PI INTERNATIONAL

PROFIBUS PA
System Description

Technology and Application

Open Solutions for the World of Automation

PROFIBUS PROFINET

Mission Statement

We are and will remain the world's leading automation organization for communication solutions, serving our users, our members and the press with the best solutions, benefits and information.

Introduction

The field of industrial communications continues to develop at an astonishing pace with the result that the field of automation technology is constantly changing. Initially, automation focused almost exclusively on production; however, it has now grown to include 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 provide a link between automation technology and information technology, thereby enabling consistent communication from the field level to the corporate management level.

PROFIBUS and PROFINET are standardized solutions characterized by their unusual ability to combine total integration with high a high degree of application orientation. With its standard protocol, PROFIBUS encompasses all sub-processes found in factory and process automation, including safety-related communication and motion control applications. It thereby provides the ideal basis for ensuring horizontal automation system integration. 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. Therefore, both communication systems are able to facilitate network-wide, integrated solutions that are optimized for the relevant automation tasks.

The main reason that PROFIBUS stands out from other industrial communication systems is because it offers such an extraordinary breadth of applications. Application-specific requirements have been incorporated into application profiles and these have been combined as a whole to create a standardized and open communication system. This provides the basis for ensuring extensive protection for the investments of both end users and manufacturers.

The application profile for PA devices (PA profile) plays a key role in process automation. It defines manufacturer-independent device parameters and functionalities for devices used in process engineering, e.g., transmitters, actuators and analyzers. The profile provides the foundation for harmonized applications, simplified engineering and increased availability by means of standardized diagnostic information.

Contents

Content

This document describes the essential aspects of PROFIBUS used in process automation and takes into account the level of technology available at the beginning of 2007. Its objective is to provide a comprehensive description of PROFIBUS and PROFINET, the world's leading fieldbus systems, without entering into specific details.

This brochure not only offers sufficient information to readers with a basic knowledge who are interested in obtaining an overview, but it also introduces experts to more extensive specialized literature. In this context, we should like to point out that although every care has been taken in the drafting of this brochure, only the official PI (PROFIBUS & PROFINET International) documents are to be considered definitive and binding.

Chapter 1 provides an introduction to PROFIBUS and its use in process automation.

Chapters 2 to 4 deal with the core aspects of PROFIBUS PA.

Chapter 5 offers a brief outline of engineering.

Chapter 6 deals with the integration of existing structures into PROFIBUS PA and the transition to PROFINET.

Chapter 7 outlines the test procedures required for certification.

Chapter 8 explains the advantages of using PROFIBUS PA.

Chapter 9 concludes the document with information about PI and its range of products and services.

This chapter is followed by the index.

1. Industrial communication with PROFIBUS

Since the cost-pressure associated with the operation of production facilities is so high, achieving maximum system availability and minimum total cost of ownership have high priorities. Therefore, holistic approaches not only take into account the procurement and maintenance costs associated with system components but also the costs of optimizing process control. In process engineering, ideal process control should support monitoring and controlling of a process in the most cost-effective way given the requirements of the process and system. This requires extensive information about the process and the system. Today, this information is made available by intelligent field devices and communicated via fieldbuses. The problem-free and consistent availability of all necessary data is an important prerequisite for optimized processes.

1.1 Consistent communication with PROFIBUS

Operators of process engineering systems find themselves facing a whole range of very different technical challenges and are looking to achieve standardization wherever possible. Accordingly, “Integration instead of interfaces” and “One technology instead of multiple technologies” are the requirements to be met by fieldbuses to support such standardization. PROFIBUS is the homogeneous technology meeting these requirements, thereby generating significant added value throughout the life cycle of a system.

PROFIBUS is the fieldbus-based automation standard from PI (PROFIBUS & PROFINET International). It offers comprehensive solutions encompassing actual communication, application profiles, system integration and engineering. The standard for PROFINET, an Ethernet-based automation fieldbus, was recently released by PI. PROFIBUS and PROFINET use identical profiles, thereby creating investment security and investment protection for both the users and manufacturers of these technologies. Both PROFIBUS and PROFINET are characterized by their support for both factory and process automation and, in particular, by their ability to facilitate implementation of hybrid applications.

