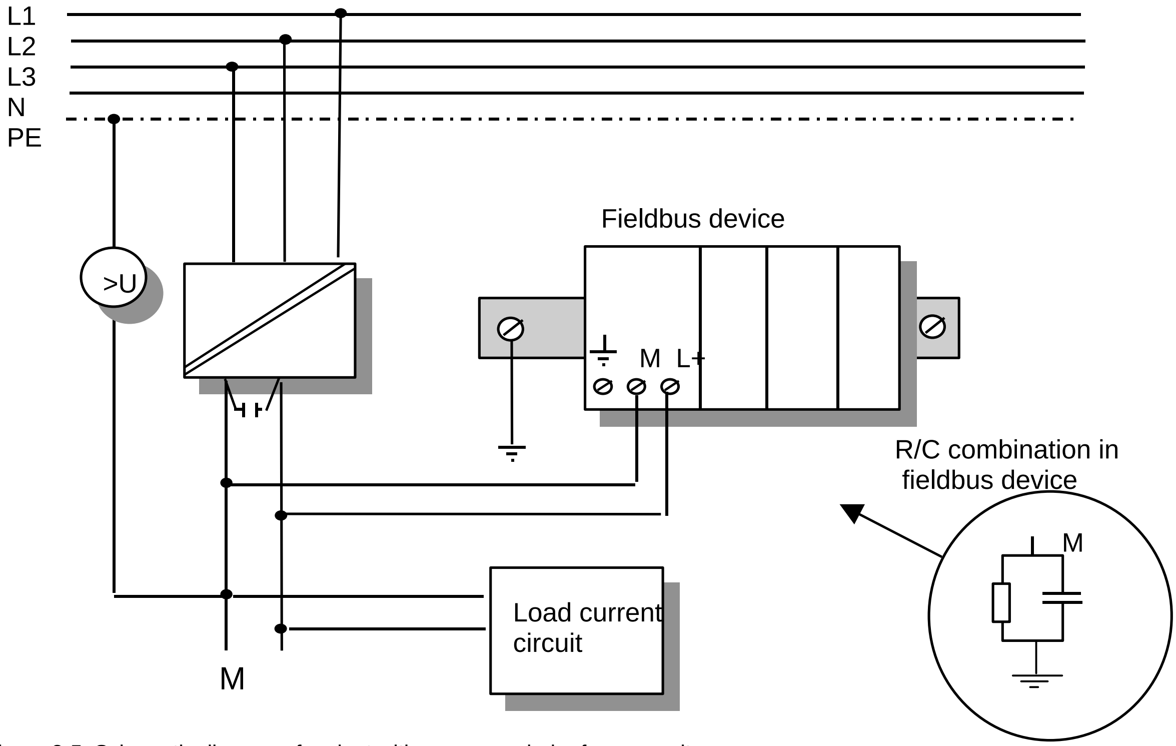


Figure 3-5: Schematic diagram of a plant with non-grounded reference voltage

3.5 Connecting up a repeater

Choice of the appropriate repeater type is dependent on the application. The regularly updated PROFIBUS Product Guide which is available from the PROFIBUS User Organization contains details of available repeater types.

Repeaters are generally supplied with power from an external power source. Repeaters should preferentially be connected as a non-grounded system to allow galvanic isolation between the two bus segments. Observe the manufacturer’s guidelines when installing the repeater.

Repeaters should preferably be mounted in control cabinets on a top-hat rail. When mounting on a top-hat rail, additional grounding measures are not normally necessary if the repeater has a contact spring at the rear to ensure electrical contact to the top-hat rail. If this method of mounting is not possible, the repeater should be grounded using a large-area connection to conductive parts of the equipment. An ohmmeter should be used to ensure that the repeater has a low impedance connection to the functional ground. If the repeater is attached to one of the two ends of the segment, terminating resistors must be fitted to avoid cable reflections.

4 Commissioning of PROFIBUS equipment

The measurements described below allow you to test an installed network and eliminate the most common errors, such as reversal of the cable polarity, short circuits and incorrectly connected terminating resistors.

