



PROFIBUS System Description

Technology and Application

Introduction

The field of **industrial communications** is continuing to develop at an astonishing pace with the result that the field of **automation** technology is constantly changing. Initially, automation focused exclusively on production, but now it is part of a network that covers service and maintenance, warehousing, resource optimization and the provision of data for MES and ERP systems in addition to the actual task of automation.

Fieldbus technology, which has facilitated migration from centralized to decentralized automation systems and supports the use of distributed intelligence, has been the driving force behind this development. Ethernet-based communication systems link automation technology with information technology, thus implementing consistent communication from the field level to the corporate management level.

Standardized solutions can be found in PROFIBUS and PROFINET, which provide absolute consistency and are highly application-oriented. With its standard protocol, **PROFIBUS** takes in all subprocesses found in production and process automation, including safety-related communication and drive applications, thereby providing the ideal basis for ensuring horizontal consistency within an automation system. **PROFINET** also features a standard protocol which, in addition to horizontal communication, also supports vertical

communication, thereby linking the field level with the corporate management level. Both communication systems are, therefore, able to facilitate cross-networked, integrated solutions that are optimized for the automation tasks concerned.

Since 1989, **PROFIBUS** has developed into a worldwide leading fieldbus system used in machine and production plant automation. The main reason why PROFIBUS stands out from other fieldbus systems is because it offers such an extraordinary breadth of applications. Application specific requirements have been integrated into application profiles, and these applications have been combined as a whole to create a standardized and open communication system. The use of open standards instead of proprietary solutions ensures long-term compatibility and expandability, which forms the basis for implementing comprehensive investment protection for users and manufacturers. This is a very important concern of PROFIBUS & PROFINET International. Established worldwide support offers members long-term perspectives.

With well over 30 million devices (as of the end of 2009), PROFIBUS is currently present in every branch of industrial automation and makes an important contribution to the economic and technological success of the companies.

Table of Contents

1.	INTRODUCTION TO PROFIBUS	1	3.5	<u>STANDARDIZED FUNCTION BLOCKS (FB)</u>	12
1.1	MARKET POSITION	1	3.6	<u>COMM FBS AS A SYSTEM-NEUTRAL</u> <u>INTERFACE WITH PROFIBUS</u>	12
1.2	<u>MODULAR DESIGN IN SYSTEM BUILDING</u> <u>BLOCKS</u>	1	4.	APPLICATION PROFILES	13
1.3	<u>APPLICATION-SPECIFIC SOLUTIONS</u>	2	4.1	<u>PROFIDRIVE</u>	14
1.4	<u>HYBRID AUTOMATION</u>	3	4.2	<u>PROFIBUS PA (PA DEVICES, "PA</u> <u>PROFILE")</u>	14
1.5	<u>OSI LAYER MODEL AS A BASIS</u>	3	4.3	<u>IMPROVEMENTS IN PROFILE 3.02</u>	14
1.6	<u>STANDARDIZATION</u>	3	4.4	<u>HART ON PROFIBUS</u>	15
2.	TRANSMISSION TECHNOLOGY	4	4.5	<u>PROFISAFE</u>	16
2.1	TRANSMISSION AS PER <u>RS485</u> AND <u>RS485-IS</u>	4	4.6	<u>IDENTIFICATION & MAINTENANCE (I&M)</u>	16
2.2	TRANSMISSION AS PER MBP AND <u>MBP-IS</u>	5	5.	DEVICE INTEGRATION	16
2.3	<u>OPTICAL TRANSMISSION</u>	5	6.	QUALITY ASSURANCE AND CERTIFICATION	17
2.4	<u>WIRELESS TRANSMISSION</u>	5	7.	PRODUCT IMPLEMENTATION	19
2.5	TRANSMISSION TECHNOLOGY IN <u>HAZARDOUS AREAS</u>	5	7.1	<u>STANDARD COMPONENTS</u>	19
2.6	<u>TOPOLOGY</u>	6	7.2	<u>IMPLEMENTING TRANSMISSION</u> <u>INTERFACES</u>	20
2.7	<u>REDUNDANCY</u>	7	8.	USER BENEFITS	20
2.8	INSTALLATION INFORMATION FOR <u>RS 485</u>	8	8.1	<u>STANDARDIZED AND CONSISTENT</u>	21
2.9	INSTALLATION INFORMATION FOR MBP ..	8	8.2	<u>ECONOMY</u>	21
2.10	<u>BUS DIAGNOSTICS</u>	9	8.3	<u>QUALITY CONSCIOUSNESS</u>	21
3.	COMMUNICATION WITH PROFIBUS	9	8.4	<u>INNOVATION AND PROTECTION OF</u> <u>PRIVILEGES</u>	21
3.1	<u>PROFIBUS DP</u> COMMUNICATION PROTOCOL	9	8.5	<u>GLOBAL SUPPORT</u>	21
3.2	DEVICE CLASSES	10	8.6	<u>FUTURE COOPERATION</u>	21
3.3	<u>CYCLICAL COMMUNICATION AND</u> <u>PROFIBUS DIAGNOSTICS</u>	11	9.	PROFIBUS & PROFINET INTERNATIONAL (PI)	22
3.4	<u>ACYCLICAL COMMUNICATION AND</u> <u>PARAMETER ADDRESSING</u>	11	9.1	<u>RESPONSIBILITIES OF PI</u>	22

Information on Contents

This system description deals with all the main aspects of PROFIBUS in 2010 without delving into technical details. Please refer to appropriate technical literature. In this regard, we would also like to point out that, despite the fact that the utmost care was taken while creating this brochure, only the normative documents from PROFIBUS & PROFINET International (PI) are authoritative and binding.

- **Chapter 1** contains an introduction of PROFIBUS and gives the hurried reader an overview of the market position and technologies used, the modular design and the application-specific solutions made possible by it.
- **Chapters 2 through 4** deal with the core technologies of PROFIBUS (transmission technology, communication and application

profiles) with technical and application-oriented information.

- **Chapter 5** deals with the topic of device integration and explains the current technologies used here.
- **Chapter 6** deals with the topic of certification and quality assurance of PROFIBUS and explains the process for obtaining a certificate.
- **Chapter 7** addresses those responsible for products and contains information on product implementation.
- **Chapter 8** again deals with the most important features of PROFIBUS and shows how they benefit users.
- **Chapter 9** provides information on PROFIBUS & PROFINET International as the world's largest interest group for industrial automation with information on the organization, membership, service offerings and global positioning.

1. Introduction to PROFIBUS

Automation technology has been characterized by rapidly changing technology for many years. The driving force for this was and still is the pressure to lower production costs, the demand for high and consistent product quality, improved operating reliability and the availability and flexibility of the systems, especially the consistent flow of data within a company. A visible sign of this change is the development of fieldbus technology with a transition from analog to digital communication and thus the possibility to exchange detailed information on the status of a production system and its environment very quickly. Digital communication also enables functions of the centralized controller to be relocated to decentralized field devices, which simplifies cabling considerably. The world-wide standardization of the interfaces opens up the path to consistent automation, and leaves previous solutions using a large number of proprietary systems behind.

PROFIBUS contributed considerably to the development of fieldbus technology. It links controllers and control systems with sensors and actuators on the field level (field devices) and also enables simultaneous consistent data exchange with superordinate systems. PROFIBUS is the fieldbus-based automation standard of PROFIBUS & PROFINET International (PI). PI has also developed the PROFINET Ethernet-based automation standard and launched it successfully on the market. PROFIBUS and PROFINET use identical device profiles, thereby creating investment security and investment protection for the users and manufacturers of these technologies. Both systems cover the fields of production and process automation and therefore also enable mixed (hybrid) applications, which are often seen in the pharmaceutical, food and beverage industries.

PROFIBUS consistency is based on the standardized "PROFIBUS DP" communication protocol, which supports a variety of applications in production automation and process automation as well as motion control and safety-related tasks. This integration makes planning, installation and service easier. Training, documentation and maintenance need only be carried out for one technological aspect.

1.1 Market position

The first fieldbus systems, which were proprietary, were introduced to the market in the 1980s. With the objective of far-reaching standardization, 21 companies and institutes came together in 1987 to create a joint project with the task of developing and testing an open fieldbus standard. This project was the starting point for the development of PROFIBUS. After the joint project was complete, the PROFIBUS Nutzerorganisation e.V. (PNO) was founded in 1989 to continue the work. This

organization was comprised of 10 companies, four scientific institutes and ZVEI. Two years later, it grew to over 100 members, and today (2010) there are about 1,400 members who have joined together under the globally positioned PROFIBUS & PROFINET International (PI) fieldbus organization, which was founded in 1995. Today, there are 27 regional PI associations in countries on every continent. The common goal is the continuous development and global distribution of PROFIBUS and PROFINET technologies. With well over 30 million devices installed in the field, PROFIBUS is a global market leader in the field of industrial communication systems.

The success of PROFIBUS is equally due to its advanced technology and the successful activities of the organization, which was founded to represent the interests of manufacturers and users.

In addition to the many measures employed for technological development and its propagation, additional global support services for members (users and manufacturers) are available in the form of consulting, information and measures for quality assurance and standardization of the technology in international standards.

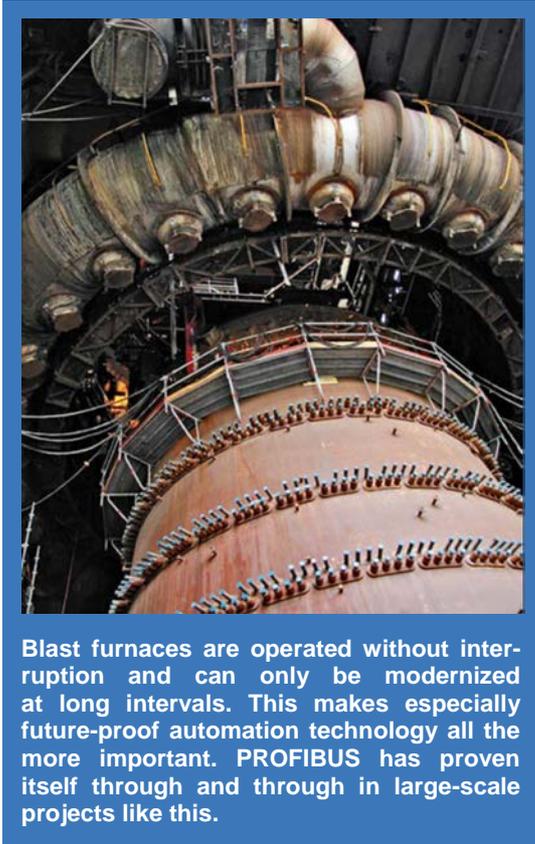
PI forms the largest user group for industrial communication in the world, which offers opportunities for the future and at the same time comes with certain obligations. The opportunities are in the creation and propagation of market-leading technologies which are beneficial to the user. The obligation is for those responsible for this user group to fully maintain PROFIBUS's goals of openness and investment protection in the future as well. This obligation serves as a guideline for everyone involved.

1.2 Modular design in system building blocks

PROFIBUS's module concept is what has allowed it to reach its top position in the global market. The communication protocol can be combined with a variety of application-specific technology modules which are compatible with one another (transmission technologies, application profiles, integration technologies). This ensures complete consistency with a large breadth of applications. With such a "system building block" (Figure 1), all the applications of automation technology can cover tasks in the production and process industries, including safety-related ones.

The core of the system building block is the PROFIBUS DP (Decentralized Peripherals) communication protocol, which is the same for all applications and is used for communication between centralized automation devices and decentralized field devices.