PROFIBUS consistency is based on the standardized “PROFIBUS DP” communication protocol. It supports a wide variety of applications in factory automation and process automation as well as motion control and safety-related tasks, thus facilitating planning, assembly and service. Additionally, training, documentation and maintenance are only required to support a single technology.

Users with “hybrid” automation applications (see Chapter 1.3) in particular benefit from the unique ability of PROFIBUS technology to seamlessly integrate process-oriented and factory-oriented tasks. This is of particular relevance in the pharmaceutical and foodstuffs industries.

The modular structure of PROFIBUS

PROFIBUS technology has a modular structure, comprised of mutually compatible technology components which can be selected and combined in accordance with application requirements – in much the same way as a modular system (Figure 1).

At the heart of the system is the PROFIBUS DP protocol, which is identical for all applications (see Chapter 3). Various data transmission media are available: RS485 for standard applications, RS485-IS for areas with explosion protection, MBP for intrinsically-safe transmission with device power supply via the bus, fiber optics, radio-based transmission (see Chapter 2), infrared- and laser-based transmission, slip rings, etc.

In order to ensure the interoperability of devices by different manufacturers that is so vital to a wide range of applications and to transmit extensive information from complex devices in accordance with defined standards, application profiles have been specified for PROFIBUS. These profiles specify application-typical device features which “profile devices” must exhibit as a mandatory requirement. These profile features might span multiple device classes, e.g., safety-relevant behavior, or features that are specific to a particular device class, e.g., to be exhibited by process devices or drives. Devices with different profiles can operate on the same bus system. Very simple devices, e.g., decentralized binary I/O devices, do not usually use application profiles. PI has specified the profile for PA devices (“Profile for Process Control Devices” or PA profile) for process automation (see Chapter 4).

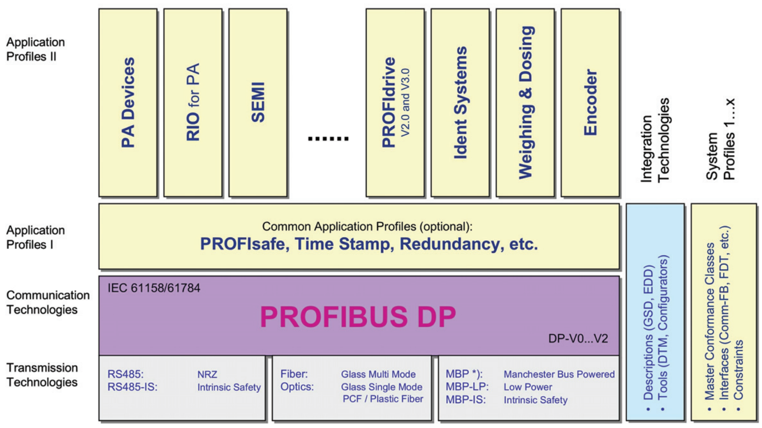

Figure 1: The PROFIBUS modular system

1.2 PROFIBUS for process automation (PROFIBUS PA)

Defined in general terms, “PROFIBUS PA” designates a specific selection of PROFIBUS technology components (modular system components) meeting the particular requirements of process automation. PROFIBUS PA encompasses all technology components used to connect intelligent field devices to controllers, control systems and engineering stations and offering ideal solutions for process automation.

MBP (Manchester-encoded, Bus Powered) technology, a 2-wire technology which combines the functions of data transmission and power supply, is usually used on PROFIBUS PA. MBP-IS (IS = intrinsically safe) is available for use in hazardous areas. With short-circuit protection and power limitation, the installation technology supports the explosion-protected operation of field devices in Zones 0, 1 and 2 and/or Class I/Div.1 and Class I/Div.