The measurements should be carried out for each bus segment after installing the PROFIBUS cables and attaching the bus connectors.

When laying cables, changes are often made for constructional reasons to the originally intended cable route. The following measurements are intended to document the actual physical route of the cables and the total bus length together with the lengths of each of the sections.

When the bus is in operation, terminating resistors should only be fitted at each end of the bus segment. When fitting the bus connectors, the bus terminating resistors at the end of the segment are sometimes forgotten and/or additional terminating resistors are inserted within the segment. During operation, this can cause data errors due to reflections at the non-terminated cable ends and/or due to signal attenuation caused by additional resistors. According to the design of the bus connectors, terminating resistors may be permanently installed or switchable or can be disabled/enabled with jumpers. Furthermore, connectors are available both with and without series inductors. Some connector types disconnect the incoming cables from the outgoing cables when the terminating resistors are inserted.

PLEASE NOTE:
The following measurements are not designed to determine the cable lengths to 100 % accuracy; rathermore, the intention is solely to test for correct installation of the bus segment with the help of simple test equipment (general purpose AVO meter). The measurements assume that the same cable and connector types are used within each segment.

It is recommended to document the measurements and file them for future reference, e.g. by entering the resistance values determine with the method in section 4.4 into the equipment report described in section 5.

4.1 Testing the PROFIBUS bus cable and bus connectors

Data errors can occur if the PROFIBUS cable is incorrectly attached to the bus connectors. Such basic errors can be detected and remedied with the simple test method described below.

The test method shown schematically in figure 4-1 allows you to detect data wires which are swapped over in the bus connectors. During the test, the bus connectors must not be connected to any PROFIBUS devices. In addition, all bus terminating resistors should be removed or disabled.

The tests require two 9 pin female Sub-D test connectors. Test connector 1 is provided with a single pole changeover switch, the moving contact of which is connected to the shield (case) of the test connector. The two fixed contacts are connected to pin 3 (data wire B) and pin 8 (data wire A), respectively. Test connector 2 is used to connect an Ohmmeter to the bus.

During the cable tests, the two test connectors 1 and 2 are initially plugged into the two bus connectors at each end of the bus segment. The following tests can be made by taking measurements between the contacts 3 and 8 and the shield of test connector 2 while operating the changeover switch on test connector 1:

- Data cable swapped over
- Open circuit of one of the data cables
- Open circuit of the cable shield
- Short circuit between the data cables
- Short circuit between the data cables and the cable shield
- Additional bus terminating resistors inserted unintentionally