A number of different data transmission alternatives are available, depending on the usage case. RS485 transmission technology is intended for use in the production industry and in the process industry in applications without explosion protec-



Blast furnaces are operated without interruption and can only be modernized at long intervals. This makes especially future-proof automation technology all the more important. PROFIBUS has proven itself through and through in large-scale projects like this.

PROFIBUS application profiles are specified for standard data exchange between field devices on the user level. The use of such profiles guarantees interoperability in the data exchange between field devices from different manufacturers. These profiles specify application-typical device features, and "profile devices" must comply with them. They might be cross-device-class features (e.g. safety-relevant behavior) or device-class-specific features (e.g. to be exhibited by process devices or drives). Field devices with different application profiles can be operated in the same automation system. Simple devices with universal functionality, e.g. decentralized binary I/O devices, do not usually use application profiles.

Additionally to the layers for transmission and communication, the system building block also provides the required **engineering technologies** for device description and integration.

1.3 Application-specific solutions

The system building block makes it possible to cover very different applications using "solutions" specifically arranged for them by combining the appropriate components. Examples include solutions for the production industry, process automation, drive engineering and safety-related systems. The structure of these modular "solutions" can be seen in Figure 2. Only the communication protocol is the same with all solutions and ensures the high consistency of PROFIBUS already mentioned.

tion. RS 485-**IS (Intrinsically Safe)** covers uses in explosion protected areas. The MBP (Manchester coded Bus Powered) and MBP-IS transmission technology is specifically oriented toward the process industry and also handles power supply to devices on the bus, in addition to data transmission. Several optical transmission technologies are also available.

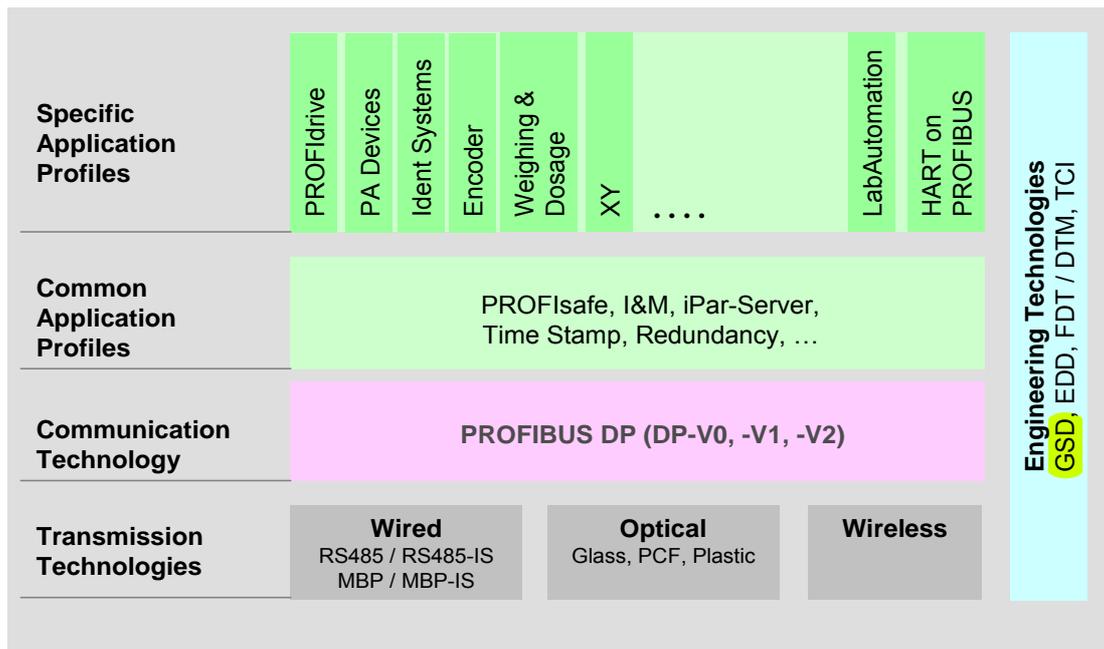


Figure 1: PROFIBUS system building blocks

Market Segment	Process Automation <small>Ex / non-Ex areas</small>	Factory Automation	Motion Control	Safety Application
PROFIBUS Solution (Common term)	PROFIBUS PA	PROFIBUS DP	PROFIdrive	Safety
Application Profile	PA Devices (and others)	e.g. Ident Systems	PROFIdrive	PROFIsafe
Communication Technology	PROFIBUS DP	PROFIBUS DP	PROFIBUS DP	PROFIBUS DP
Transmission Technology	MBP / MBP-IS RS 485 / 485-IS	RS 485	RS 485	RS 485 MBP-IS

Figure 2: PROFIBUS solutions for different market segments

1.4 Hybrid automation

In the past, production automation and process automation had to be viewed as two strictly separate fields and automated using different technologies. The reason for this were the different marginal conditions of an automation system. Production automation is based on fast processes and an accordingly shorter system service life. Process automation, on the other hand, is characterized by slow procedures and a longer system service life. This led to insular solutions within the overall system. Today, a user can avoid such insular solutions by using a PROFIBUS solution that is consistent for all the applications of the production chain. PROFIBUS is the only fieldbus that fulfills the requirements of such consistent (hybrid) automation of production-control (inbound and outbound logistics) and process-control process steps (Figure 3).

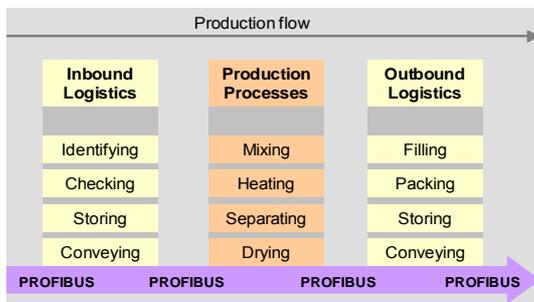


Figure 3: Consistent PROFIBUS solution in a single production system

Examples

In the pharmaceutical industry, the manufacture of medicines is a process-control procedure. The packaging of tablets, for example, uses production-control tasks with complex packaging machines, however.

In the food industry, at a brewery for example, the typical process-control procedures in the brew-house and fermenting cellar are followed by the production-control procedures of bottle cleaning and filling and the stacking of crates by robots.

In vehicle production, the paint shop, with its process-control requirements (explosion protection), is part of a production chain that otherwise involves production-control tasks.

1.5 OSI layer model as a basis

The design of the technology modules with PROFIBUS is oriented toward the OSI layer model (Open Systems Interconnection Reference Model). Here, the communication process between two nodes is distributed over seven "layers", from layer 1 ("physical layer", transmission technology) to layer 7 ("application layer", interface to the application). PROFIBUS uses layers 1, 2 and 7 (Figure 4):

- Layer 1 defines the physical transmission. With PROFIBUS, there are copper-wire versions (RS485 and MBP) and optical and wireless transmission.
- Layer 2 defines the description of the bus access method, including data security. With PROFIBUS, this is the master-slave method in conjunction with the token method.
- Layer 7 forms the interface to the application and thus represents the link between the application and communication. With PROFIBUS, the communication protocol PROFIBUS DP is used here.
- The actual application process lies above layer 7 and is not part of the OSI model.

	User program	Application profiles
7	Application Layer	PROFIBUS DP Protocol (DP-V0, DP-V1, DP-V2)
6	Presentation Layer	Not used
5	Session Layer	
4	Transport Layer	
3	Network Layer	Fieldbus Data Link (FDL): Master Slave principle Token principle
2	Data link Layer	
1	Physical Layer	Transmission technology
	OSI Layer Model	OSI implementation at PROFIBUS

Figure 4: References between OSI model and PROFIBUS

Figure 4 shows the definition of the seven OSI layers on the left and the implementation of PROFIBUS on the right.

1.6 Standardization

The contents of the OSI layers are specified by standards so that the openness of the system is ensured when the standards are complied with. Together with other fieldbus systems, PROFIBUS is part of IEC 61158 ("Digital data communication for measurement and control – Fieldbus for use in industrial control systems") and IEC 61784 ("Profile sets for continuous and discrete manufacturing relative to fieldbus use in industrial control systems").



The supply of clean water requires major investment in existing and new waste water treatment plants. Maximum availability and optimum utilization of process technology are required. PROFIBUS is the preferred solution of many planners and operators in this area.

2. Transmission technology

2.1 Transmission as per RS485 and RS485-IS

The easy-to-use and cost-effective RS485 transmission technology is preferred for use with tasks which require a high transmission speed, but which do not require explosion protection (intrinsic safety). It is widely used in the production industry and is also found in parts of the process industry. A twisted, shielded copper cable with a pair of wires is used. The bus structure enables non-reactive coupling and decoupling of stations and incremental commissioning of the system. Subsequent system expansions do not affect stations already in operation within certain specified limits. Details can be found in Table 1 and Table 2.

IEC 61158

IEC 61158 deals with the technologies used and describes the method of functioning of the fieldbus. It is divided according to the OSI model. The individual fieldbuses are differentiated by the definition of "fieldbus protocol types" in this standard. Here, PROFIBUS is type 3 and PROFINET type 10.

IEC 61784

IEC 61784 defines the subsets of the service and protocol supersets specified in IEC 61158 (and other standards) which are used by a certain fieldbus system for its communication. They are collected in "Communication Profile Families (CPF)"; for PROFIBUS, it is "Family 3" with a subdivision into 3/1 (RS485 and fiberoptics) and 3/2 (MBP). Part 3/3 is concerned with PROFINET.

In compliance with certain values, the use of the RS485 interface with its high transmission rates is also possible in intrinsically-safe areas (RS485-IS). When the interface was specified, the levels for the current and voltage, which must be complied with by each individual node to ensure safe functioning when connected together, were defined. Within a circuit, certain maximum currents are permissible with a set voltage. When connecting active sources together, the total current of all the nodes may not exceed the maximum permissible current. The difference between this concept and the FISCO model (see 2.5) with only one intrinsically-safe source is that all nodes represent active sources here.

