



APPLICATION GUIDELINE

SPECIFICATION PROPOSAL FOR PROFIBUS PA

Based on international and European standards

PROFIBUS PA is used in a wide range of different application. Typically for each application a dedicated specification is required.

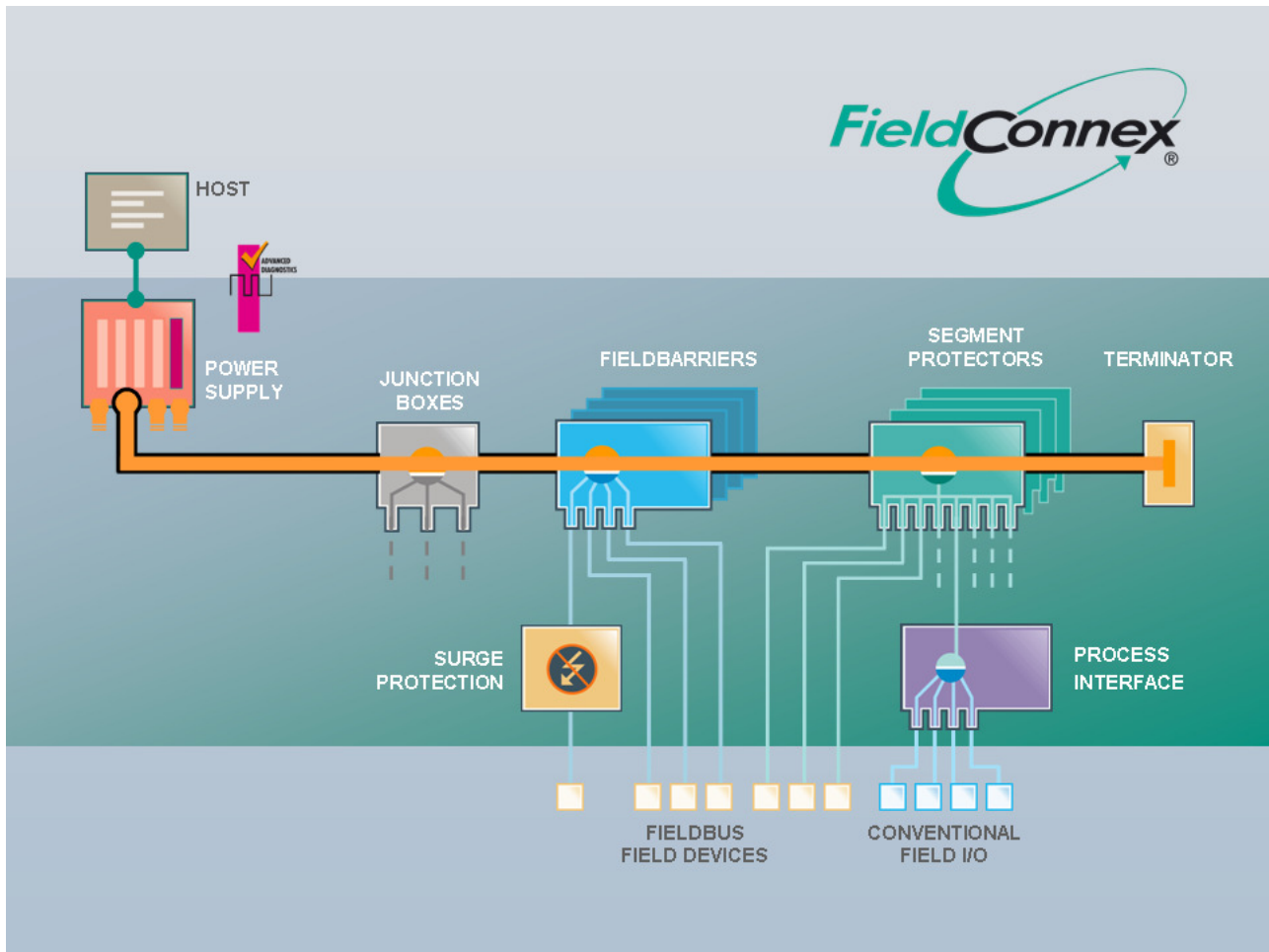
This document is a guideline regarding physical layer parameters. It serves as a cookbook recipe for the preparation of requests for proposals and quotations. It provides guidelines so that constraints are met, which have to be observed for successful planning of PROFIBUS PA infrastructure. Special focus is given to application in hazardous areas zone 0, 1 and 2.

This document is based on IEC and European standards and directives like ATEX, EC etc.

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Pepperl+Fuchs is the proven market leader for innovative and highly available components for your fieldbus according to IEC 61158-2. With quality components to fit your process automation system and demands in the field our highly reliable and energy-efficient design allows you to focus on the task at hand. Knowing that your fieldbus is running.

The High-Power Trunk Concept with Entity or FISCO devices: Connect the maximum number of devices to the same fieldbus trunk; and at the same time make use of maximum cable lengths. This concept utilizes standard power supplies such as the easy to install and configuration free Power Hub. Segment Protectors and FieldBarriers are installed close to field devices and limit the energy at the spur. You are free to work on field devices without hot work permit.

Advanced Diagnostics: Take control of your fieldbus installation. This latest innovation brings transparency to fieldbus. Speed up commissioning with automated documentation. Measure fieldbus performance and detect changes in the control room before they become critical to your plants operation.

You can rely on products built to serve your every need in fieldbus for process automation. You can gain from the experience of knowledgeable engineers to create your fieldbus solution. You can be at ease with products and solutions from Pepperl+Fuchs.

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1. Scope

This document

- defines PROFIBUS PA system design requirements for the physical layer
- gives information which additional requirements needs to be defined.
- is based on international and European standards where hazardous area applications are concerned.

2. Purpose

The purpose of the document is to define the PROFIBUS PA system design requirements to:

- Ensure consistency across the entire project.
- Minimize the validation requirement.
- Minimize commissioning related problem.

3. Definitions and Abbreviations

3.1. Definitions

3.1.1. General

- Shall refers to a mandatory requirement
- Should refers to a recommendation
- May refers to one acceptable course of action

3.2. PROFIBUS PA Definitions

The following table explains definitions of Fieldbus terms used within this procedure.

Terms and definitions:

Term	Definition
Bus	A Fieldbus cable between a host and field devices connected to multiple segments, normally through the use of repeaters.
Control loop	A Control loop contains all field instruments which are needed to close the loop (Sensor and actuator). E.g. Pressure transmitter and valve.
DP/PA gateway	A device which converts the PROFIBUS DP protocol to PROFIBUS PA protocol. It adopts e.g. transmission speed and converts from an asynchronous to synchronous telegram format.
DP Slave	A field device which is directly connected to PROFIBUS DP.