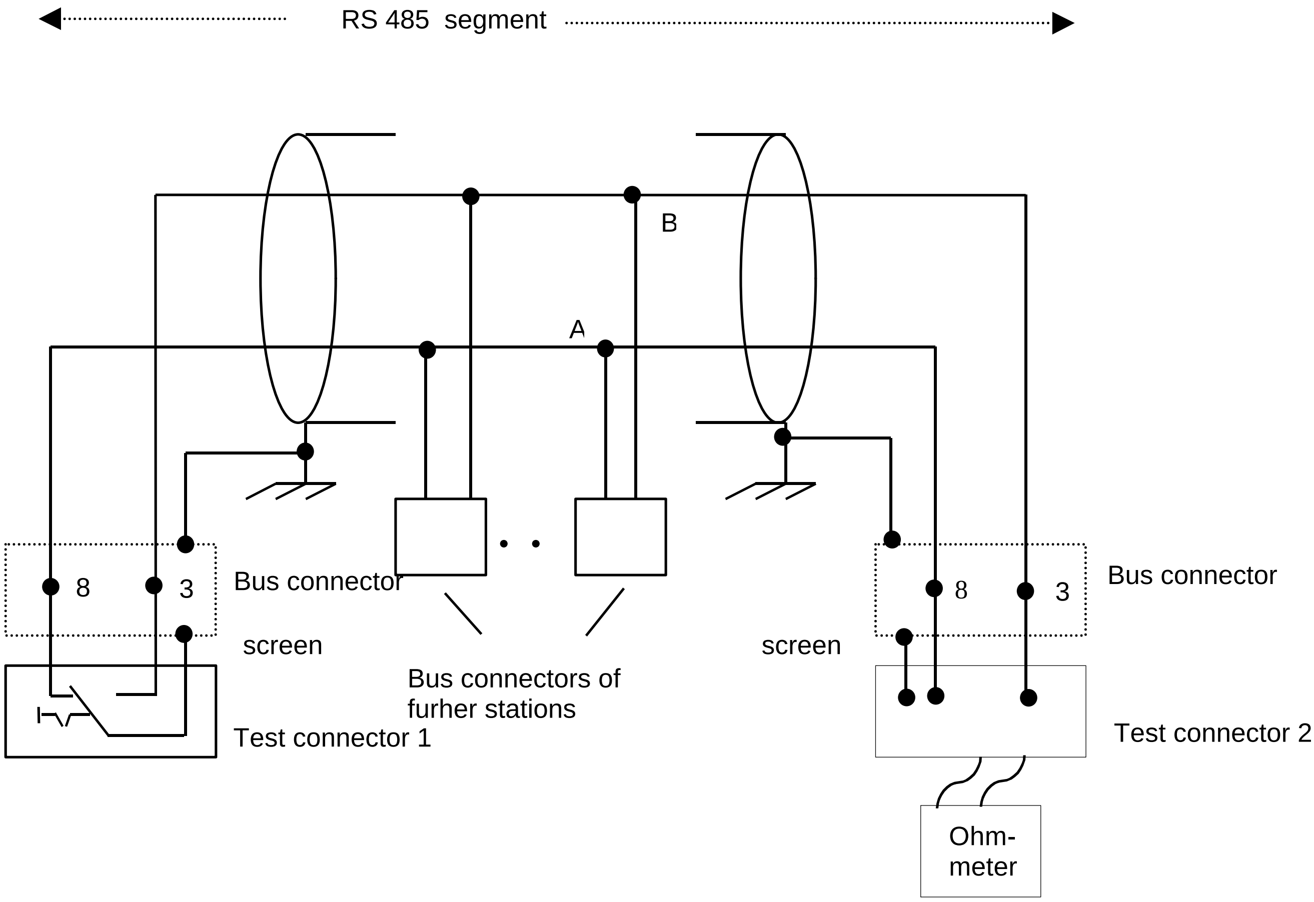


Figure 4-1: Schematic diagram of testing the PROFIBUS cable

Carrying out the tests

Configuration A:
Set switch of test connector 1 to position 3 (connects pin 3 to the screen). Connect ohmmeter to test connector 2 between pin 3 and the screen.