	RS485	RS485-IS	MBP	MBP-IS	Fiber Optic
Data transmission	Digital; differential signals acc. to RS485, NRZ (no return to zero)	Digital; differential signals acc. to RS485, NRZ	Digital, bit-synchronous, Manchester coding	Digital, bit-synchronous, Manchester coding	Optical, digital, NRZ
Transmission rate	9.6 to 12000 Kbit/s	9.6 to 1500 Kbit/s	31.25 Kbit/s	31.25 Kbit/s	9.6 to 12000 Kbit/s
Data security	HD=4; parity bit; start/end delimiter	HD=4; parity bit; start/end delimiter	Preamble; fail-safe start/end delimiter	Preamble; fail-safe start/end delimiter	HD=4; parity bit; start/end delimiter
Cable	Twisted, shielded two-wire cable, cable type A	Twisted, shielded two-wire cable, cable type A	Twisted, shielded two-wire cable, cable type A	Twisted, shielded two-wire cable, cable type A	Multi- and single mode glass fiber; PCF; plastic fiber
Remote power supply	Possible using additional cores	Possible using additional cores	Optional using signal cores	Optional using signal cores	Possible using hybrid cable
Ignition protection types	None	Intrinsic safety Ex ib	None	Intrinsic safety Ex ia/ib	None
Topology	Line topology with termination	Line topology with termination	Line topology with termination	Line and tree topology with termination; also combined	Star and ring topology typical; line topology possible
Number of nodes	Up to 32 nodes per segment. Max. total 126 per network	Up to 32 nodes per segment. Max. total 126 per network	Up to 32 nodes per segment. Max. total 126 per network	Up to 32 nodes per segment. Max. total 126 per network	Up to 126 nodes per network
Number of repeaters	Max. 9 with signal refreshing	Max. 9 with signal refreshing	Max. 4 with signal refreshing	Max. 4 with signal refreshing	Unlimited with signal refreshing; note signal propagation delay

Table 1: Overview of transmission values

Transmission rate [Kbit/s]	Transmission range per segment [m]	Applies to
9,6 19,2 45,45 93,75	1200	RS485
187,5	1000	RS485
500	400	RS485
1500	200	RS485
3000 6000 12000	100	RS485
31,25	1900	MBP
The values above apply to <u>cable type A</u> with the following properties		
Wave resistance	135 ... 165 Ω	
Capacitance per unit	≤ 30 pF/m	
Loop resistance	≤ 110 Ω/km	
Core diameter	> 0.64 mm	
Core cross-section	> 0,34 mm ²	

Table 2: Transmission values of RS485 and MBP

2.2 Transmission as per MBP and MBP-IS

MBP (**M**anchester Coded, **B**us **P**owered) transmission technology implements the simultaneous supply of power to the connected field devices and communication of the data over a single cable, i.e. directly via the bus medium. This enables wiring overhead to be significantly reduced, meets requirements for much simpler and safer installation and boasts all the benefits of digital transmission down to the field device. MBP was specifically developed to meet the demands of process automation and is standardized in IEC 61158-2. Details can be found in Table 1 and Table 3.

Fieldbus standard IEC 61158-2 for MBP transmission technology
Up to 32 nodes in one segment
Data transmission rate 31.25 Kbit/s
Per field device: Min. working voltage 9 V DC Min. current consumption 10 mA
Transmission of digital communication signal in zero-mean Manchester II coding (MBP) through ± 9 mA amplitude
Signal transmission and remote power supply using twisted-pair cable
Fieldbus cable type A
Connection of field devices via stubs (spur) to a main cable (trunk) for trouble-free disconnection of devices without affecting other nodes
Max. total length of main cable, including all stubs, is 1900 m

Table 3: Characteristics of MBP and MBP-IS

In the MBP-IS version, this transmission technology is especially suitable for use in hazardous areas and is therefore widely used in applications of the chemical, oil and gas industries. Explosion protection is implemented via limiting power in the

incoming bus supply or more frequently in the installation components in the field. Working on field devices during active operation is made possible, for example, by means of intrinsically safe ignition protection. The easiest way to be verified for intrinsic safety is to go through models such as FISCO or Entity. If all the components used conform with the standards, no further calculations are necessary.

2.3 Optical transmission

There are fieldbus usage conditions under which wired transmission technology reaches its limits, for example in an environment with heavy interference or when bridging long distances. In these cases, optical transmission via fiberoptic cables is available. The corresponding PROFIBUS guideline specifies the technology available for this. When the specifications were being made, it was ensured that existing PROFIBUS devices could be integrated into a fiberoptic cable network without adverse affects. This ensures compatibility with existing PROFIBUS installations.

The supported fiberoptic cable fiber types are shown in Table 4. Due to the transmission characteristics, typical topology structures are the star and the ring; linear structures are also possible. The implementation of a fiberoptic cable network in the simplest case involves the use of electro-optical converters which are connected to the field device with the RS 485 interface and the fiberoptic cable on the other side. This also makes it possible to switch between RS 485 and fiberoptic cable transmission within an automation system, depending on the prevalent conditions.

Fiber type	Core diameter [μm]	Transmission range
Multi-mode glass fiber	62.5 / 125	2 - 3 km
Single-mode glass fiber	9 / 125	> 15 km
Plastic fiber	980 / 1000	Up to 100 m
HCS® fiber	200 / 230	Approx. 500 m

Table 4: Supported fiberoptic cable types

2.4 Wireless transmission

PROFIBUS is also used in wireless communication. Even if PI has not made any provisions in the form of specifications or guidelines, interoperability with wired systems is still ensured. This is supported by the many applications in use.

In PROFIBUS systems, solutions for the wireless connection of sensors and actuators are also possible. Corresponding guidelines which specify the integration of WirelessHART (used in process automation) and Wireless Sensor/Actuator Network (WSAN, used in production automation) are in process.

2.5 Transmission technology in hazardous areas

When operating fieldbuses in hazardous areas, the interface PROFIBUS MBP is the typical

choice. Besides the IEC 61158-2 (fieldbus standard, Table 3), the more stringent explosion protection standard IEC 60079-11 (electrical equipment for hazardous areas) must be observed. Here two concepts are principally used

- The FISCO model (IEC 60079-27) enables the implementation of explosion protection, including regulatory approval without individual calculations. It is characterized, however, by a considerable low input power into a segment and thus by short cable length and low number of field devices.
- The High-Power Trunk concept, whereby the limitations in power of FISCO are removed by using the ignition protection type increased safety. Intrinsic safety is applied where working on field devices is permitted also without "hot work permit".

In certain cases, the RS485 interface in compliance with Ex e ignition protection type can also be used in the hazardous area.

The FISCO model (IEC 60079-27)

The FISCO model (Fieldbus Intrinsically Safe Concept) makes it easy to plan, install and expand PROFIBUS networks in hazardous zones of type 1. This model is based on the specification that a communication network is intrinsically safe and does not require calculations for validating intrinsic safety if the relevant components, such as the field devices, cables, segment couplers and bus termination values conform to a set of limit values (for voltage, current, output, inductivity and capacity). Intrinsic safety is considered verified if all the components operated in the segment in question are certified as per FISCO. The following constraints have also be met:

- Each segment only has one power supply source
- The total cable length is up to 1000 m

FISCO ensures that

- The field devices always act as passive sinks
- the permissible input values of each field device are greater than the possible and permissible output values of the associated supply unit if a fault were to occur.

The ignition protection type intrinsic safety Ex i (IEC 60079) is the most often used protection type in measurement and control technology. It is based on the parameter of limiting current and voltage in intrinsically safe circuits to levels where neither thermal effects nor sparking could lead to the ignition of explosive mixtures. This is associated with a limitation of the supply current of a PA segment to 100 mA with corresponding limitations in cable length and the number of bus nodes.

The High-PowerTrunk Concept

The "intrinsically safe" ignition protection type is only really required in a process control system where access is required for maintenance or

device replacement during operation. In other areas, e.g. at the trunk cable, this requirement generally does not apply, which is why ignition protection type Ex e (increased safety) is applied there with the ability to transport more power. This enables longer cable length and increased number of field devices without obstructing operation. It is therefore possible to use a mixed concept comprised of protection types increased safety (Ex e) for the trunk and intrinsic safety (Ex i) at the spur, which can be implemented with devices called fieldbus barriers. The outputs of the field barriers are conventionally intrinsically safe for the connection of field devices. An overview on this can be found in Figure 5.

Likewise, in automation systems with hazardous zone 2, the trunk is designed in the "non-sparking (Ex nA)" protection type and thus

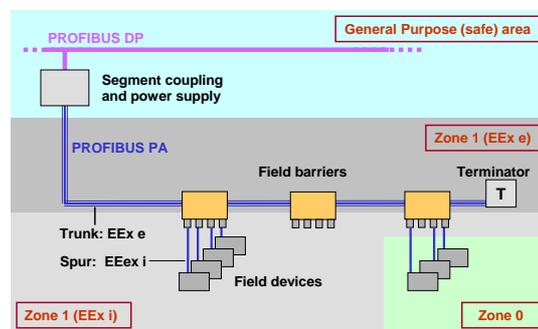


Figure 5: Utilization of different ignition protection types

enables the introduction of high currents into zone 2. Due to the less stringent explosion protection requirements simple field distributors can be used here instead of field barriers. Field devices of protection type "energy limited" (Ex nL) can be connected to their short circuit-proof outputs of 40 mA output current each.

2.6 Topology

If **RS485** transmission technology is used, all field devices are typically connected in a line structure (see Figure 6) with up to 32 nodes (master and slaves) in one segment. The beginning and end of each segment are provided with active bus termination, which must be supplied with power continuously. The bus terminations are usually implemented as optionally activatable in the devices or plugs. If there are more than 32 nodes or the network span is being extended, repeaters must be used to link the networks.

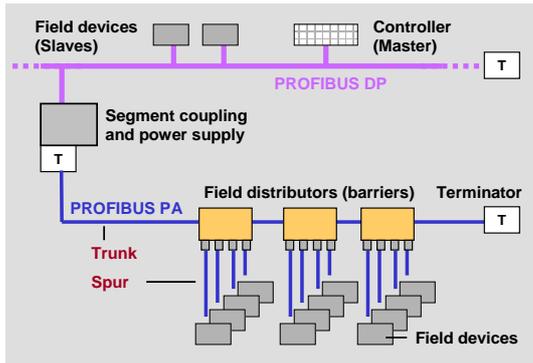


Figure 6: The connection of DP and PA segments

If MBP transmission technology is used (in process automation), basically any topology is permissible. Linear and tree structures and combinations of both are thus possible. In practice, the "trunk & spur topology" (see Figure 6) has established itself as the de-facto standard, as it is especially clear and well-laid-out. Thanks to the technically-mature installation technologies available on the market, it also exhibits a high degree of robustness. The overall length of a segment may not exceed 1,900 meters, and the length of the stubs in intrinsically-safe applications is max. 60 m and must be taken into account when calculating the overall length.

Coupling RS485 and MBP transmission technology. The MBP transmission technology is typically limited to certain subsegments of a system, e.g. a group of field devices in a hazardous area. The connection of such subsegments (designated as MBP or PA segment or PA spur) to the RS485 segment (also designated as DP segment or DP spur) is carried out using segment couplers or links. They handle the following tasks:

- Implementation of the asynchronous signal encoding with RS485 into synchronous signal encoding with MBP
- Provision of incoming supply voltage for the PA segment and limiting of incoming current supply
- Decoupling of transmission speed
- Isolation and power limiting for hazardous areas (optional)

Segment couplers are transparent from the standpoint of the bus protocol, the devices of the MBP segment are directly visible on the DP side and the segment coupler itself does not require configuration.

Links, on the other hand, are intelligent and map all devices connected in the MBP segment as a single slave in the RS485 segment. The link needs to be configured and restricts the total amount of data which can be transferred to and from the connected devices to 244 bytes. The cyclical data from the PA devices is compressed into a single DP telegram on the DP side and must be reselected by the DP master. The faster DP segment enables a number of PA segments



Drive technology is required for every automation task: Whether it's moving, adjusting, positioning, conveying or storing, it all demands perfect communication between drives and the automation system. No technology in the world is used more than PROFIBUS here.

to be integrated into a single DP network via segment couplers or links.

2.7 Redundancy

For applications which demand high system availability, such as with continuous processes, redundant systems are generally used, whereby the redundancy can extend to all system components. A differentiation is made between different concepts which can be combined with one another as desired and, in special cases, also contain complete spatial separations:

- **Master redundancy:**
The control system or the controller is designed redundantly (system redundancy, Figure 7, right)
- **Media redundancy:**
The cable paths are designed redundantly
- **Coupler/link/gateway redundancy:**
The segment couplers are designed redundantly (Figure 7) If a coupler fails, the other ones seamlessly take over its function. The master does not notice the switchover and no messages are lost.