The simple topology of PROFIBUS PA pays off as early as the planning phase: The scope of documentation can be reduced by up to 90% when compared to a 4-20 mA installation. During the commissioning phase, loop checks can be completed much more quickly, significantly reducing the total time line from planning to commissioning. The flexibility of PROFIBUS installation also makes adding more devices, retrofitting or replacing devices easier once operation is underway. When add-ons or expansions affecting older systems are required, 4-20 mA devices or HART devices can be integrated into PROFIBUS installations with ease. PROFIBUS PA installations have shown evidence of very high availability even in the harsh conditions of day-to-day operations. However, the use of diagnostic tools, e.g., to monitor voltage levels and jitter and detect evidence of wear at an early stage (see Chapter 2.5), is recommended during commissioning and periodically once a system is in operation. Redundancy solutions for PROFIBUS PA to increase system availability (see Chapter 2.6) are available for applications with high availability requirements.

The PA profile classifies the devices used in process automation as transmitters, actuators, devices for digital inputs and outputs, or analyzers. For each device class, the profile specifies the associated functions and parameters which can be used to adapt the device functions to the individual application and process conditions. The specification is based on function blocks and parameters types are classified as input, output and internal. The profile also specifies how the services of the PROFIBUS communication protocol are used. For example, process data exchanged cyclically is based on a standard format for all process automation devices. In addition to the measured value and/or manipulated value, this format also features a status byte providing information about the quality of the value and possible limit violations.

The device functionality specified in the PA profile facilitates standard handling of process devices not only from the point of view of the controller but also from the perspective of asset management. Furthermore, the interoperability of like devices from different manufacturers facilitates the exchange of devices on the bus. The best way to appreciate the wide and varied range of PA devices, control systems and asset management systems available on the market is to take a look at the “Online product guide” at www.profibus.com.

The diagnostics concept defined in the PA profile also provides the backbone for comprehensive asset management. PROFIBUS PA can utilize these concepts to tap into the enormous potential for cutting costs, since necessary maintenance operations can be planned in line with the production schedule and/or scheduled downtimes.

PROFIBUS is internationally standardized in IEC 61158/61784 and is the most successful and proven fieldbus technology on the market. More than 20 million installed PROFIBUS devices make PROFIBUS the most successful communication standard in the world. Of this total, over 3.5 million are in use in the process industry and more than 700,000 devices conform to the PA profile and utilize MBP communication. Users from all sectors of industry can use PROFIBUS to significantly improve their production processes and dramatically reduce the total cost of ownership. Supporting PROFIBUS, PI is an organization with representation at national levels, with competence centers and test laboratories in countries all over the world (see Chapter 7).

1.3 PROFIBUS for all system components

Many production facilities run process control procedures that are characterized by continuous measurement and control processes alongside sequences that rely heavily on manufacturing technology that is very much based on discrete process stages. In such systems, the overall process comprises three stages: inbound logistics (pre-production), production itself and outbound logistics (post-production). Inbound logistics includes processes such as handling of incoming goods, warehousing and supply of materials. Outbound logistics includes the packaging and shipping of finished products, for example.

Some typical examples are:

- In the pharmaceuticals industry, the manufacture of medicines is a process control procedure, but packaging, e.g., of tablets, is a discrete manufacturing procedure using complex packaging machines.
- In a brewery, the process control tasks typical of the brewhouse and fermentation cellar are followed by discrete manufacturing tasks. Such tasks might include bottle cleaning and filling as well as the stacking of crates for delivery, a task for which robots may be used.
- In vehicle construction, the paint shop, with its process control requirements, is part of a production chain that is otherwise typical of discrete manufacturing.

The use of PROFIBUS enables all areas within a production facility to be automated with a single technology. Production facilities with heterogeneous fieldbus solutions for different areas and their associated additional expenditures for engineering, data storage and documentation, and the additional costs involved in training, have become a thing of the past.