Term	Definition
Fieldbus	A Fieldbus is a digital, two-way, multi-drop communication link among intelligent measurement and control devices. It serves as a Local Area Network (LAN) for advanced process control, remote input/out and high-speed factory automation applications.
Fieldbus Power Supply	A device which switches the power supply onto the PROFIBUS PA cable. All PA devices will be powered from this device.
FISCO Fieldbus Intrinsically Safe Concept	Allows more power to an IS segment for approved FISCO devices, allowing for more devices per IS segment. Avoids the need to calculated inductances and capacitances for the proof of intrinsic safety.
Interchangeability	Interchangeability is the capability to substitute a device from one manufacturer with that of another manufacturer on a Fieldbus network without loss of functionality or degree of integration.
Master class 1	PROFIBUS DP Master which is typically responsible for the cyclic data exchange of process variables. Typically it is a part of the CPU
Master class 2	PROFIBUS DP Master which is typically used for configuration and parameterization of field devices. Additionally it will be used for maintenance purposes and will be linked or is a part of the Asset Management System. typically it is a PC or Workstation with an integrated PROFIBUS DP interface.
Monitoring loop	Contains Field devices whose values are not used in control loops.
PA device (Fieldbus device)	A field device which is connected directly to a PROFIBUS PA fieldbus.
Segment	A Segment is a section of a fieldbus that is terminated in its characteristic impedance. Segments can be linked by devices to form a longer fieldbus segment.
Segment Coupler	A device which converts from PROFIBUS DP to PROFIBUS PA and vice versa. Typically it consist of a DP/PA gateway and Fieldbus Power Supplies.
Spur	A Spur is a fieldbus branch line connecting to the trunk that is a final circuit.
Terminator	A Terminator is an impedance-matching module used at or near each end of a transmission line. Two Terminators must be used on each fieldbus segment.
Topology	The Segment structure; Tree, Daisy Chain, etc. are examples.
Transmitter	A Transmitter is an active PROFIBUS PA device containing circuitry, which applies a digital signal on the bus.

Term	Definition
Trunk/Home-run	A Trunk is the main communication highway between devices on an PROFIBUS PA network. The Trunk acts as source of main supply to Spurs on the network.

Table 1: List of used terms

3.3. Abbreviations

The following list gives the used abbreviations in this document.

Abbreviations:	Abbreviations	Description
	AI	Analog Input
	AO	Analog Output
	AWG	American Wire Gauge
	CCR	Central Control Room
	CPU	Central Processing Unit
	DCS	Distributed Control System
	DI	Discrete Input
	DD	Device Description
	DO	Discrete Output
	DTM	Device Type Manager
	EI	Early Involvement
	EC	Engineering Contractor
	FCS	Field Control Station
	FCU	Field Control Unit
	FDT	Field device Tool
	FGS	Fire & Gas Detection System
	FISCO	Fieldbus Intrinsic Safety Concept
	FPS	Fieldbus Power Supply
	GSD, GSE	Geraetestammdatendatei, a form of electronic data sheet which is required for configuration of the cyclic data exchange.
	HART	Highway Addressable Remote Transmitter
	HIS	Human Interface Station with having system builder function
	I/O	Input/Output

Abbreviations	Description
IS	Intrinsic Safety
LAN	Local Area Network
MOV	Motor Operated Valve
MVC	Transmitter Measurement, Validation & Comparison
PID	Proportional/Integral/Derivative Control
PMC	Project Management Contractor
PLC	Programmable Logic Controller
PRM	Plant Resource Manager
RIO	Remote I/O system
UOM	Units of Measurements
SIS	Safety Instrumented system
UPS	Uninterrupted Power Supply

Table 2: List of abbreviations

4. FIELDBUS SYSTEM OVERVIEW

4.1. Project Objectives

The Distributed Control System should be based on the Open System Architecture concept with PROFIBUS interfacing capabilities to smart devices in the field.

Key driver for this technology is the ability to realize an infrastructure that is ready to implement diagnostics/advanced diagnostics and asset management capabilities and to be prepared for predictive/proactive maintenance. Guidelines provided in this document are intended to design the Fieldbus based system with minimum risks and no errors.

4.2. Overall System Configuration

4.2.1. General

A Fieldbus system refers to a control system that uses a digital, two-way, multi-drop communication link among intelligent measurement and control devices. It serves as a Local Area Network (LAN) for advanced process control, remote I/O and high-speed factory automation applications. With the DCS system, it is possible to build a Fieldbus system according to the Process Automation requirements and to operate and monitor processes in the same manner as conventional solutions did in the past.

The following figure shows a typical PROFIBUS structure:

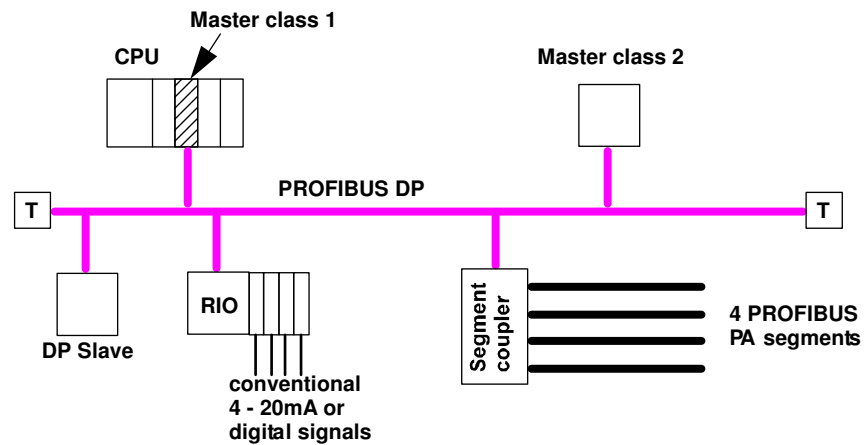


Figure 1: Typical PROFIBUS structure

4.2.2. Integration of Control Function in DCS Controller

PROFIBUS is using a hybrid access procedure, a mixture of Master/Slave and Token passing procedure.

All process variables will be transmitted to the Master class 1 which is part of the CPU. The CPU is a part of the PLC or DCS system. Depending on this all control related functions are an integral part of the PLC or DCS.

4.2.3. Integrated Engineering Function in DCS

The DCS shall be able to integrate the fieldbus system functions, such as configuration of PROFIBUS DP/PA segments, integration of DP and PA devices and control drawings containing function blocks.

In addition, a Plant Resource Manager (PRM) or Asset Management function shall be provided. This function is not directly related to above engineering, operation and monitoring functions, but is a maintenance related function with long-term data storage capability.

These functions will efficiently handle PROFIBUS device maintenance management.

Such systems also supports traditional analog devices, Remote I/O systems and HART devices and can provide integrated management of PROFIBUS and HART devices.