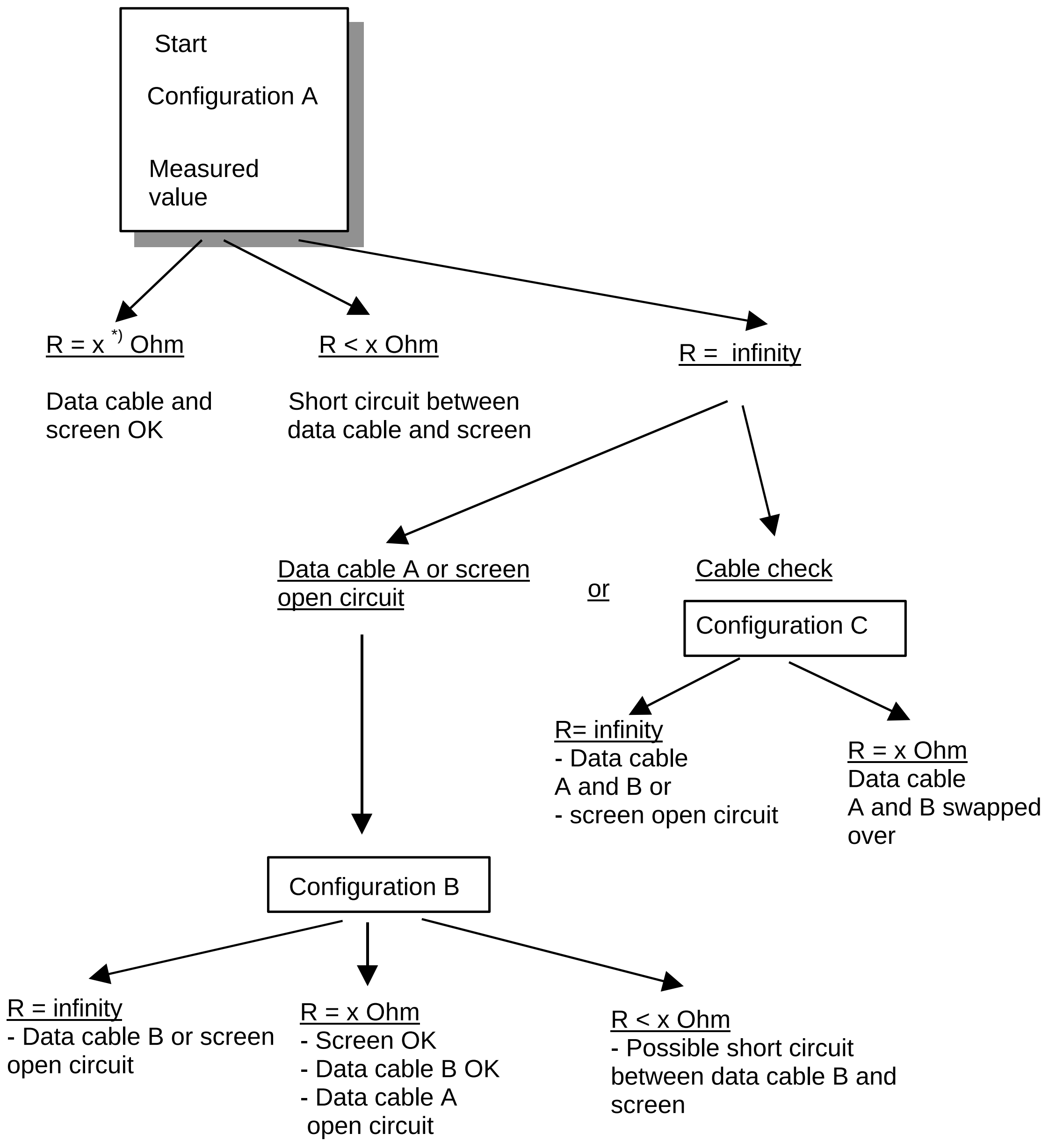
Configuration B:
Set switch of test connector 1 to position 8 (connects pin 8 to the screen). Connect ohmmeter to test connector 2 between pin 8 and the screen.

Configuration C:
Set switch of test connector 1 to position 3 (connects pin 3 to the screen). Connect ohmmeter to test connector 2 between pin 8 and the screen.

Configuration D:
Switch position of test connector 1 is not important. Connect ohmmeter to test connector 2 between pin 3 and pin 8.

Warning: The measured value can be falsified if the ohmmeter connections are touched.

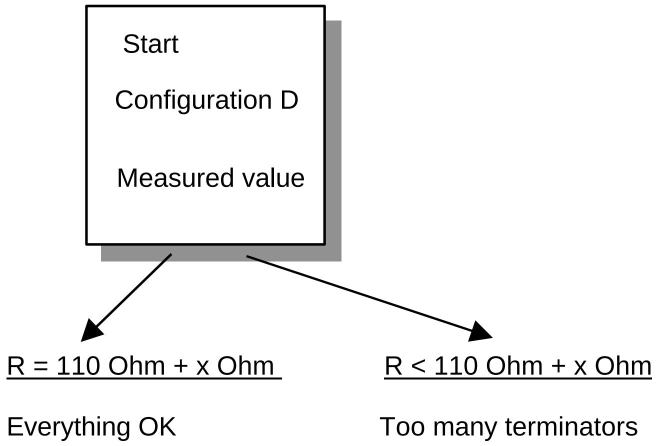
Test 1



x) = 110 Ohm/km.

Test 2: Same as test 1 except configuration A and configuration B are exchanged, i.e. start with configuration B.

Test 3: Too many bus terminating resistors inserted



In order to assess the measurements you make, it is necessary to know the loop resistance of the bus cable segment. This is dependent on the cable typse used and the installed cable length.