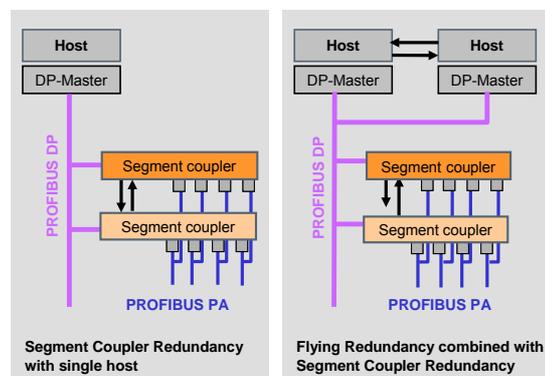


Figure 7: Various redundancy concepts

- **Ring redundancy**

The combination of redundant couplers and field devices with active field distributors implements ring redundancy and creates expanded media redundancy. Subsegments which have become defective due to a short circuit or wire break are automatically and seamlessly operated further via a coupler each in a line structure (Figure 8).

- **Slave redundancy:**

The field devices or the PROFIBUS connection in the field device are designed redundantly. Concepts for slave redundancy are described in the PROFIBUS specification titled "Slave Redundancy". Field devices designed with redundancy need to be on an equal footing and determine between themselves which is to act as the primary node and which as the secondary node. Manufacturer-specific solutions are available for transmission media and master redundancy.

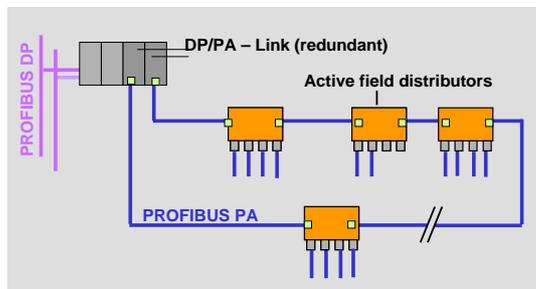


Figure 8: Ring redundancy with PROFIBUS PA

2.8 Installation information for RS 485

A number of different cable types (type designation A through D) for different usage cases are available for the connection of devices to one another and to network elements (e.g. segment couplers, links and repeaters). If the RS485 transmission technology is used, cable type A (data in Table 2) is strongly recommended.

When connecting the nodes, ensure that the data cables are not mixed up. To achieve high interference resistance of the system against electromagnetic radiation, a shielded data cable (type A is shielded) should definitely be used. The shielding is to be connected to the protective ground on both sides ensuring good conductivity via large-area shield clamps. Equipotential bonding of all connected field devices is also recommended. Also ensure that the data cable is laid as far away from all high-current cables as possible. Stubs must absolutely be avoided with transmission rates greater than or equal to 1.5 MBit/s. The number of nodes which can be connected to a segment is limited to 32.

The plugs offered on the market enable incoming and outgoing data cables to be connected directly in the plug. This avoids stubs, and the bus plug can be connected to and disconnected from the bus at any time without interrupting the data traffic. The plug connectors suitable for RS485 transmission technology differ by protection type. In protection type IP 20, a 9-pin D-Sub plug connector is preferable for use. In protection type IP 65/67, different solutions are recommended as per the guideline:

- M12 round plug connector as per IEC 60947-5-2
- Han-Brid plug as per DESINA recommendation and
- Hybrid plug connector
- 7/8" plug

The hybrid plug systems also include a variant for transmitting data over fiber-optic cable fibers and 24 V operating voltage for the peripheral devices via copper cables in a single hybrid cable.

Experience shows that difficulties with the transmission technology in PROFIBUS networks can most often be traced back to improper cabling and installation. Bus test devices, which can ferret out many typical cabling errors before commissioning, can remedy this situation.

The reference addresses of the many different plugs, cables, repeaters and bus test devices can be obtained from the PROFIBUS product catalog (www.profibus.com).

2.9 Installation information for MBP

The intrinsically safe MBP transmission technology is normally limited to certain subsegments (field devices in the hazardous area) of a system which are then linked to the RS485 segment (control system and engineering devices in the measuring station) via segment couplers or links.

As already mentioned, segment couplers are signal converters which adapt the RS485 signals to the MBP signal level and vice versa. They are transparent from the viewpoint of the bus protocol.

Links, on the other hand, are intelligent. They map all field devices connected in the MBP segment upwardly as a single slave in the RS485 segment; downwardly, it functions as a master. If links are used, the transmission rate in the RS485 segment is not influenced by the connected PA segments. This also allows fast networks to be implemented using field devices with an MBP connection for control tasks, for example.

A two-wire shielded cable (type A) is used as the transmission medium. The bus' main cable is provided with passive line termination at both ends. The bus termination is already permanently integrated at the segment coupler or link. A field device using MBP technology which is connected

with wrong polarity in most cases does not negatively affect the functionality of the bus, as these devices are normally equipped with automatic polarity detection.

A typically free of charge planning software should be used for segment design. (www.segmentchecker.com) Hereby the electrical function of a segment can be checked before installation work starts. Planning and checking steps comprise cable length and number of devices possible. This planning procedure protects the user from possible costly subsequent modifications of the installation.

The operation of bus-supplied and externally-supplied devices together is permissible. Note that externally-supplied devices draw a base current via the bus connection, which must be taken into account accordingly when calculating the maximum available supply current.

2.10 Bus diagnostics

Bus diagnostics enables the physical layer to be measured on a segment- and field device-specific basis and simplifies commissioning. Once installation is complete, the loop check is carried out at the push of a button using corresponding tools available on the market. Extensive expert knowledge about waveforms and possible causes are no longer required for commissioning.

Although simulated aging tests of installations did not show any relevant risks, there are other, substantive reasons for continuous monitoring of the physical layer itself. The most common cause of changes on a fieldbus installation are authorized interventions during maintenance or assembly operations, more so than unwanted changes due to environmental conditions. All important parameters affecting transmission quality are monitored using diagnostics tools to ensure that they remain within permissible limits.

By integrating bus diagnostics into the power supply technology, it becomes possible to monitor systems permanently rather than just sporadically, thereby facilitating the identification of errors which might otherwise slip through unnoticed during operation. This also makes it possible to detect changes on the physical layer and rectify errors which might cause the bus to fail. Bus diagnostics also make troubleshooting much easier, as maintenance personnel are provided with detailed information, often with information in plain text, about possible errors.

Notice: Explanations of field device diagnostics are found in Chapter 4 under "PA profile".

3. Communication with PROFIBUS

PROFIBUS devices communicate using the PROFIBUS DP (Decentralized Periphery) communication protocol, which is the same for all applications and which allows cyclical and acyclical communication and specifies rules for this. The core of the communication process is the master-slave method, where a master (active communication nodes: PLC, PC or control system) cyclically prompts the connected slaves (passive communication nodes: field devices, I/Os, drives) to exchange data. The polled slave answers the prompting master with a response message. A request message contains the output data, e.g. setpoint speed of a drive, and the associated response message contains the input data, e.g. the latest measured value from a sensor. A bus cycle comes to an end once all connected slaves have been polled in order.

In addition to this cyclical communication for the fast exchange of input and output data between the master and slaves at regular intervals, need-based data can also be transmitted using PROFIBUS, e.g. device setting data. A master has the initiative, accessing the data of a slave in read or write mode acyclically. There can be more than one master in a PROFIBUS system. In such a case, the access authorization passes from the active master to the next master (token-passing principle).

3.1 PROFIBUS DP communication protocol

For optimum fulfillment of the requirements of different areas of use, the functions of the PROFIBUS DP communication protocol are distributed over three performance levels: DP-V0, DP-V1 and DP-V2 (Figure 10).

Version DP-V0 provides the basic function of the communication protocol. This includes, in particular, cyclical communication and device-, module- and channel-specific diagnostics for quick fault localization. Examples of this include "excess temperature" and "short circuit on output".

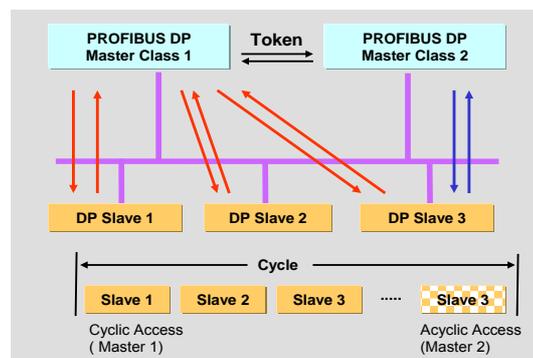


Figure 9: Cyclical and acyclical communication with DP-V1



Manufacturers of fine chemicals must respond flexibly and quickly to customer orders and frequently adapt their systems accordingly. Thanks to its enormous flexibility, PROFIBUS offers the best prerequisite for this.

Version DP-V1 supplements DP-V0 with functions for acyclical communication, i.e. for functions such as parameterization, operation, monitoring and alarm handling. DP-V1 enables online access to bus nodes via engineering tools for this purpose (Figure 9).

Version DP-V2 contains additional functions as extensions of DP-V1, in particular functions which are required for drive control. These include functions for communication between slaves, cycle synchronization and time stamping.

Field devices for process automation are typically slaves of performance level DP-V1 and can therefore communicate acyclically to set device parameters.

3.2 Device classes

PROFIBUS devices are divided into three classes based on their functions:

PROFIBUS DP master (class 1)

A PROFIBUS DP master of class 1 (DPM1) is a master which uses cyclical communication to exchange process data with its associated slaves. Devices of this type are often integrated in a memory-programmable controller or an automation station of the process control system.

PROFIBUS DP master (class 2)

A PROFIBUS DP master of class (DPM2) was originally defined as a master used as a tool in the context of PROFIBUS system commissioning. In the course of the DP-V1 and DP-V2 functional expansions, a DPM2 has been more specifically defined as a master which can be used to set device parameters via acyclical communication. Devices of this type are usually part of an engineering station used for device configuration. A DPM2 need not be permanently connected to the bus system.

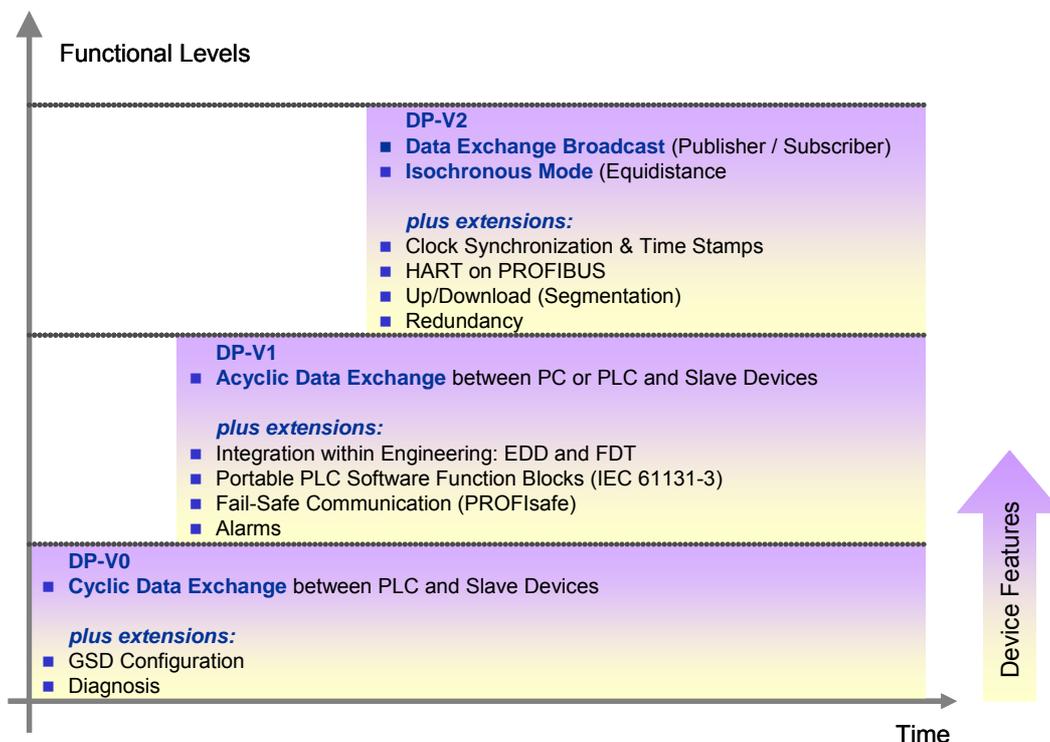


Figure 10: PROFIBUS DP protocol, performance levels

PROFIBUS slave

A PROFIBUS slave is a passive communication node which reacts to prompts from the master by sending a response message. Devices in this class are usually field devices (remote I/O, drive, valve, transducer, analyzer) which acquire process variables or play a part in the process by means of manipulated variables. A differentiation is made between compact and modular slave devices. A modular device comprises a head station containing the fieldbus interface and a number of slots into which various modules can be inserted. By combining different modules, modular slaves can be adapted flexibly to respond to prevailing requirements with regard to input and output data. Compact devices have a fixed set of input and output data – comparable to a modular device with precisely one permanently installed module.