A typical PROFIBUS structure for general purpose application is shown in figure 2:

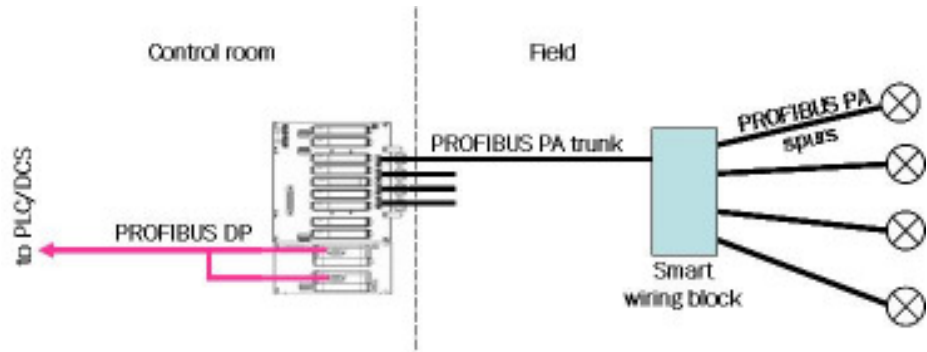


Figure 2: Typical PROFIBUS structure for general purpose application

A typical Fieldbus structure for Zone 2 application (High Power trunk/Ex nL or Ex ic) is shown in figure 3:

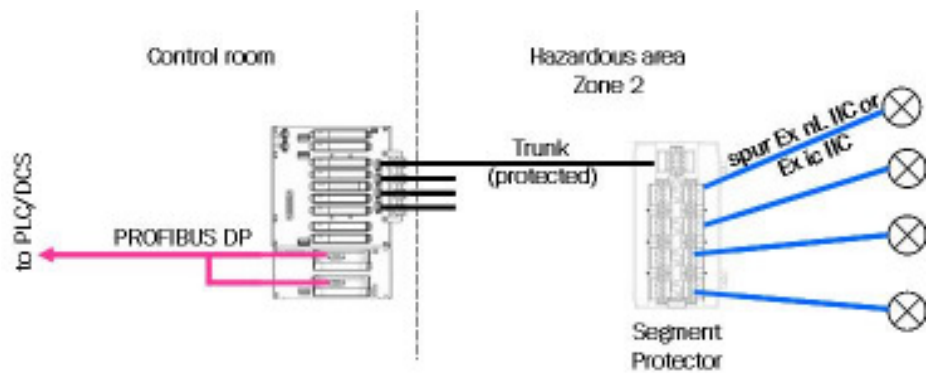


Figure 3: Typical PROFIBUS structure for Zone 2 application

A typical Fieldbus structure for a Zone1/ Zone 0 application, using intrinsic safety as explosion protection method, is shown in figure 4 (High Power trunk/Ex ia IIC)

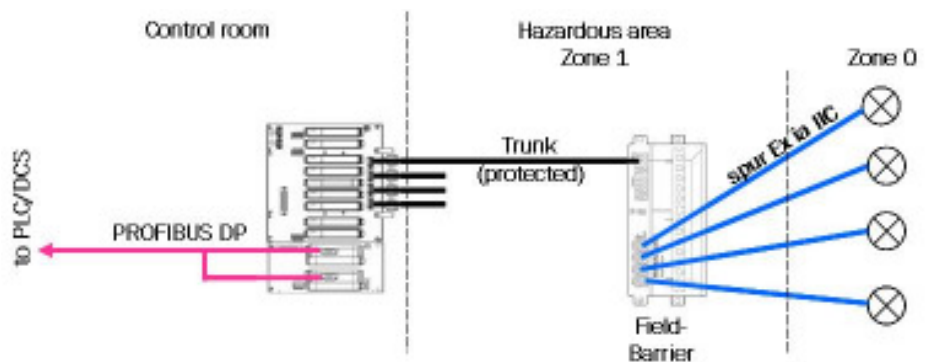


Figure 4: Typical PROFIBUS structure for Zone 1/ Zone 0 application

5. FIELD SYSTEM DESIGN GUIDELINES

5.1. General

PROFIBUS PA is an all-digital, serial, two-way communication protocol that connects field devices (instruments), such as sensors, actuators, and controllers. PROFIBUS PA enables advanced diagnostics from all fieldbus components including the physical layer. This allows higher plant availability. A typical Fieldbus installation provides connection from a network of field devices via a segment coupler to a host system via a two way, serial communication link. The cabling and connections are arranged in a multi-drop fashion, requiring only a single pair cable with parallel connections to field devices. PROFIBUS PA is different from the traditional approach of connecting 4 to 20 mA devices to a DCS/PLC system using dedicated pairs of wires for each device.

Each Fieldbus running from the segment coupler to the field is known as a segment (see figure 2 to figure 4). Each segment consists of a trunk or home-run, running from the segment coupler to the processing plant with parallel connected spurs linking to field devices such as transmitters and control valves. Smart wiring blocks with integrated short circuit protection, such as Segment Protectors or FieldBarriers, protect the trunk against short circuit on a spur. Such protectors are preferred to connect the individual instruments to the trunk.

The interconnection from a PROFIBUS PA trunk to PROFIBUS DP is realized with a segment coupler. The segment coupler

- converts the PROFIBUS PA physics based on the IEC 61158-2 to the PROFIBUS DP physics based on RS 485.
- adapts the transmission speed of 31.25 kbit/s (PROFIBUS PA) to the adjusted transmission speed of PROFIBUS DP (9.6 kbit/s to 12 Mbit/s).
- converts the synchronous data transmission of PROFIBUS PA to asynchronous data transmission of PROFIBUS DP

All above described functionalities are working from PROFIBUS PA to PROFIBUS DP and vice versa.

Additional the segment coupler provides conditioned power to the trunk and all devices on the PROFIBUS PA segment.

5.2. Fieldbus Application

The use of PROFIBUS PA shall be maximized for all regulatory process control devices where a suitable PA device is available and in addition, shall also apply to all Packaged Equipment (except in those packages with their own PLC).

PROFIBUS PA shall not be used for the following applications:

- Emergency Shut Down System and Fire & Gas Detection System signals due to safety reasons.

5.3. Field Device Selection

5.3.1. Interoperability

PROFIBUS PA devices must be interoperable with the DCS/PLC. This eliminates the proprietary protocols and custom software drivers and maximizes the benefits of the advanced diagnostic features of Fieldbus. To ensure full interoperability, all PA devices shall be supplied with the gsd and, if required, the DD file or DTM and firmware revisions.

Based on the above objective, the following selection method shall be applied for PA devices excluding valve positioners (in order of preference):

- 1st Selection DCS PA devices.
- 2nd Selection Other PA devices.

Similarly, the selection method for valve positioners shall be as follows (in order of preference).

- 1st Selection valve positioner from other vendors
- 2nd Selection DCS valve positioner

Any other PA device and/or positioner shall, as a minimum, have the following features available:

- PROFIBUS PA Certification
- The PA Device shall be capable of performing continuous diagnostics, including self-test functions, to provide specific diagnostic information to the Asset Management System.

In addition a sample device of each instrument type shall be submitted to DCS/PLC Supplier for interoperability testing with both the DCS/PLC and Asset Management System. On successful completion of these tests, the DCS/PLC vendor or EC shall provide the necessary approval for use and shall update the "Approved Device Listing".

The DCS/PLC vendors are responsible for getting all necessary data for the "Interoperability Tests" and coordinating with the instrument vendors to successfully complete the tests.

5.3.2. Field Device Management

Each device's fieldbus address and Physical Device (PD) Tag must be set prior to installation to enable connection of multiple devices during construction and commissioning. Either the Device manufacturer prior to shipment or the Subcontractor prior to connection shall do this.

5.3.3. Field Device Power

PROFIBUS PA devices are normally powered from the segment. Bus-powered devices typically require 10-25 mA of current at between 9 and 32 volts, but devices requiring more than 25 mA shall be subject to approval.