For comprehensive planning and optimization, the consistency of a communication system at the field level should also take into account the capability for vertical integration into the corporate management level utilizing, for example, Ethernet-based communications technology. Network transitions from PROFIBUS to PROFINET enable PROFIBUS systems to be linked "seamlessly" to PROFINET and thus into the corporation management level (see Chapter 6).

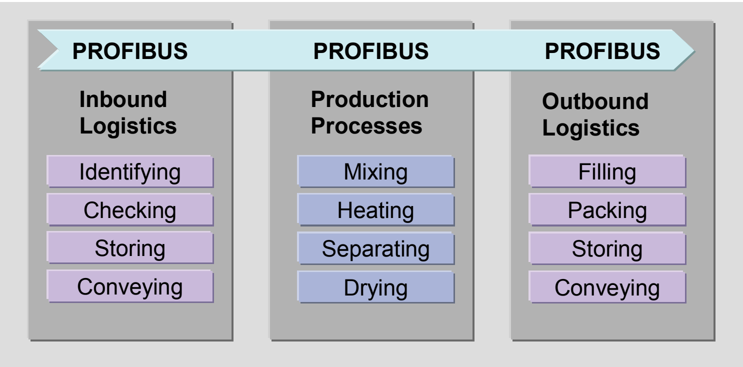

Figure 2: Integrated PROFIBUS solution in a production facility

1.4 Integration of existing systems

These days, a significant share of the investments made in process engineering is spent on expansion and modernization. Many projects have proved just how suitable PROFIBUS is for such situations. The "Remote I/O" and "HART on PROFIBUS" profiles support the integration of installed 4-20 mA devices into a PROFIBUS communication system without requiring changes to be made to cables, thereby allowing maximum benefit to be derived from the advantages of a fieldbus system (see Chapters 2.7 and 6.1).

2. Transmission technology and installation

2.1 Power and communication via a single cable

Like conventional 4-20 mA or HART communication technologies, fieldbus technology supports the simultaneous transmission of power and communication data via a single cable, even in potentially explosive atmospheres. Furthermore, with wiring overheads significantly reduced, it meets the requirements for simpler and safer installation and boasts all the benefits of digital transmission.

IEC 61158-2 defines MBP (Manchester-encoded, Bus Powered), as a transmission technology satisfying all requirements of and developed specifically for the needs of process automation. This transmission technology makes it possible to supply power to the connected devices directly via the bus medium. MBP is characterized by the following features:

- Transfer rate: 31.25 kbps
- Transmission technology: Half-duplex, synchronous, self-clocking, with Manchester biphase L encoding
- CRC (cyclic redundancy check)
- Data security: Preamble, fail-safe start-end delimiters
- Cable: Shielded, twisted pair line (type A or type B)
- Topology: Line and tree topology with termination; combined topology possible
- Number of stations: Up to 32 stations per segment
- Ignition protection: Several methodologies and technologies

Explosion protection is implemented via power limiting of the incoming bus supply as well as installation components in the field. Live maintenance on field devices during plant operation is made possible, for example, by means of intrinsically safe explosion protection. The easiest way to verify intrinsic safety of a segment is to use the FISCO model. In this case, since all components used comply with FISCO standards simple comparisons of power voltage and current eliminate further calculations (see Chapter 2.4).

2.2 Topology

PROFIBUS PA offers quite flexible installation concepts which, thanks to the advanced installation technologies available on the market, can lead to incredibly robust systems. In principle, all topologies are supported. However, in practice, the trunk & spur topology (Figure 3) has established itself as the de facto standard due to the fact that it is so clear and easy to understand and maintain. The total length of a segment in the most ideal situation must not exceed 1,900 meters. Transmission conditions for PROFIBUS PA can be optimized by using type A cable consisting of a single shielded, twisted pair. All segments must be terminated correctly with terminating resistors ("T" in Figure 3). These terminations are very important for reliable operation due to their effect on signal quality.