The location of a fault can be determined without opening up the bus connectors by unplugging test connector 1 and plugging it into another bus connector which is closer to test connector 2 while carrying out repeated Ohmmeter measurements at test connector 2.

4.2 Determining the loop resistance

PROFIBUS cables of type A have a characteristic loop resistance Rs <=110 Ω/km. This value can differ with special cables and in this case the loop resistance should be determined by measuring a known length of cable. This is done by short circuiting the A and B wires at one end of the reference cable and measuring the resistance between these two wires at the other end.

Loop resistance (Rs Ω/km) = measured value (Ω) * 1000 m / length of reference cable (m)

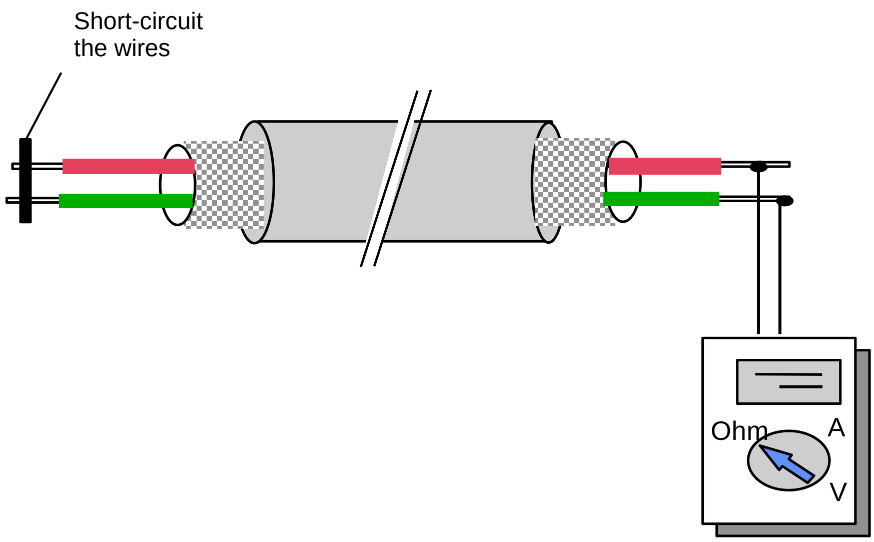


Figure 4-2: Determining the cable length

4.3 Testing for correct bus termination

The bus connectors should be unplugged from all PROFIBUS devices in the segment. Where this is not possible in exceptional cases (e.g. the bus cables are permanently attached to repeaters), the cables must be removed and temporarily connected together to ensure continuation of the incoming and outgoing data wires and shields.

Generally speaking, measurements can be made without opening up the bus connectors, although - depending on the bus connector type - this may still be necessary at the two ends of the segment to allow access to the terminating resistors.

A voltage measurement is first made at the one end of the segment between the A and B wires to ensure that no voltage is present. If a voltage can be detected, it is likely that an active device (e.g. repeater or PROFIBUS device) is still connected to the bus segment. All active devices must be unplugged from the bus segment during the following resistance measurements!

Provided that no voltage is present on the bus, a resistance measurement should be carried out to check whether additional terminating resistors are unintentionally connected to the segment.

During this test, the bus terminating resistors must be removed from both ends of the segment

Standard bus termination connects a resistor of 220 Ohms between the A and B wires.

If the test measurements shows an open circuit between the A and B wires, the cable segment is correctly installed, other possibilities are as follows:

Measured value R ≤ 220 Ω:	One or more additional terminating resistors are inserted in the segment or there is a short circuit between the A and B wires All connectors must be checked.
Measured value R > 220 Ω to < 330 Ω:	If the segment length is max. 10000 m, **one** additional 220Ω terminating resistor is inserted in the segment. The approximate distance X in m of the terminating resistor from the measurement point can then be calculated with X = 1000 * (R - 220) / Rs.

All additional terminating resistors should be removed from the bus segment.