PA devices can be polarity sensitive and therefore wiring polarity shall be maintained for all devices.

5.3.4. Device Upgrading

PA device firmware changes can be made while the hardware is left unchanged. To accommodate easy device upgrading, devices shall be specified with flash memory capabilities, so that upgrades can be done on-line.

Furthermore, it is important to document each devices GSD and DD or DTM revision.

5.4. Segment Coupler

The segment coupler is the core of every PROFIBUS PA installation. The functionalities are described in General. Typically a Segment Coupler consists of a (redundant) gateway and separate fieldbus power supply modules. When required the fieldbus power supply modules could be redundant

To avoid any problems in terms of

- Availability
- PROFIBUS PA cycle time
- Limitation in data volume to be transmitted via the Segment Coupler.
- Communication between Master class 1 or Master class 2 and a PA devices

the Segment Coupler shall support the following functionalities:

- Transparent communication between Master class 1 or Master class 2 and PROFIBUS PA devices.
- Single or redundant gateway
- One integrated PROFIBUS PA Master per segment. In case of a redundant gateway the integrated PROFIBUS PA master shall also be redundant.
- Single or redundant fieldbus power supply module(s) per segment.

5.5. Segment Grouping

In order to maximize the benefits of the PA technology, all devices of a particular loop should be connected to the same PROFIBUS DP master class 1. However, in order to minimize the effect, this is not a mandatory requirement, but shall be followed where possible, without incurring excessive cable run lengths.

5.6. Segment cycle times

The PROFIBUS PA cycle times need to be defined. Up to 70% of the cycle time could be used for cyclic data exchange and at least 30% of the cycle time should be free for acyclic communication.

The cycle times depend on

- The process
- Number of instruments in the segment
- Type of loop

The following differentiation between type of loops is recommended:

- Control loops

- Monitoring loops

Segments containing control loops should have a shorter cycle time than segments which only contain monitoring loops. An approximate calculation of the PROFIBUS PA Segment cycle time could be done by using the following equation:

$$t_{PA_cycle} = n * (0.256 \text{ ms} * L + 12 \text{ ms}) + 40 \text{ ms}$$

with

t_{PA_cycle} = PROFIBUS PA cycle time

n = Number of connected PA instruments on this segment

L = The effective data length. L is a unit less variable calculated as the average input and output data quantity (in bytes) of all devices.

Example: In case of 20 PA instruments connected to a single segment and each instrument is transmitting 5 Byte data, independent of input or output, the PA cycle time will be approximately 305.6 ms.

5.7. Hazardous Area Classification

Hazardous area protection depends on the application and shall be as follows:

Zone 0

- Intrinsic Safety shall be the preferred explosion protection method for Zone 0 applications. The field device shall be marked accordingly. Minimum requirement is Ex ia IIC (Temperature class must be defined).

Zone 1

- Intrinsic Safety shall be the preferred explosion protection method for Zone 1 applications. The field device shall be marked accordingly. Minimum requirement is Ex ib IIC, better Ex ia IIC (Temperature class must be defined).

Zone 2

- Intrinsic Safety shall be the preferred explosion protection method for Zone 2 applications. The field device shall be marked accordingly. Minimum requirement is Ex ic IIC, better Ex ia IIC or Ex ib IIC (Temperature class must be defined). Energy limitation (Ex nL) can be used where intrinsic safety is not possible. The field device shall be marked accordingly. Minimum requirement is Ex nL IIC better Ex ia/ib/ic IIC.

Attention:

In July 2006 the 5th edition of the IEC 60079-11 was published. This edition contains the type of protection “Ex ic” as an alternative to “Ex nL” according to the 3rd edition of IEC 60079-15 for Zone 2 application. Due to harmonization “Ex nL” remains in the 3rd edition of IEC 60079-15 for an interim time until the 4th edition is published (probably in 2011) but will not be a part of the 4th edition anymore. Under the aspects of the ATEX directive 94/4/EC as a consequence vendors are

not allowed to sell new “Ex nL” components after the 4th edition of IEC 60079-15 has been published. Just replacement business can be maintained.

It is strongly recommended (if available) to use “Ex ic” or higher classified components for Zone 2 application to avoid in future any trouble with spare parts and/or further extensions, since it is expected that device vendors will switch soon their product portfolio to “Ex ic” compliant devices. In case “Ex nL” instrumentation will be used the installation shall be prepared for the “Ex ic” enhancements in the near future. One installation aspect is for example that “Ex nL/Ex ic” wires shall be installed separated from non-intrinsically safe ones.

Intrinsic Safety and Energy Limitation are the only explosion protection methods which allow live maintenance on the spur without additional, mechanical explosion protection methods or gas clearance certificate.

All devices shall be at least ATEX, Factory Mutual, UL, CSA and/or CUL or comparable certified and labeled for the required area classification where they will be installed.

To reduce the required proof of intrinsic safety down to the absolute minimum FISCO certified field devices are preferred, when FISCO devices are not available Entity certification will also be accepted. To keep the selection of the appropriate barrier for Zone 1/ Zone 0 applications simple, the barrier outputs shall be certified in accordance to FISCO **and** Entity.

5.8. Critical Loop definition and Application

In an application there are typically loops available with different levels of criticality. These levels need to be defined. The following paragraphs can be recognized as an example.

The level of criticality shall be shown on both the segment and loop drawings.

5.8.1. High Criticality Loop

Definition:

A failure of a high criticality loop will result in a total system trip, causing a shutdown of the entire unit, or other unavoidable losses in excess of e.g. \$10M. Normal positioner failure mode is to be used for this classification.

5.8.2. Medium Criticality Loop

Definition:

Failure of a medium criticality loop will result in a total system trip, causing a shutdown of the entire unit, or other unavoidable losses in excess of e.g. \$100K. However, the medium criticality loop positioners' process dynamics allow time for quick recovery from the failure, either by quickly fixing a fault or by taking manual control. The difference in high and medium criticality loops are dependent on operations ability to respond to a single failure.

5.8.3. Low Criticality Loop

Definition:

Failure of this Positioner will not result in any short-term risk of total unit shutdown or major operating losses. Low criticality loop valves can go to their fail position without requiring immediate operator action.

5.9. Redundancy

Redundancy is required at least for segments which contain high criticality loops. To enhance the overall availability the following redundant equipment shall be incorporated within the host system, DCS, EC:

- Redundant DCS Bulk Power Supplies with 30-minute battery backup (UPS).
- Redundant DCS System Controller Power Supplies.
- Redundant DCS System Controllers.
- Redundant Master class 1 as preferred option (not mandatory).
- Redundant PROFIBUS PA Power Supplies / Power Conditioners serving 1 segment per pair of Power Supplies/Power Conditioners as a preferred option.
- Redundant PROFIBUS PA Master

Additionally at least segments which contain high criticality loops shall be monitored continuously by an advanced physical layer diagnostic module.

5.10. Physical Device Loading Requirements on PROFIBUS PA

5.10.1. General Requirements

PROFIBUS PA supports up to 32 devices per segment. This includes the PA Master integrated in the Segment Coupler. The field devices shall be bus powered by the fieldbus cable.