2.3 Connection of DP and PA

The connection between a PROFIBUS DP and a PROFIBUS PA segment is accomplished using segment couplers or DP/PA links. Essentially, both components perform the following tasks:

- Converts the asynchronous RS485 bus physics into the synchronous MBP bus physics
- Supplies voltage for the PA segment and limits the segment current supply
- Decouples the transmission speeds of RS485 and MBP bus physics
- Optional: Provides isolation and power limitation for hazardous areas

An essential feature of segment couplers is the ease with which the entire network can be configured. All PA devices are visible by address (transparent solution) on the DP side. The couplers themselves do not need to be configured.

The DP/PA link appears on the DP bus as a separate modular slave device with the connected PA devices appearing as plug-in "modules". An essential feature of the DP/PA link is the provision of a totally isolated address space for its connected PA devices (non-transparent solution). It has to be configured separately and restricts the total amount of data which can be transferred to and from the connected PA devices to 244 bytes. The cyclic data from all the connected PA devices is compressed into a single DP telegram.

The faster DP segment enables a number of PA segments to be integrated into a DP network via segment couplers or links.

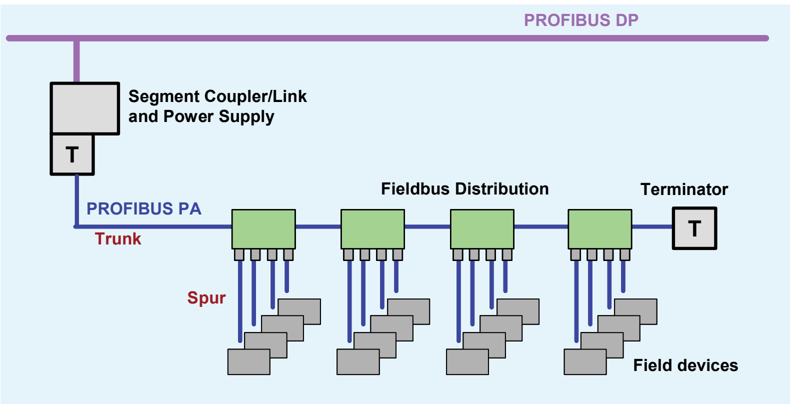

Figure 3: Trunk & spur topology

2.4 PROFIBUS PA in hazardous areas

Significant care must be taken when designing segments if PROFIBUS PA is to be used in hazardous areas. The FISCO (Fieldbus Intrinsically Safe Concept) model referred to above can make planning, installing and expanding PROFIBUS networks in hazardous areas significantly easier. The model is based on the concept that a network segment can be considered intrinsically safe (with no separate intrinsic safety calculation required) if the voltage, current, power, inductance and capacitance values of the relevant components (cable, segment couplers, bus terminators) are within the boundaries of prescribed FISCO limits and all field devices are FISCO certified.

The FISCO model is based on the following principles:

- Each segment only has one power source (the supply unit).
- Each field device consumes a constant basic current of at least 10 mA.
- The field devices always act as passive current sinks. Even when a station is transmitting, no power is fed into the bus.
- There is a passive line terminator at each end of the main bus line.
- Line, tree and star topology networks are possible.

Components and instrumentation by various manufacturers can be operated on the same segment provided that all of them meet the requirements described. Intrinsic safety is considered proven if all stations on an electrical circuit have been certified in accordance with FISCO as defined in IEC 60079-27. A simple comparison of current, voltage and power of the supply and the field device is required to validate explosion protection. For Zone 2, energy can be limited to Ex nL (non-incendive). Both concepts have been included in the revised version of IEC 60079-27. ("Entity" is another intrinsically safe model which is used in the USA and regions with close ties to the United States.)

Power limiting in potentially explosive atmospheres can significantly restrict cable lengths and the number of configurable field devices per segment. The high-power trunk concept overcomes this obstacle by means of the spatial distribution of the "fieldbus power supply" and "protection via intrinsic safety" functionalities. This concept is based on the typical practice that service operations and/or device expansions are usually performed on field devices and their connecting cables (spurs) and only rarely on the main trunk line between the control room and the distributors in the field. Based on this typical practice, it is therefore possible to split the fieldbus installation into two different types of explosion protection.