4.4 Determining the segment length and cable route

In order to determine the cable length, the bus terminating resistors should be removed or disabled (check for open circuit between the A and B wires). Following this, the bus segment is **short circuited** at one end and the resistance R between the two data wires is measured at all bus connectors and at all additional connectors. The total cable length can be calculated from the resistance measurements at the far end of the segment. The distance between a particular connector within the segment and the short circuit at the other end of the segment and thus the physical route of the bus cable can be calculated from the resistance measurements at that connector.

If bus connectors are fitted with built-in series inductors, it is necessary to subtract the resulting series resistance as specified by the manufacturer for each connector between the measurement point and the short circuit. In addition, half of this value should be subtracted for the connector at the measurement point itself.

After making these subtractions, the cable length X can be calculated as follows:

X = 1000 * R / Rs.

After finishing the measurements, terminating resistors should be correctly inserted again at both ends of the segment and all bus connectors attached to the corresponding PROFIBUS devices and/or the devices must be re-connected.

4.5 Other test methods

The PROFIBUS User Organisation e.V. has set up a working group to investigate measuring methods and common faults. The results of this working group can be accessed in the Internet at http://www.profibus.com under FAQ.

The following test methods are usually not required if the PROFIBUS segment has been correctly installed. They are mainly needed for additional investigations if problems are encountered with the bus. Accordingly, these methods will only be described briefly.

Note: if bus connectors with an additional Sub-D test tap-off are used, ensure that all 9 pins of the test connection are connected up. This is unfortunately not the case for all types of test connectors.

Signal voltage measurements at the ends of the segments:
Check the DC voltage feed supplied by the two PROFIBUS devices at each end of the bus using a **DC-Voltmeter**.

Logical data traffic with the bus in operation:
This test is carried out with a **PROFIBUS scope**, which consists of software and a plug-in card for a PC or a PCMCIA card. If possible, the test connection to the bus should use an active tap off.

Signal waveform with the bus in operation:
This test is carried out with a **storage oscilloscope.**

Faults due to reflection or injected interference, direct measurement:
This test is carried out with a **PROFIBUS cable tester** through which the bus is looped. This requires the bus to be interrupted briefly. Measurements are also possible without interrupting the bus by using a short active tap off.

Faults due to interference injection during bus operation, indirect measurement:
This test is carried out with an **electrical field meter** or **magnetic field meter (Tesla meter)** using sensors on the bus cable.

Current flow through the shield of the PROFIBUS cable due to potential equalization currents:
This measurement is made with the bus in operation using a **clip-on ammeter.** If possible you should use an ammeter type which measure TRMS to ensure that non-sinusoidal currents and frequencies higher than 50 Hz are also measured (this is particularly relevant if the bus is installed in the vicinity of a frequency inverter).

5 Equipment report

It is recommended to make an equipment report for each bus segment similar to the example below to ensure that documentation is available later in case of faults.

Plant section: Example equipment

Segment no. 1 **Data transfer rate (in kbit/s):** 1500

Resistance value (pins 3/8) in Ohms 230

Cable type	Distance in m	Connector type	Address	Device	Symbolic name
	70				
		GER+	1	SPS	Master controller 1
STD	20				
		GER	4	200B16DI	Inputs
FLEX	10				
		GER+	6	AG95U	Slave controller
STD	20				
		Repeater			>>>>**to segment no. 5**
STD	20				
		GER	8	TR transducer	Position measurement

Figure 5-1: Equipment report

Legend for Figure 5-1

STD: Standard cable from the "xy" company
FLEX: Flexible cable
GER+: Connector, top entry, with integrated tap-off for programming device
GER: Connector, top entry
Rep: Repeater

You can use the blank report form on the next page to make your own equipment report.

Plant section:

Segment no. **Data transfer rate (in kbit/s):**

Resistance value (pins 3/8) in Ohms

Distance in m **Address**

Cable type **Connector type** **Device** **Symbolic name**

6 Test and diagnostics equipment

The regularly updated PROFIBUS Product Guide which is available from the PROFIBUS User Organization contains details of available test and diagnostics equipment.

7 Further information

The GSD (device master data) files required to set up your PROFIBUS network can be downloaded from the Internet at http://www.profibus.com

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