There are limitations which need to be observed:

- DCS/PLC related limitations
- Physical layer related limitations

5.10.1.1. DCS/PLC related limitations

The DCS/PLC could limit

- The Number of addressable nodes. Typically PROFIBUS supports the address range from 0 to 127. Address 127 is a broadcast message which is not usable as a device address. Address 126 is the default address of every PROFIBUS PA device. Therefore this address shall also not be used for normal operation to ensure an easy exchange of a PROFIBUS PA instrument. When address 126 is not in use a new PA instrument could be readdressed via the bus.
Depending on this there are 126 (address range 0 to 125) addresses free for use. This includes the addresses of all PROFIBUS DP Master (Master class 1 and 2).
It is recommended to use address 0 for Master class 2 (maintenance station) and the addresses 1 and 2 for Master class 1. This address setting will cover also the case of a redundant Master class 1.
The addresses of the (redundant) PROFIBUS PA Master must **NOT** be taken into account because these addresses are not visible on the PROFIBUS DP side. Typically the default addresses of the PROFIBUS PA Master are 1 (main master) and 2 (redundant master). This avoids also

any conflicts with field device addresses, independent of if the devices are connected to PROFIBUS DP or PROFIBUS PA.

- Amount of data per PROFIBUS telegram. PROFIBUS supports up to 244 bytes per telegram. The PROFIBUS DP master shall support this data volume.

These limitations have to be observed.

5.10.1.2. Physical Layer related limitations

Field devices shall be supplied from the fieldbus cable. The average current, drawn by the field devices connected to the same segment is, depending on the type of field devices, between 12 mA and 18 mA per field device.

Depending on the limitations explained in chapter 5.10.1.1, it is not recommended to connect more than 22 field devices per segment (including required spare see Segment Spare Philosophy Requirements). To avoid any additional limitations, the Fieldbus Power Supply shall support a supply current of at least 500 mA.

In case it is ensured that the required supply current per segment is less or equal to 350mA (including required spare) Fieldbus Power Supplies with a supply current of 360mA are acceptable.

An additional limitation is given by the IEC 61158-2 standard. This standard defines the maximum spur cable length as a function of connected nodes to the segment. The PROFIBUS PA master(s) counts as a node. The following table shows the definition made within the IEC standard:

Number of addresses in use	Maximum spur cable length
1 -12	120m
13 - 14	90m
15 - 18	60m
19 - 24	30m
25 - 32	≤ 1m

Table 3: Maximum spur cable length in accordance to IEC 61158-2.

5.10.2. Requirements for Safe Area Application

To avoid a breakdown of the entire segment due to a short on a spur or a field device, the Wiring Blocks shall support short circuit protection (Segment Protectors). The Segment Protectors shall support a supply current of 40mA and the short circuit current shall be limited to no more than 60mA.

In case of a distributed segment architecture (two or more Segment Protectors per segment) the trunk shall be able to be disconnected without interrupting the communication to the following Segment Protectors.

5.10.3. Requirements for Zone 2 application

To avoid limitations in the no. of connectable field devices standard Fieldbus Power Supplies with a minimum supply current of 360mA (500mA) shall be used. The trunk shall be installed in accordance with IEC 60079-14.

The IEC 60079-14 standard defines the following installation requirements for Zone 1 **and** Zone 2 applications:

- The cable needs to be protected against
 - mechanical damaging
 - chemical influences
 - corrosion
 - effects of heat
- Allowed cable materials are
 - Thermoplastic sheathed cables
 - Thermosetting sheathed cables
 - Elastomeric sheathed cables
 - Mineral insulated metal sheathed cables, e.g. armored cables.

To allow a simple live maintenance capability the field devices shall be certified Ex nL or Ex i. The Segment Protectors shall be certified Ex nA [ic] or Ex nA [L]. The requirements given in chapter 5.10.2 are also valid for Zone 2 application.

5.10.4. Requirements for Zone 1/ Zone 0 application

There are two solutions available for Zone 1/ Zone 0 applications

- High Power Trunk concept
- Full FISCO solution

The following figures show the structures of both solutions:

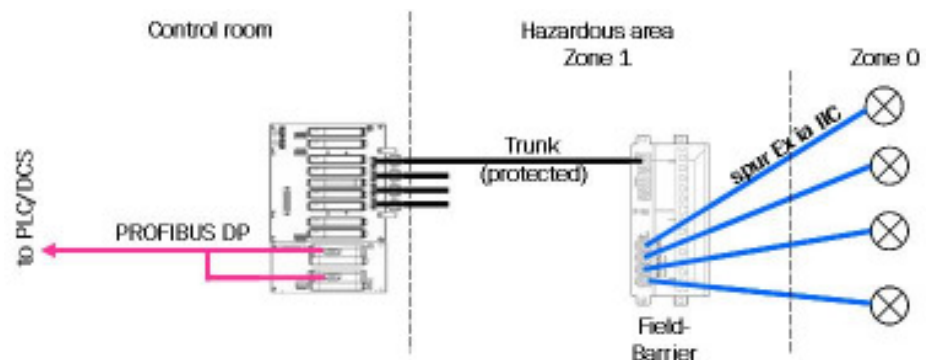


Figure 5: Structure High Power Trunk Concept

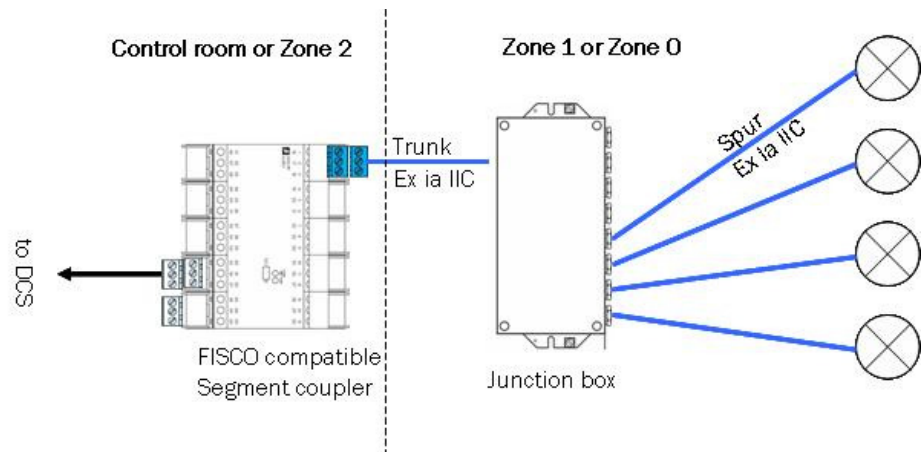


Figure 6: Structure Full FISCO System

The typical supply current of FISCO compatible Segment Coupler (EEx ia IIC) is 100mA. The typical supply voltage of this component is 12.8 vdc. These limitations do mean:

- The number of field devices per segment is reduced (depending on the real current consumption of the field devices down to 4 to 8). This would require more Fieldbus Power Supplies compared to the High Power Trunk concept
- the max. cable length is reduced. This depends on the low supply voltage of a FISCO power supply
- typically short circuit protection for the spurs is not supported. The reason is that the wiring blocks with short circuit protection causes an additional voltage drop which reduces the max. cable length additionally.