The majority of slave devices in process automation are modular devices on which, rather than being physically present, the individual modules simply exist in the device software (virtual modules). These virtual modules (and, therefore, access to the associated input and output data) are activated or deactivated when cyclic communication is established. The virtual modules of which a slave device in process automation is able to make use are specified in the device profile for PA devices.

Frequently, PROFIBUS master devices support the functions of both a DPM1 and a DPM2. Similarly, there are also automation devices which are able to operate as both masters and slaves. In practice, it is rarely possible to unequivocally categorize physical devices into the function classes outlined above.

3.3 Cyclical communication and PROFIBUS diagnostics

Once the configuration has been loaded on the class 1 master with the help of the configuration tool, the master establishes cyclical communication with the associated slave devices (MS0 channel). During this power-up phase, the slave adopts a two-stage approach to checking the configuration data received from the master.

First, the parameters set in the configuration (e.g. master address, watchdog time and ID number) are transferred to the slave (parameterization) and checked (configuration). The ID number is unique for each device type and is assigned by PI. Cyclical communication can only take place if the ID number from the configuration tallies with the ID number saved in the slave. Next, the information about the configured modules – in other words, the configuration bytes – is transferred to the slave and checked. Cyclical communication can only be established if the modules which are physically present tally with those set in the configuration or if the device can adapt to the configuration received.

Successful establishment of communication is then verified via the requested diagnostics data. The slave reports invalid parameter or configuration data to the master through corresponding errors in the PROFIBUS standard diagnostics. If the parameter and configuration data is valid, the master will initiate cyclical communication with the slave device.

PROFIBUS diagnostics comprise both PROFIBUS-specific standard diagnostics and advanced diagnostics. The latter contains device-specific diagnostics data relating, for example, to measuring or setting procedures. Any changes to device-specific diagnostics data are reported by a slave in the response message during cyclical communication; the master will respond accordingly in the next bus cycle by polling the diagnostics data, rather than the process data, of the slave concerned. Each PROFIBUS slave can only engage in cyclical data exchange with one DPM1. This ensures that a slave can only receive output data from one master, thereby avoiding data inconsistency.

3.4 Acyclical communication and parameter addressing

A key part of the acyclical data exchange process is the writing or reading of device parameters at the behest of the master. These device parameters can be used by a centralized operator tool to configure a field device, thereby adapting it to the specific task it has been charged with performing in the technical process.

There are two different channels for acyclical communication, MS1 and MS2. In this context, a link between a master and a slave (MS1 link) via the MS1 channel can only ever be established if cyclical data exchange is taking place between the master and slave concerned.

As a slave is only able to exchange data cyclically with one master at once, a slave can only have up to one MS1 link. Subject to corresponding parameterization data, the MS1 link is established implicitly when cyclical communication is initiated and monitored by the watchdog time.

A slave can have an MS2 link with one or a number of masters simultaneously as long as it is not engaged in cyclic communication. The MS2 connection has to be established explicitly by the master. It has a separate time monitoring mechanism by means of which an MS2 link will be closed if it is not used for a set period of time. Unlike for cyclical communication, a complex configuration based on the device master file is not required for acyclical communication; usually, knowledge of the address of the device concerned is all that is needed to establish an MS2 link on the master side.

Device parameters are addressed in a slave device by means of the specification of the slot and index. The "slot" (values from 0 to 254) is a slot on a modular device; on PA devices, a slot



Foods are bound by especially stringent specifications for quality and traceability of the manufacturing process, including the communication technology. With PROFIBUS, these features are of the highest priority, which is evidenced by its wide distribution in the food industry.

addresses a function block (see Chapter 4). The "index" (0 to 254) is the address of a parameter within the slot concerned.

Devices with PA profile 3.0 and higher must have an MS2 channel, although the MS1 channel is optional. Since, in practice, very few PA profile devices implement an MS1 channel, the MS2 channel is used universally for acyclical data transmission in process automation.

3.5 Standardized function blocks (FB)

When developing and using cross-manufacturer application profiles, the technology of the standardized function blocks (FB) plays an important role, because the growing functional scope of modern field devices allows different controllers to be integrated without specific communication knowledge and without manufacturer-specific adaptations to the application program. Function blocks, which contain the sometimes complex functions of field devices (e.g. calibration, motor power-up, speed change etc.) in encapsulated form, are used for this. They therefore function as a "representative" (Proxy FB) of the corresponding field devices placed in the control program. The function blocks are generally created in the standardized programming language of "Structured Text" (ST) as per IEC 61131-3. A Proxy FB presents access to its functions in encapsulated graphic form and can therefore also be called by the "simpler" programming languages of IEC 61131-3, such as LD/COP (Ladder Diagram/ Contact Plan), FBD/FUP (Function Block Diagram/ Function Plan) or IL/APL (Instruction List/ Application List).

Proxy FBs are generally specified by device profile working groups and provided to the user in different ways, depending on the business model. The advantage here is that they can be used in controllers from different manufacturers. Individual device manufacturers can also make use of this to give their "slaves" competitive advantages by encapsulating certain functions.

For the practical use of FBs by application programmers, an interface that is system-neutral from the viewpoint of the many controller manufacturers (Application Programmer's Interface or API) must be defined in addition to the known PROFIBUS communication interface (communication platform, MS0, MS1, MS2, Figure 11) specified in IEC 61158. This makes it easy to port user software and the proxy FBs used from the programmable logic controller (PLC) of manufacturer A to the PLC of manufacturer B using standardized communication blocks ("Comm FBs") if the controller manufacturer offers Comm FBs in their programming library.

3.6 Comm FBs as a system-neutral interface with PROFIBUS

The PNO has defined function blocks (shown in yellow in Figure 11) for the system-neutral interfaces in the "Communication and Proxy Function Blocks according to IEC 61138-3" guideline. These function blocks are supported by the languages of IEC 61131-3 and the communication services of IEC 61158 defined for PROFIBUS. The guideline defines communication blocks for master classes 1 and 2 and slaves and several additional help functions as well. The technological functions of a field device can be addressed uniformly using these Comm FBs. All FBs share a common concept for displaying errors with coding as per IEC 61158-6.

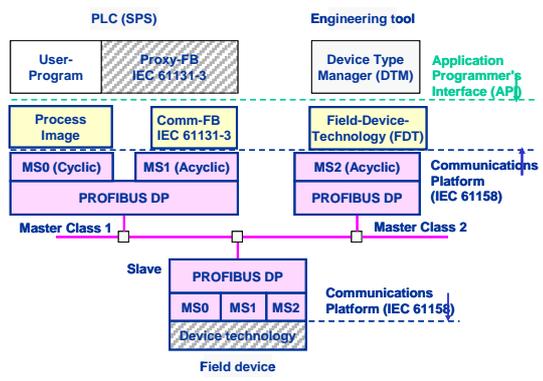


Figure 11: The use of function blocks (Proxy FB and Comm FB)

PLC manufacturers offer such standard communication blocks in PLC-specific "IEC libraries".

Profile Name	Profile Content	PNO Guideline
Specific application profiles		
Dosing / Weighing	Profile describes the use of dosing and weighing systems on PROFIBUS	3.182a; 3.182 b
Encoder	Profile describes the connection of rotary, angular, and linear encoders with single-turn and multi-turn resolution	3.062
Fluid Power	Profile describes the control of hydraulic drives via PROFIBUS (cooperation with VDMA)	3.112
HART on PROFIBUS	Profile defines the integration of HART devices in PROFIBUS systems	3.102
Ident Systems	Profile describes the communication between identification devices (barcode reader, transponder)	3.142
LabDevices	Profile specifies the properties of laboratory automation devices on PROFIBUS	2.412
Liquid Pumps	Profile defines the use of liquid pumps on PROFIBUS (cooperation with VDMA)	2.422
Low Voltage Switchgear	Profile defines data exchange for low-voltage switchgear (switch disconnecter, motor starter, etc.) on PROFIBUS	3.122
PA Devices	Profile specifies the properties of process automation devices on PROFIBUS	3.042
PROFdrive	Profile describes the device behavior and access behavior to data for variable speed electric drives on PROFIBUS	3.172; 3.272
Remote I/O	Profile defines the interchangeability of remote I/O devices in process automation	3.132
SEMI	Profile describes properties of semiconductor manufacturing devices on PROFIBUS (SEMI standard)	3.152
General application profiles		
Identification & Maintenance	Profile specifies a concept for identification of PROFIBUS devices and Internet access to device-specific information	3.502
iPar-Server	Profile defines the saving of additional i-parameters in the controller and the read-back of i-parameters after a device replacement	3.532
PROFIsafe	Profile defines safe communication of safety-related devices (emergency OFF switch, light array, etc.) with safety controllers via PROFIBUS	3.092
Redundancy	Profile specifies the mechanism for field devices with redundant communication behavior	2.212
Time Stamp	Profile defines the precisely timed assignment of certain events and actions by time stamping	3.522

Table 5: PROFIBUS application profiles

In addition to the previously mentioned "neutralized" access to acyclical communication functions via MS1, the FDT interface (see page 17) completes the Application Programmer's Interface (via MS2) for the access of engineering and configuration tools.

4. Application profiles

To ensure smooth interaction between the bus nodes of an automation solution, the basic functions and services of the nodes must match. They have to "speak the same language" and use the same concepts and data formats. This applies both for communication and for device functions and industry sector solutions. This uniformity is achieved through the use of "profiles" relating to device families or special industry sector solutions. These profiles specify features which "profile devices" must exhibit as a mandatory requirement.

These can be cross-device-class features, such as safety-relevant behavior (Common Application Profiles) or device-class-specific features (Specific Application Profiles). Here, a differentiation is made between

- Device profiles for robots, drives, process devices, encoders, pumps etc., for example
- Industry profiles for laboratory technology and rail vehicles, for example
- Integration profiles for the integration of subsystems such as HART or IO-link systems

Figure 1 shows the classification of profiles in the PROFIBUS system building blocks, and Table 5 provides an overview of currently available PROFIBUS profiles. The following contains further information on several of them.