The trunk between the safe area and the fieldbus distributors is designed with Ex-e ("increased safety") and, unlike Ex-i ("intrinsic safety"), imposes virtually no restrictions in terms of power limitations. The "fieldbus barriers", which support the connection of up to four field devices, then act as distributors mounted in Zone 1. Connecting several fieldbus barriers in series enables the possible cable length and number of stations per segment to be multiplied many times over in comparison with either the Entity or the FISCO model. Here too, the FISCO or Entity concept is applied to each spur to verify Ex-safety; each output is verified separately, with the fieldbus barrier as power source and the field device as sink.

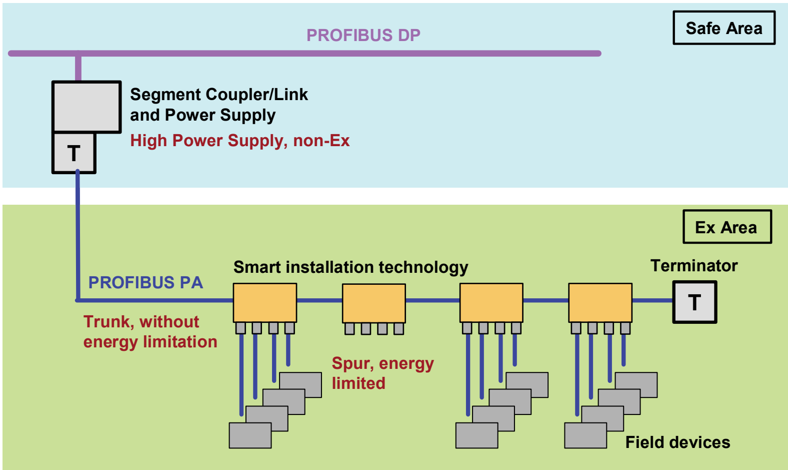

Figure 4: Fieldbus barriers with High Power Trunk

Since the incoming power supplied via the Ex-e-protected trunk is so high, this concept is also referred to as the "high-power trunk" concept.

2.5 Bus diagnostics

Fieldbus diagnostics enables the physical layer to be measured on a segment- and field device-specific basis. Bus diagnostics considerably simplifies commissioning. Once installation is complete, the loop check can be carried out at the touch of a button (subject to appropriate software support). Extensive expert knowledge about waveforms and possible causes are no longer always required for commissioning.

Although no evidence of artificial ageing was detected during laboratory testing, there are other substantive reasons for permanent monitoring. The most common causecauses of changes on a fieldbus areis authorized or unauthorized interventions in the context of maintenance or assembly operations. All parameters affecting transmission quality are monitored using diagnostics tools to ensure that they remain within permissible limits.

By integrating 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 go 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 makes troubleshooting much easier, as maintenance personnel are provided with detailed information, often with content in plain text, about possible errors.

(Note: Chapter 4.4 deals with diagnostics relating to the state of field devices.)

2.6 Redundancy

Redundant systems are generally used for applications requiring increased availability, e.g., continuous processes. In such systems, both the master and the communication system (media and segment couplers) are designed with redundancy. There are various redundancy concepts:

- Master redundancy: The control system/controller is designed with redundancy, e.g., flying redundancy (Figure 5, right).
- Media redundancy: The cable routes are designed with redundancy.
- Segment coupler redundancy: The segment couplers are designed with redundancy (Figure 5, left). If one DP-PA gateway fails, the other will take over its function seamlessly. The master is unaware of the switchover and no frames are lost.
- Ring redundancy: In addition to the redundant design of the DP-PA couplers, the ring structure also enables media redundancy to be achieved on the PA side (Figure 6).
- Slave redundancy: The field devices/PROFIBUS interface in the field device are designed with redundancy.