In practice and in order to minimize the Fieldbus validation and commissioning related problems, High Power trunk concept with FieldBarriers shall be used. FieldBarriers will be powered via standard Fieldbus Power Supplies. The trunk needs to be installed in accordance to IEC 60079-14 (for details please refer to chapter 5.10.3).

The number of FieldBarriers shall be limited to four.

The FieldBarrier works as an IS barrier. The outputs of this barrier shall be [EEx ia] IIC certified. This will at least allow live maintenance on the field device level.

To avoid any additional limitations the FieldBarrier outputs shall be certified in acc. to FISCO **and/or** Entity. The outputs shall be short circuit limited with a short circuit current no more than 50mA.

Additional it is recommended that the FieldBarrier is DIN rail mountable. Then it could be easily mounted in any project specific enclosure.

5.11. Segment Coupler Requirements

To avoid limitations on overall cable length the Fieldbus Power Supplies, which are part of the Segment Coupler, shall support high output voltage. PA field devices are working within the voltage range from 9 vdc ... 32 vdc.

Typical FPS's are offering a supply voltage of 28Vdc at 500mA supply current. In case it is ensured, that the required

- supply voltage is less than 25Vdc (including required spare)
- supply current is less than 350mA (including required spare)

Fieldbus Power Supplies with a supply voltage of 25Vdc at 360mA may be accepted

The Segment Coupler, consisting of a (redundant) Gateway and Fieldbus Power Supplies shall be mountable in a Zone 2 environment.

5.11.1. Additional Fieldbus Power Supply Requirements

The FPS shall support physical layer diagnostics. Based on application requirements it can be differentiated by:

- Basic Physical Layer diagnostics
- Advanced Physical Layer diagnostics.

Basic Diagnostic

Basic diagnostic shall support one alarm relay contact for:

- Trunk over current
- Trunk under voltage
- Faulty power supply module (essential for redundant power supply)
- Bulk power supply under voltage

Advanced Diagnostic

Advanced diagnostics can be used during

- commissioning to ensure that the physical layer offers the best possible physical layer values during start up. Additionally it offers the capability to detect physical layer problems at a very early point and it allows to solve the networking problems before starting production.
- operation to receive warning or alarm messages before a segment fails to operate
- troubleshooting to pinpoint the problem area.

The Advanced Diagnostic Module must be an integral part of the motherboard hosting the Fieldbus Power Supplies. It shall imply all basic diagnostic functionalities and shall furthermore offer the following additional information to guarantee highest availability of Fieldbus communication by monitoring:

- Amplitude of the communication signal which is an indication for
 - termination faults
 - too high wave attenuation depending on changed cable parameters, corroded terminals, ...
- Noise

- Balance to ground. If the system is unbalanced the sensitivity to noise is increased.
- Jitter. PROFIBUS PA is using a rectangular signal for data transmission (Manchester II coding). A PROFIBUS PA node is expecting an edge in the middle of the bit time. The polarity of the edge is indicating the logical status "0" or "1". The edge should cross the supply voltage level exactly in the middle of the bit time. Depending on existing inductances and capacitances there will be a deviation from this ideal crossing point. This deviation is called Jitter. A PROFIBUS PA node is not measuring the signal itself; it opens a time window (at least $\pm 3.2 \mu\text{s}$) around the ideal crossing point and check the edge for their polarity only. In case the Jitter is too high the edge will cross the supply voltage level outside of the measurement window. This causes that this bit gets lost. Depending on this the complete telegram will be detected as wrong and therefore rejected. This causes a retry of this telegram during the actual PROFIBUS PA cycle. In case this telegram gets also lost it will be repeated again until the configured "Retry limit" is reached. If the PROFIBUS PA Master is not receiving a valid telegram from a PROFIBUS PA slave until the Retry limit is reached, the slave will be excluded from the cyclic data exchange.
Nearly all possible faults on a fieldbus segment will influence the jitter and therefore this is one of the most important measures.

These values shall be measured for the system and, except balance, for each connected node address.

The Advanced diagnostic module shall support the following functionalities:

- Commissioning wizard to ensure a fast and secure checkout of the segments. Additionally this wizard shall support an automatic report generation.
- Diagnostic function, which leads the maintenance personnel to the problem area. For this functionality it is required that the diagnostic module interprets the combination of changed physical layer values.
- History function to have the capability to detect long term changes in the physical layer values.
- Oscilloscope to measure the signal form. The oscilloscope shall support fieldbus specific trigger events.

Because the required bandwidth for fully featured advanced diagnostics solution cannot be covered by transmitting the diagnostic data via PROFIBUS PA itself, the data shall be transmitted via a separate diagnostic bus (e.g. RS485 or Ethernet) or via the acyclic channel of PROFIBUS DP V1.

5.12. Segment Spare Philosophy Requirements

The total number of devices per segment shall not exceed 22 as detailed in Physical Layer related limitations. However, to include for the 20% pre-wired spare capacity, the maximum number of devices shall be 17 per segment.

5.12.1. Segment Execution Time Requirements

5.12.1.1. Segments Used for Regulatory Control and Monitoring

A PROFIBUS PA cycle time needs to be defined for each segment. Acyclic services shall be no more than 30% of the total PROFIBUS PA cycle time.

The following definitions are an example for defining communication related issues. These definitions ensure enough time for each cyclic and acyclic communication during segment execution:

- PROFIBUS PA cycle time - 500 msec.
- Cyclic communication time - \leq 350 msec.
- Acyclic communication time - 150 msec.

Any deviation to the above will require additional validation and shall be subject to EC approval.

5.13. Segment Wiring Design Requirements

5.13.1. Overall Wiring Design Philosophy

PROFIBUS PA implementation shall mimic the traditional implementation method as follows:

- The trunk cable shall be
 - either a Multicore cable where each pair of cable is individually screened with the 1st pair used for the 1st PROFIBUS PA segment and the 2nd pair for the 2nd PROFIBUS PA segment and so on. Additionally an overall screen is required. (The max. number of segments per multicore cable needs to be defined).
 - or a single pair screened trunk cable.
- The field junction box distributing the PROFIBUS PA trunk shall accommodate no more than two PROFIBUS PA segments with each accommodating up to 22 PA devices as detail in chapter 5.10.1.2.
- Each PA device shall be connected to the Fieldbus junction box via a single pair shielded spur cable.

Any deviation from the above shall be subject to approval by EC.

5.13.2. Topology

The chicken-foot or tree topology consists of a Fieldbus segment connected to a common JB via the trunk cable from the marshalling cabinet as detailed in figure 7 below.