Humidity measurement plays an important role in the processes of almost all industries, but its integration into fieldbus technology remained disregarded for a long time. PROFIBUS provided the solution. One example is the humidity measurement carried out when producing pasta.

4.1 PROFIdrive

The PROFIdrive profile is used in production automation. It defines the device behavior, the access method and the data formats for the drive data of electrical drives on PROFIBUS, from simple frequency converters to highly dynamic servo controllers. All the details on this can be found in the relevant system description (Order No. 4.322).

4.2 PROFIBUS PA (PA devices, "PA profile")

The PROFIBUS PA profile is the basis for using PROFIBUS in process automation. In addition to this profile, this application is characterized by frequently intrinsically-safe operation and device power supply via the bus cable. The PA profile defines the functions and parameters for process-control devices, such as transmitters, actuators, valves and analyzers. These functions and parameters are used to adapt the devices to the respective application and process conditions. The specifications are based on function blocks, and the parameters are classified as input, output and internal parameters. The profile also specifies how the various services of the PROFIBUS communication protocol are used. Accordingly, for example, process data exchanged cyclically is based on a standard format for all devices. In addition to the measured value and/or manipulated measurement value, this format also features a status providing information about the

quality of the value and possible limit violations. It thereby provides the foundation for harmonized applications, simplified engineering, device exchangeability and increased reliability by means of standardized diagnostic information. PA profile version 3.02 has been expanded with a host of application-oriented functions since the previous version of 3.01. These functions take into account the years of operating experience in PROFIBUS PA systems and implements the resulting user demands.

4.3 Improvements in PA-Profile V3.02

The improvements made to PA profile 3.02 concentrate on the optimization of lifecycle management of the devices with the goal of linking the simplicity of traditional 4 - 20 mA technology with the performance potential of fieldbus technology.

Version flexibility when replacing devices

Up until now, it was necessary to fall back on devices of the same generation as the installed devices when devices had to be replaced, even though a more state-of-the-art version with additional innovative features was available on the market. Version 3.02 of the profile does away with this limitation by enabling (new) devices to automatically adjust themselves to the version and functions of its predecessor device (Automatic ID Number Adaption, Figure 12). Here, the (new) device is notified of the version of the predecessor device from the controller or control system and automatically adapts itself to that device's functions without interrupting the process. This device feature is part of the certification testing of devices with profile version 3.02. The next time the system is planned to stop, the new device can be integrated into the control system and the new functions can be used.

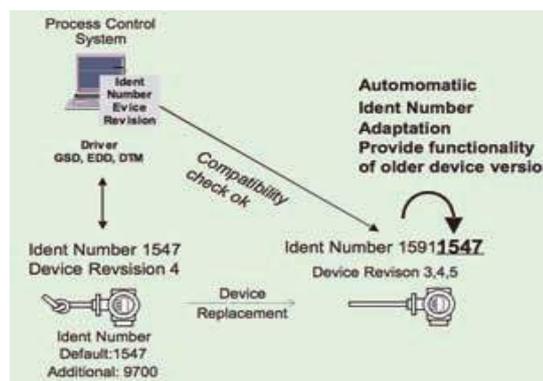


Figure 12: Device replacement with transfer of the predecessors' functions

Simplified device integration

In contrast to the trusted configuration of 4 - 20 mA devices in the field, the integration of fieldbus devices puts greater demands on the operator

due to the larger function scope. Working with the device descriptions required for this must be possible for the user without special knowledge, however.

The simplification implemented in profile 3.02 is based on cross-manufacturer rules for ensuring unambiguous compatibility between the description files (GSD, EDD, DTM) and the field devices. Among other things, the rules stipulate the storage of standardized parameters in the device and device description, which enables the integration tools to automatically assign devices and description files (Figure 13). This means considerable simplification during the initial installation or device replacement. In addition, simple and clean labeling on the device housing makes unambiguous assignment of devices to description files easier, e.g. when removing devices from storage. These device features are part of the certification testing.

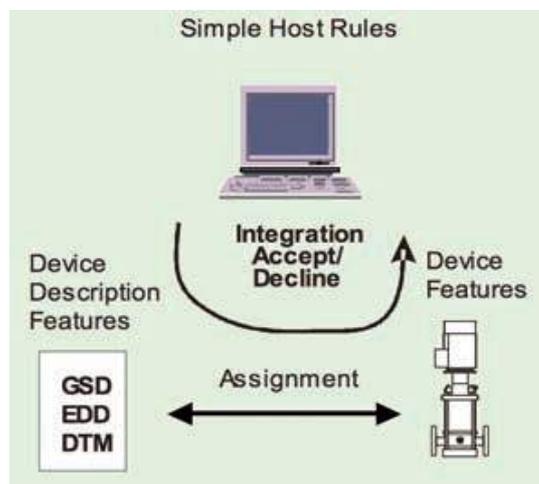


Figure 13: Unambiguous assignment of devices and description files

Accelerating data uploads and downloads

Depending on the phase of the life cycle of a system, considerable amounts of data must be transmitted when adapting parameters, during commissioning and during maintenance or device replacement. Depending on the function scope of the devices, this could be several hundred parameters, which makes the time required for transmission more important. Profile 3.02 optimizes transmission through optimum grouping of the parameters and simplified access. Depending on the amount of data being transmitted, the time required could be reduced by a factor of 10.

Continuously standardized device diagnostics

Consistency in device replacement is also ensured with regard to the output of diagnostic information. Devices with profile 3.02 are required to output diagnostic information as per the categories of NAMUR recommendation 107 (Figure 14), whereby the mapping is already carried out by the manufacturer. When replacing devices, the

owner therefore need not spend time or effort on any adaptations or changes. All devices provide identically-structured diagnostic information by default, thereby ensuring a quick and easy overview of the system. Additional detailed information enables device replacement and repair to be planned, system downtimes to be avoided, which saves money, and the service life of the system to be increased.

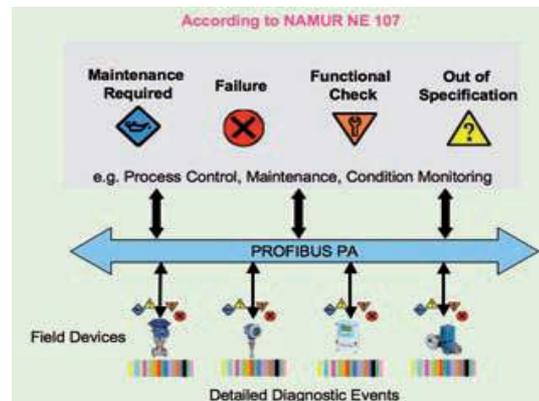


Figure 14: Diagnostic mapping as per NAMUR recommendation 107

4.4 HART on PROFIBUS

In view of the very large number of HART devices installed in the field, their integration into existing or new PROFIBUS systems is a pressing task for most users. The "PROFIBUS Profile HART" document (Order No. 3.102) offers an open solution for this. It defines the use of the PROFIBUS communication mechanism without changes to the protocol and services of PROFIBUS. The document defines a profile of PROFIBUS, which is implemented in the master and slave above level 7 and therefore enables the mapping of the client-master server model of HART on PROFIBUS. Full compatibility with HART specifications has been assured by collaborating with the HART Foundation in drafting the specification.

The HART client application is integrated in a PROFIBUS master and the HART master in a PROFIBUS slave (Figure 15), whereby the latter serves as a multiplexer and takes over communication with the HART devices.

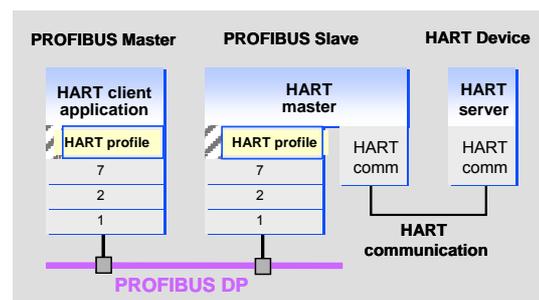


Figure 15: Operating HART devices on PROFIBUS



The use of PROFIBUS with the PROFIdrive profile is widespread in the control of packaging machines. All functions are executed on a single bus, which considerably reduces the expenditure for engineering, hardware and training.

A communication channel which works independently of the MS1 and MS2 connections has been defined for the transmission of HART messages. One HMD (HART Master Device) can support a number of clients. The number depends on the implementation.

Version 2.0 of the profile extends the existing integration to include standardized PROFIBUS modules for hard-wired HART devices as well as for the new WirelessHART® device generation. As a result, there is no need to implement a profile layer in the DP master for cyclic data exchange with DP and channel-specific diagnostics.

HART devices can be connected to the HMD via various components or to PROFIBUS via modules. These originate from a GSD of the component or are created with a device-specific module configurator. This is typically implemented as a class 2 DP master and as an HMD; furthermore, it can offer the detailed configuration of complex HART devices using an EDD or the FDT/DTM concept.

4.5 PROFIsafe

The risk of human injury, damage to production systems and environmental harm is inherent in many industrial processes. This realization resulted in "safety-related automation technology" becoming of great importance, as its safety requirements are far above and beyond those of standard automation technology. This demand must also be satisfied by the fieldbus technology, and the PROFIsafe communication profile serves this purpose for PROFIBUS.

All the details on this can be found in the relevant system description (Order No. 4.341).

4.6 Identification & Maintenance (I&M)

The definitions collected in the Identification & Maintenance (I&M) application profile are binding specifications for the storage of specific data in each PROFIBUS device. This gives the owner standard access to all device data through all devices during configuration and commissioning as well during parameterization and update procedures. The database for this are XML files stored on the www.profibus.com server. These files are managed online by the device manufacturers and are therefore kept up-to-date over the entire device life cycle (Figure 16). Using an engineering tool, this data can be read out at any time, whereby the "device-local" data is compared to the centralized, daily-updated information from the manufacturer for the device in question. This is very helpful for system documentation, order processes and maintenance processes, for example.

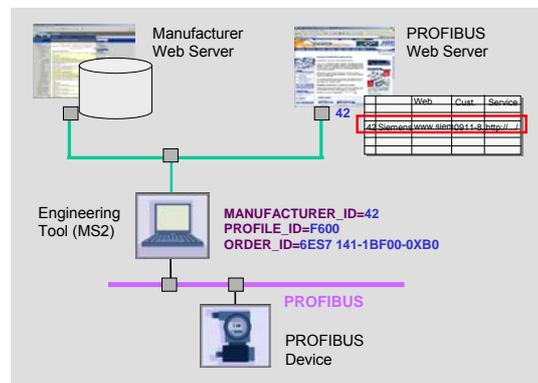


Figure 16: The principle of I&M functions

5. Device integration

A particular advantage of PROFIBUS is openness, which in turn brings with it compatibility with a large number of device and system manufacturers. However, this does mean that the benefit of numerous different device and systems suppliers is countered by a correspondingly high number of different possible HMIs. Standards for the centralized and uniform integration of fieldbuses into automation systems have been developed in order to ensure that a disproportionate amount of time and effort is not required with regard to installation, version management and device operation. Devices are usually integrated by means of mapping their functionality to operator software. The process is optimized by consistent data management throughout the life cycle of the system, with identical data structures for all devices. All standards cited in the following can be used in conjunction with PROFIBUS.

A summarized representation of device integration can be found in Figure 17.

General Station Description (GSD)

The GSD is provided by the device manufacturer and is the electronic data sheet for the communication properties of each and every PROFIBUS device. It supplies all information necessary for cyclical communication with the PROFIBUS master and for the configuration of the PROFIBUS network in the form of a text-based description. It

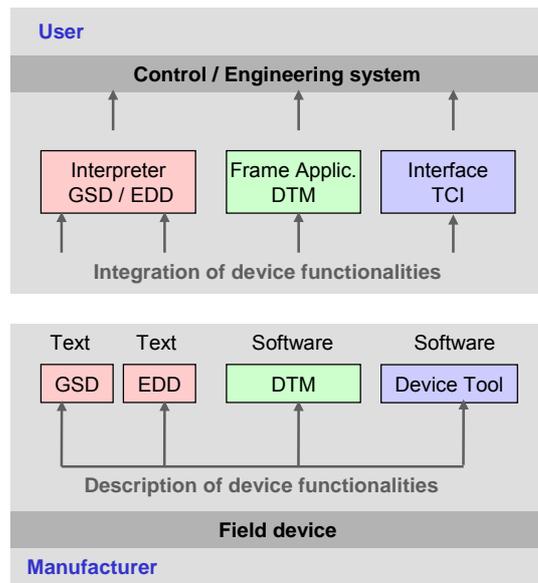


Figure 17: Technologies for device integration

contains the key data of the device, information about its communication capabilities and information about, e.g. diagnostic values. The GSD alone is sufficient for the cyclic exchange of measured values and manipulated variables between field device and automation system.

Electronic Device Description (EDD)

The GSD alone is not sufficient to describe the application-specific functions and parameters of complex field devices. A powerful language is required for the parameterization, service, maintenance and diagnostics of devices from the engineering system. The Electronic Device Description Language (EDDL) standardized in IEC 61804-2 is available for this purpose. Further development is promoted jointly by PI, the HART Communication Foundation, the Fieldbus Foundation and the OPC Foundation.

An EDD is a text-based device description which is independent of the engineering system's OS. It provides a description of the device functions communicated acyclically, including graphics based options, and also provides device information such as order data, materials, maintenance instructions etc.

The EDD provides the basis for processing and displaying device data on the EDD Interpreter.

The EDD Interpreter is the open interface between the EDDs and the operator program. It provides the operator program with data for visualization with a standard look & feel, regardless of the device and manufacturer.

Device Type Manager (DTM) and Field Device Tool (FDT) interface

In comparison to the GSD and EDD technologies based on descriptions, the FDT/DTM technology uses a software-based method of device integration. The DTM is a software component and communicates with the engineering system via the FDT interface. The FDT/DTM technology is being developed further by the FDT Group.

A DTM is a device operator program by means of which device functionality (device DTM) or communication capabilities (communication DTM) are made operational; it features the standardized FDT (Field Device Tool) interface with a frame application in the engineering system. The DTM is programmed on a device-specific basis by the manufacturer and contains a separate user interface for each device. DTM technology is very flexible in terms of how it is configured.

The FDT interface is a cross-manufacturer open interface specification which supports the integration of field devices into operator programs using DTMs. It defines how DTMs interact with an FDT frame application in the operator tool or engineering system. The interface itself is independent of the communication protocol and is available at present for more than 13 protocols including PROFIBUS, PROFINET and IO-Link.

Tool Calling Interface (TCI)

The requirement for centralized operability of communication-capable sensors and actuators of a production system from the engineering station of the automation system led to the development of TCI. TCI is an open interface between the engineering tool of the overall system and the device tools of complex devices, e.g. with drives or laser scanners, which enable centralized parameterization and diagnostics from the engineering station during operation. TCI is non-manufacturer-specific and allows dynamic parameters to be loaded to devices without having to exit the automation-system engineering tool. For users, this means a considerable simplification and time savings when calling up device tools and when carrying out configuration and online diagnostics of the systems and machines. In addition to directly-integrated device tools, technologies such as EDDL and FDT can be used via corresponding application software.

6. Quality assurance and certification

For PROFIBUS devices of different types and manufacturers to be able to perform different tasks in the automation process correctly, they must exchange information over the bus without errors. A prerequisite for this is a standard-compliant implementation of the communication protocols and application profiles by the device manufacturer. To ensure that this demand is met, the PI established a quality-assurance procedure where certificates are granted for test-passing devices using test reports as a basis (Figure 18).

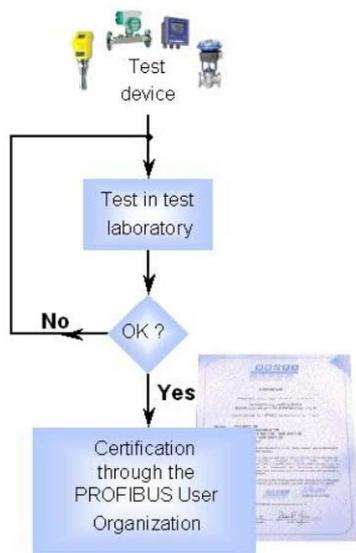


Figure 18: Device certification, test procedure

The aim of certification is to provide users with the assurance that PROFIBUS field devices from different manufacturers are capable of error-free operation when used together. For this purpose, the field devices are tested in practical applications in accredited independent test laboratories with the required testing accuracy as per the quality guidelines of PI. This makes it possible to identify any misinterpretation of the standards at an early stage so that manufacturers can take the necessary remedial action before devices are implemented in the field. The test also examines the field device's compatibility with other certified field devices. Once the tests have been passed successfully, a device certificate is issued by PI's certification center upon application by the manufacturer.

The test procedures and certification process are described in the respective guidelines.

The test procedure

The prerequisites for testing are an issued ID number and a GSD file. An EDD for the field device or the field device itself may also be required.

The test procedure, which is the same for all test laboratories, is comprised of several steps:

- **A GSD/EDD check** ensures that the device description files comply with the specifications.
- **During the hardware test**, the electrical properties of the PROFIBUS interface on the test subject are tested for compliance with the specifications. This includes, for example, the terminating resistors, the suitability of driver modules and other modules used and the quality of the performance level.
- **The function test** addresses the bus access protocol, transmission protocol and the functions of the test subject. The parameterization and adaptation of the test system are carried out using the GSD. When the test is being carried out, the black-box method is used. Here, no knowledge of the internal structure of the implementation is required. The responses generated by the test subject and their time relations are recorded by the bus monitor.
- **The conformity test** is the focal point of testing. It verifies that protocol implementation is in line with the standard. The test primarily covers the state machine, behavior in case of errors, addressability, diagnostic data and mixed operation.
- **During the interoperability test**, the interplay between the test device and the PROFIBUS devices from other manufacturers is tested in a multi-vendor system. It is determined whether the functionality of the system is maintained when the test specimen is added to it. Operation with various different masters is also tested.
- **The profile test** is carried out to determine whether the test devices work together smoothly during operation. The profile test is carried out for the PROFIdrive, PA device and PROFIsafe profiles. The test determines whether the profile functions were implemented in accordance with the specifications.

All the steps of the test are documented in detail. The notes are available to the manufacturer and the certification office. The test report provided to the orderer is used as the basis for issuance of the certificate by PI.

Once a field device has passed all the tests, the manufacturer can request a certificate from the PROFIBUS user organization. Each certified device includes a certification number as a reference. The certificate has a validity of 3 years and can be extended by a manufacturer declaration or after new testing. The addresses of the test laboratories can be obtained from the PROFIBUS website on the Internet.

7. Product implementation

This chapter contains information on options for implementing communication interfaces in automation and field devices.

A broad spectrum of base technology components and development tools (PROFIBUS ASICs, PROFIBUS stacks, bus monitors, test tools and commissioning tools) and services are available for device development and implementation of the PROFIBUS protocol. They enable device manufacturers to carry out development efficiently. An overview of this is found in the product catalog from PI (www.profibus.com/products/product-guide/). For further information, see the technical documentation, and for competent consulting, refer to the PI Competence Center.

When implementing a PROFIBUS interface, note that the device behavior is determined by the PROFIBUS protocol and the implemented application. For this reason, the entire field device is tested during a certification test. Base technologies are generally only "pre-certified", i.e. tested using a sample application. This does not guarantee that each field device based on this base technology behaves in compliance with the standards. The application in a field device has a major influence on the device's behavior.

7.1 Standard components

Interface modules

For small to medium quantities, PROFIBUS interface modules are suitable. They are available in a wide variety of versions on the market. The various designs of these modules implement the full bus protocol and offer an easy-to-use user interface for each application. This relieves the device manufacturer of communication tasks. They can be attached to the main PCB of the device as a supplementary module.

Protocol chips

For large quantities, individual implementations of the PROFIBUS protocol based on common base technology components are available. Here, a differentiation is made between

- single chips, where all PROFIBUS protocol functions are integrated on the chip and which do not require a separate microcontroller (this is a hardware-only solution with a fixed functional scope).
- communication modules which implement smaller or larger portions of the protocol on the chip. An additional microcontroller and firmware offered for the chip are required for full implementation of the PROFIBUS protocol.
- protocol chips which already include a microcontroller in the communication module. In conjunction with firmware offered for the chip, the application communicates via an easy-to-use user interface.

The decision for a suitable implementation variant mainly depends on the complexity of the field device, the required performance, the quantity and the performance scope to be implemented. Several examples are provided in the following.

Implementing simple slaves

Simple I/O devices can be implemented with single chip ASICs. All protocol functions are already integrated on the ASIC. No microprocessor or additional communication software is required. Only the components for bus connection, e.g. bus driver, optical coupler, quartz etc., are required externally.

Implementing intelligent slaves

With this form of implementation, the essential layer-2 portions of the PROFIBUS protocol are implemented with a communication module. The remaining protocol portions are implemented as software on a microcontroller. In most available ASICs, the cyclical protocol portions are realized on the chip and are generally responsible for the transmission of time-critical data.

For highly time-critical applications, protocol chips with an integrated microcontroller represent an alternative which already handles the entire PROFIBUS protocol autonomously. If necessary, an externally-connected microcontroller can then be used entirely for the application. Depending on the performance required, the field device manufacturer can also use the microcontroller which is already integrated in the protocol chip for the application.

The available ASICs offer an easy-to-use interface and work with commonly used microcontrollers. Another option is presented by microprocessors with an integrated PROFIBUS core.

Implementing complex masters

The time-critical parts of the PROFIBUS protocol are also implemented using a communication module and the remaining protocol portions as software on a microcontroller here.

As with slave implementations, ASICs from different manufacturers are available for implementing complex master devices. They can be operated in conjunction with common microprocessors.

A corresponding overview of available protocol chips is provided on the PROFIBUS website. For further information on the products, we also suggest you contact the respective providers.

PROFIBUS stacks

In many cases, chips and supplemental protocol software (PROFIBUS stacks) come from different providers. This increases the number of solutions available on the market.

Using this as a basis, technically custom-tailored and cost-optimized products which fulfill industry-specific requirements can be created, which is also the focus PI. The fact that the PROFIBUS



From raw material supply to the brewing process to filling: "Beer brewing" is a good example showing the interplay between the discreet and continuous procedures in a process. PROFIBUS handles precisely this task with its own bus system and has no competition here.

chip and the stack can come from different sources is further evidence of the openness and multi-vendor capability of PROFIBUS, which is not only limited to the specification, but extends to product implementations as well.

Pure software solutions can seldom be found on the market. The reason behind this is that the price-performance ratio of the processors to be used is considerably less favorable than with chip-oriented implementations. Pure software solutions are therefore more likely to be used in cases with specific marginal conditions. An overview of the available variants of the protocol software is found on the PROFIBUS website.