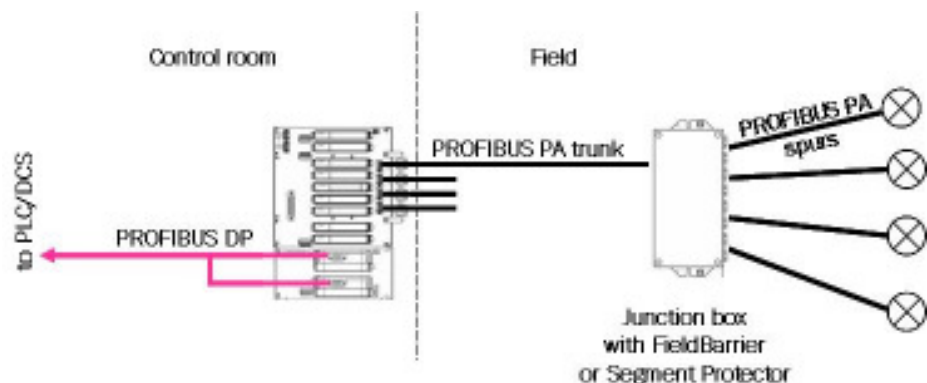


Figure 7: Typical PROFIBUS PA Topology

Any deviation from the above shall be subject to approval by EC.

5.13.3. Cable Type

The same cable type could be used to wire the trunk and the spurs. The recommended cable type is cable type A as defined in chapter 12.8.2 of IEC 61158-2 Ed. 3.0.

Cable characteristics

The main characteristics are:

- One pair insulated, overall screen and PVC sheath or a multicore cable with PVC sheath and an individual screen for each pair of leads plus an overall screen.
- Cross section: 0.8 mm² for standard application. For special application 1.0 mm² or 1.5 mm² could also be used.
- Lead resistance: 44 ohm/km per loop at 20 °C for standard application. For special application 36 ohm/km or 24 ohm/km per loop at 20 °C could also be used.
- Max capacitance: 200 nF/km
- Max. capacitive unbalance of 4nF/km
- Max inductance: 1 mH/km
- Attenuation: 3 db/km
- Impedance 100Ω ±20%

The segment design will be based on default values. If these values are exceeded further attention and/or validation of the segment design will be required.

5.13.4. Cable Length

According to the Physical Layer specification (IEC 61158-2 Ed. 3.0) the maximum allowed overall cable length of a fieldbus segment is limited to 1900 metres. This total segment length is computed by adding the length of the main trunk line and all the spurs that extend from it.

- Total Segment Length = Trunk + All Spurs

The Total Segment length is limited by voltage drop and signal quality (i.e. attenuation and distortion).

In order to eliminate the need to calculate the physical loading of each segment and to reduce the validation requirement, project specific limits for

- max. trunk cable length
- max spur cable length

needs to be defined and validated for the highest available ambient temperature. As validation tool the software Segmentchecker from Pepperl+Fuchs could be used. This software could be downloaded free of charge from the web site:

www.segmentchecker.com

The following values are an example for these limits:

- Trunk cable length < 500 metres.
- Spur cable length < 60 metres.

Any deviation from the defined cable lengths shall be subject to EC.

5.13.5. Power Consumption

Depending on the type of application (Zone 0, Zone 1 or Zone 2) the number of maximum connectable PA devices is different as defined in Physical Layer related limitations and Requirements for Zone 1/ Zone 0 application. The overall current consumption can be done with a calculating tool, e.g. the Segment checker www.segmentchecker.com

Power Consumption for Zone 1 / Zone 0 application

Following the High power Trunk concept, because it allows more devices than FISCO, the maximum layout is 16 devices per Segment which contains 20% spare. If the average current consumption of the field device is 18 mA the required supply current is 288 mA including the spare. Additionally the FieldBarriers require current from the Fieldbus cable.

Under short circuit conditions the additional supply current to be fed by the Fieldbus Power Supply is:

- Short circuit current (50 mA) - minimum supply current of a device (10 mA) = 40 mA.

The Fieldbus Power Supply shall offer enough current to be able to feed at least one short circuit of any spur.

Therefore the Fieldbus Power Supply shall offer at least 500 mA supply current to have enough spare for the FieldBarriers.

The maximum current required by a single PA device shall not exceed 25 mA.

Power Consumption for Zone 2 application

The maximum layout for a segment is 22 field devices per segment which includes 20% spare. If the average current consumption of the field device is 18 mA the required supply current is 396 mA including the spare. Additionally the Segment Protectors require current from the Fieldbus cable (typically ≤ 9 mA).

Under short circuit conditions the additional supply current to be fed by the Fieldbus Power Supply is:

- Short circuit current (60 mA) - minimum supply current of a device (10 mA) = 50 mA.

The Fieldbus Power Supply shall offer enough current to be able to feed at least one short circuit of any spur.

Therefore the Fieldbus Power Supply shall offer at least 500 mA supply current to have enough spare for the Segment Protectors.

The maximum current required by a single PA device shall not exceed 25 mA.

5.13.6. Minimum Operating Voltage

The minimum voltage at the PA device shall be 9.9 vdc at highest ambient temperature. This value includes a 10% safety margin.

5.13.7. Attenuation

PROFIBUS PA operates at a frequency of 39 kHz where a standard cable type A has an attenuation of 3 dB/Km @ 39 kHz or around 70% of the original signal after 1 km of cable.

A Fieldbus "transmitter" can have a signal as low as 0.75 volts peak-to-peak and a Fieldbus "receiver" must be able to detect a signal as little as 0.15 volts peak-to-peak.

Based on a 3dB/km attenuation, the fieldbus signals can be attenuated by 14dB. This normally does not provide a problem for fieldbus installation especially based on the cable limits detailed above.

5.13.8. Example Calculation

5.13.8.1. General Purpose and Zone 2 Application

In this example, made for General Purpose and Zone 2 application, the following default values are specified:

- FPS $U_{out} > 28$ vdc @ 500 mA
- max. No. of field devices per segment = 22
- max. Trunk length = 700 m.
- max. spur length = 30 m
- max. ambient temperature 50 °C
- cable type A with AWG 18 (0.8 mm²) cross section
- average current consumption per field device 18 mA