Further information on the products is available from the respective providers.

Implementing user profiles

The PROFIBUS protocol ensures the secure data transmission of bit sequences. The interpretation of data in a field device is handled by the user. User profiles represent the links between the PROFIBUS protocol and the actual application in a field device. The data formats, data access methods, parameterization and cyclical and acyclical communication diagnostics defined in the profile descriptions are implemented in software, which is often handled by the device manufacturers themselves. A host of technology suppliers provide support here.

7.2 Implementing transmission interfaces

RS485 transmission technology

For field devices which do not draw the required power from the bus, the standard RS485 interface can be implemented. This provides greater flexibility when using the field device, because it can

then be connected to PROFIBUS DP without a segment coupler or link.

RS485 technology is characterized by its low interface costs and great robustness. Data rates from 9.6 KBit/s to 12 MBit/s can be supported without any conversion. To supplement this, an intrinsically-safe version, RS485-IS, was developed.

The RS485 modules are available from various manufacturers and are time-tested (millions are in use).

MBP transmission technology

When implementing a bus-powered field device with MBP transmission technology, minimal power consumption is the main focus. For these devices, a typical supply current of only 10 - 15 mA is available on the bus cable. This has to supply the entire device, including the bus connection and the measurement electronics.

Special modem chips are available for these requirements. These modems draw the required operating energy for the entire device from the MBP bus connection and make it available as supply voltage to the other electronic components of the device. In addition, they convert the digital signals of the connected protocol chip to the bus signal of the MBP connection that is modulated to the energy supply.

A typical configuration with an industry-standard roundboard is presented in Figure 19.

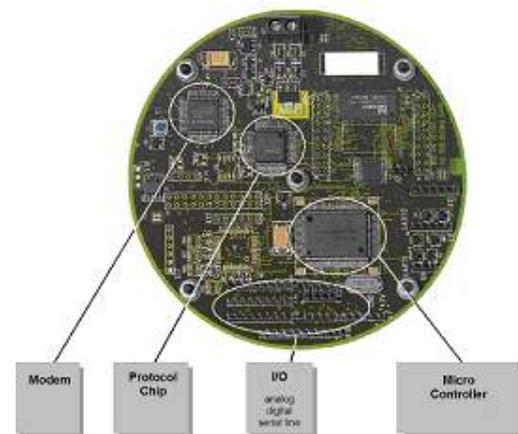


Figure 19: Example of MBP transmission technology implementation

8. User benefits

Owners of machines and automation systems in the production and processing industries place high demands on reliability and economy. The systems must fulfill their function for years, and the interplay of components and systems from

different manufacturers must be ensured. PROFIBUS, the world's leading modularly-constructed industrial communication system fulfills these requirements. The prominent feature of PROFIBUS is its ability to optimally fulfill industry-specific requirements by combining suitable modules, especially those of application profiles. PROFIBUS DP for the production industry, PROFIdrive for drive applications, PROFIBUS PA for the process industry and PROFIsafe for safety-related applications are the main examples here. Application profiles also ensure uniform behavior of the devices used, regardless of the manufacturer, and therefore their interoperability on the bus.

8.1 Standardized and consistent

PROFIBUS is based on modularity and standards; the benefits to the user are flexibility and ease of use. Modern systems and machines are often complex in structure and tightly integrated into the communication landscape of the company. The unimpeded flow of data is therefore a primary user requirement of the owner. PROFIBUS provides precisely this with its unique horizontal and vertical consistency. All PROFIBUS solutions use the same communication protocol. This enables discrete procedures (such as filling and packaging), continuous procedures (such as mixing and heating) and safety-related procedures in a system to be handled over the same bus. Separate systems are unnecessary. This "hybrid automation" with PROFIBUS overcomes limitations, makes things simpler and reduces costs over the entire operating timeframe, from planning and engineering to installation and from training and operation to maintenance and documentation.

8.2 Economy

Economy in the operation of machines and systems demands that they be highly available. The integrated redundancy of PROFIBUS is unrivaled when it comes to uninterrupted operation. Equally important are the diagnostic messages continuously available from the bus, devices and process. They provide information regarding the current machine and system status and enable timely, status-based intervention. The result is higher availability with reduced maintenance expense. Economy is also based on the option to use the respectively most suitable device technology for certain tasks. PROFIBUS provides this very option, thanks to its comprehensive device catalog from a wide variety of manufacturers and the compatibility of the devices on the bus using the device profiles.

8.3 Quality consciousness

Quality and quality assurance are of high importance with PROFIBUS, because it enables components of different types and manufacturers

to properly fulfill their tasks in the automation process. Globally-established, independent test laboratories test devices in accordance with PROFIBUS specifications for certification which are derived from international standards and which guarantee high quality standards. Specially established PI training centers offer "Certified Engineer" and "Certified Installer" courses for PROFIBUS. In addition, PI organizes workshops for users on selected topics.

8.4 Innovation and protection of privileges

PROFIBUS is known for its high degree of innovation. User requests are collected and implemented rapidly. Examples include the fulfillment of urgent demands from the process industry with the new version 3.02 of the profile for process devices and the development of direct coupling of PROFIBUS to the Ethernet-based communication of PROFINET and thus to the MES and ERP levels using proxy technology. Here, the design and communication of PROFIBUS are adapted to PROFINET, while the PROFIBUS segments and their characteristics remain completely unchanged. At the same time, existing systems can be modernized and expanded at any time with PROFIBUS. HART technology and IO-link can easily be integrated into PROFIBUS, and safety-related tasks are handled by PROFIsafe and drive tasks by PROFIdrive. All of this ensures comprehensive investment protection, because installed equipment can still be used. It's not replaced, but rather modernized and expanded.

8.5 Global support

With over 30 million PROFIBUS nodes installed, PROFIBUS has proven its reliability. Users can choose from over 2,500 devices from more than 300 manufacturers here. PROFIBUS is used globally, continuously undergoes development and is intensively supported by the world's largest fieldbus organization, PI. The regional organizations, Competence Centers and multiple test laboratories and training centers spread out across the globe provide the user with a high level of quality and support.

8.6 Future cooperation

PI's target course for the coming years is "to provide users with far-reaching solutions using PROFIBUS and PROFINET as an umbrella for new technologies." Cooperation with other organizations, contact with users and user groups and existing strengths are all to be expanded accordingly. Key technologies are to be promoted together while always complying with international standardization and consistency. PI is determined to provide direction and implement solutions that benefit the user.

9. PROFIBUS & PROFINET International (PI)

A vendor-neutral institution is needed as a working platform to maintain, advance and disseminate open technologies. For the PROFIBUS and PROFINET technologies, the PROFIBUS Nutzerorganisation e.V. (PNO) was established in 1989 as a non-profit group representing the interests of manufacturers, users and institutions. The PNO is a member of PI (PROFIBUS & PROFINET International), the international umbrella organization founded in 1995. With 25 regional PI associations (RPAs) and approximately 1,400 members, PI is represented on every continent and is the world's largest community of interest for industrial communication (Figure 20).

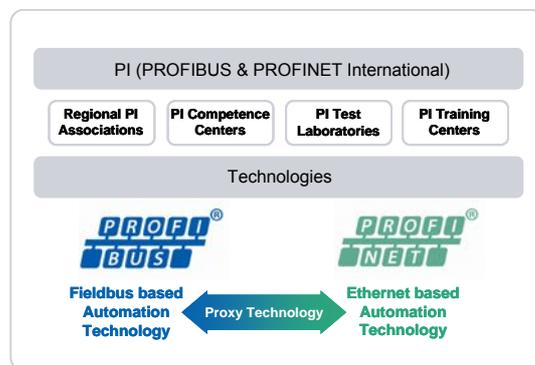


Figure 20: PROFIBUS & PROFINET International (PI)

9.1 Responsibilities of PI

The key tasks performed by PI are:

- Maintenance and ongoing development of PROFIBUS and PROFINET
- Promoting the worldwide propagation of PROFIBUS and PROFINET
- Protection of investment for users and manufacturers by influencing standardization
- Representation of the interests of members to standards bodies and associations
- Providing companies with worldwide technical support through PI Competence Centers (PICC)
- Quality assurance through product certification based on conformity tests at PI test laboratories (PITL).
- Establishment of a uniform global training standard through PI Training Centers (PITC).

Technology development

PI has handed responsibility for technology development over to PNO Germany. The Advisory Board of PNO Germany oversees the development activities. Technology development takes place in the context of more than 50 working groups with input from more than 500 experts

from development departments of member companies.

Technical support

PI maintains more than 40 accredited PICCs worldwide. These facilities provide users and manufacturers with all kinds of advice and support. As institutions of the PI, they are vendor-neutral service providers and adhere to the mutually agreed-upon rules. The PICCs are regularly checked for their suitability as part of an individually tailored accreditation process. Refer to the website for current addresses.

Certification

PI maintains 10 accredited PITLs worldwide for the certification of products with a PROFIBUS/PROFINET interface. As institutions of the PI, they are vendor-neutral service providers and adhere to the mutually agreed-upon rules. The testing services provided by the PITLs are regularly audited in accordance with a strict accreditation process to ensure that they meet the necessary quality requirements. Refer to the website for current addresses.

Training

The PI Training Centers have been set up to establish a uniform global training standard for engineers and technicians. Accreditation of the training centers and their experts ensures the quality of the training and thus of the engineering and installation services for PROFIBUS and PROFINET. Refer to the website for current addresses.

Internet

Current information about PI and the PROFIBUS and PROFINET technologies is available on the PI website www.profibus.com. This includes, for example, an online product guide, a glossary, a variety of web-based training content and the download area containing specifications, profiles, installation guidelines and other documents.

PROFIBUS System Description - Technology and Application

Version November 2010

Order number 4.332

Publisher

PROFIBUS Nutzerorganisation e.V. (PNO)

Haid und Neu-Str. 7

76313 Karlsruhe

Germany

Tel.: +49 (0)721 / 96 58 590

Fax: +49 (0)721 / 96 58 589

germany@profibus.com

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More information & contact details: www.profibus.com/community

Regional PI Associations (RPA)

Regional PI Associations represent PI around the world and are your personal local contacts. They are responsible for local marketing activities for purposes of spreading PROFIBUS, PROFINET, and IO-Link, which include trade fair appearances, seminars, workshops, and press conferences, as well as public relations activities.

PI Competence Center (PICC)

The PI Competence Centers collaborate closely with the RPAs and are your first point of contact when you have technical questions. The PICCs are available to assist you in the development of PROFIBUS or PROFINET devices and the commissioning of systems, and they provide user support and training.

PI Training Center (PITC)

PI Training Centers support users and developers in gaining experience with the PROFIBUS and PROFINET technologies and their possible uses. Individuals who successfully complete the final exam of the Certified Installer or Engineer course receive a certificate from PI.

PI Test Labs (PITL)

PI Test Labs are authorized by PI to conduct certification tests for PROFIBUS and PROFINET. You receive a certificate from PI for your product once it passes the test. The certification program plays a major role in the sustainable quality assurance of products and thus assures that the systems in use exhibit a high level of trouble-free operation and availability.

PROFIBUS Nutzerorganisation e. V. (PNO)
Member of PROFIBUS & PROFINET International
Haid-und-Neu-Str. 7 • 76131 Karlsruhe • Germany
Phone +49 721 96 58 590 • Fax +49 721 96 58 589
www.profibus.com • www.profinet.com