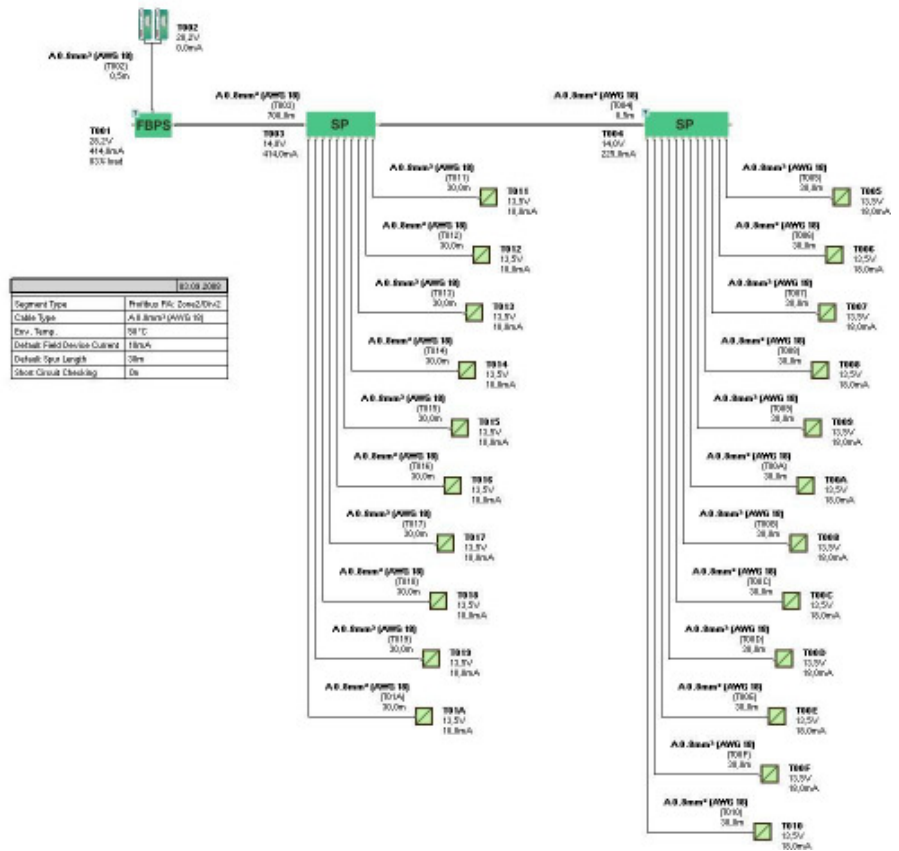


Figure 8: Calculation example for General Purpose and Zone 2 application

The example shows that, under the above specified preconditions, there will be no physical layer problems available.

5.13.8.2. Intrinsically Safe Application for Zone 1/ Zone 0

In this example, made for an Intrinsically Safe (Zone 1/ Zone 0) Application, the following default values are specified:

- FPS $U_{out} > 28$ vdc @ 500 mA
- max. No. of field devices per segment = 16
- max. Trunk length = 500 m.
- max. spur length = 60 m
- max. ambient temperature 50 °C
- cable type A with AWG 18 (0.8 mm²)
- average current consumption per field device 18 mA

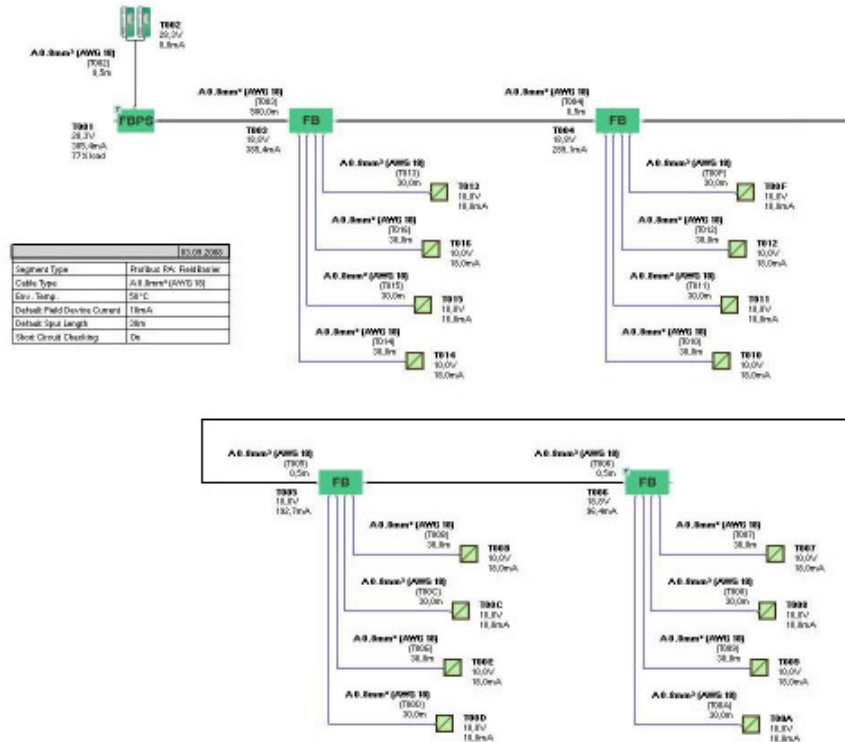


Figure 9: Calculation example for an Intrinsically Safe (Zone 1) Application

The example shows that, under the above specified preconditions, no physical layer problems will occur. By increasing the cable cross section to 15 AWG (1.5 mm²) the trunk cable length could be increased to 900 m (2,950 ft). The overall cable length than would be 1860 m (6,100 ft).

5.13.9. Segment Design Validation Tool

After defining the default values as explained above, it is required to validate a segment only in case these values will be exceeded.

These validations can be done by the Segmentchecker software from Pepperl+Fuchs (see: www.segmentchecker.com)

5.13.10. Junction Box Requirements

A Fieldbus junction box shall be adequately sized. As an example:

- To contain three Segment Protectors with 8 spur connections each for general purposes or Zone 2 application
- To contain 4 FieldBarriers with 4 spur connections each for Zone 1/Zone 0 application.

The Fieldbus junction box shall follow the same principle and standards as for traditional junction boxes.

Each “Wiring Block” shall be specifically made for PROFIBUS PA networks with the following minimum requirements:

- 4, 6, 8, 10 or 12 dedicated connection for spur cables.

- 2 dedicated connections for the PROFIBUS PA trunk/home run
 - Exception: In case Ex d devices shall be used in a Zone 1 environment and shall be connected to a segment protector mounted in a Zone 1 environment. In this case one dedicated connection for the PROFIBUS PA trunk is acceptable.
- Pre-assembled fieldbus terminator with at least redundant capacitors.
- Dedicated grounding termination points shall be provided to ground the individual cable shield for each cable (trunk and spur).
- Short circuit current shall be limited to 60mA per spur.
- Wire capacity: 0.5 mm² to 2.5 mm².
- Temperature range -50 °C to +70°C.
- DIN rail mounting.

5.13.11. Grounding of Shields

All Fieldbus signal wires shall be reliably and properly connected throughout the network, as grounding either conductor could cause all PA devices on that segment to lose communications.

The instrument shield shall be terminated at least at the host (power supply) end of the segment in the marshalling cabinet.

The type of grounding at the Junction Boxes and field devices needs to be defined. There are several possibilities:

- No grounding (floating shield in the field)
- Capacitive grounding (recommended by PROFIBUS PA installation guide line)
- Hard grounding (recommended by PROFIBUS PA installation guide line)

The type of grounding in the field depends on

- DCS requirements
- National laws and standards (especially in hazardous area application)
- Required degree of EMC protection
- Quality of the equipotential bonding

In some application there is no equipotential bonding available. In this case single point of grounding at the host (power supply) is mandatory. If there are no technical reasons available multipoint grounding or capacitive grounding in the field should be the preferred solution.

The Segment Protectors and FieldBarriers shall be prepared for all types of grounding.

5.13.12. EMC protection

Grounding of the screens is one part to achieve the required EMC protection level. Especially the fieldbus power supplies and the wiring blocks shall comply with the following standards and reach the highest available category of protection, defined in the following table:

IEC Standard	Category
ESD IEC 6100 - 4 - 2	Category A
Radiated RF Immunity IEC 6100 - 4 - 3	Category A
Burst IEC 6100 - 4 - 4	Category A
Surge IEC 6100 - 4 - 5	Category B ¹
Conducted RF Immunity IEC 6100 - 4 - 6	Category A

¹ Conducting surge tests under Class A conditions would usually destroy the test system. This is why in general Class A compliance is not available on the market for surge immunity.