Concepts for slave redundancy are described in the PROFIBUS specification titled “Slave Redundancy”. Field devices designed with redundancy must negotiate between themselves which is to act as the primary station and which as the secondary station. Manufacturer-specific solutions are available for transmission media and master redundancy.

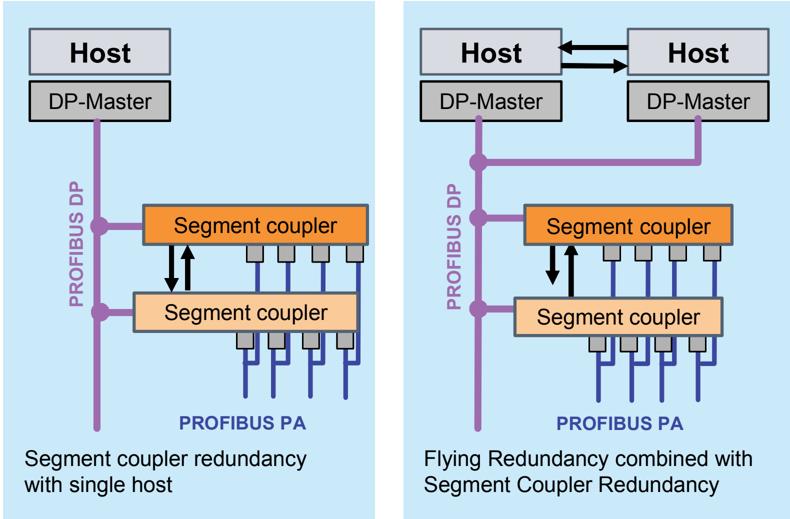

Figure 5: Segment coupler redundancy (left) and flying redundancy (right)

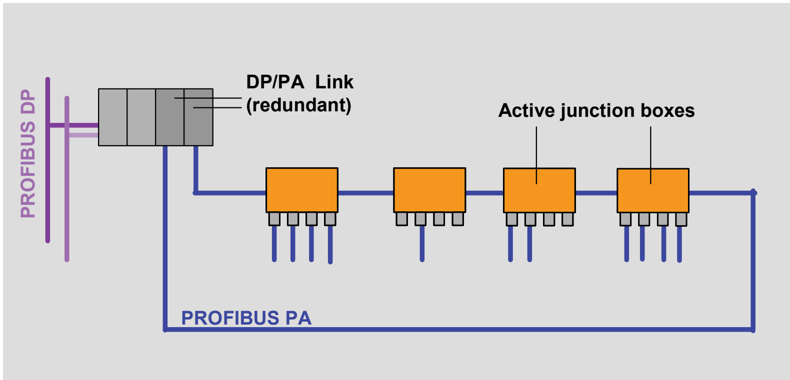

Figure 6: PA ring redundancy

2.7 Remote I/O

PROFIBUS PA devices can be used in a wide range of applications. Some devices are, able to transmit multiple measured values, thereby reducing the need for additional instruments. They are supplied with power via the bus, thus helping to reduce wiring overhead. Digital transmission helps to increase system accuracy and avoids the potential scaling errors common with 4…20 mA technology by differentiating between the settings in the control system and those in the field device. Devices can be parameterized via the bus and typically have a reduced footprint.

However, there are some process signals and/or devices which do not have a direct PA connection and for which the costs associated with a fieldbus interface bear no relationship to the low overall costs of the device. In such cases, when existing systems are being modernized, use is made of existing equipment wherever possible and installed field devices continue to be used. Remote I/O technology provides a means of integrating devices of this type into PROFIBUS PA installations. Analog and binary input and output signals are collected by a remote I/O device that is in turn connected to the control system via the fieldbus. Where HART-compatible remote I/O are concerned, parameter data is transmitted via the bus to the remote I/O device, where it is converted into HART commands on the appropriate input or output channel. In this way, the field devices can be configured from the control system or by use of a parameterization tool via PROFIBUS and the downstream HART communication system.

3. PROFIBUS communication protocol

PROFIBUS devices communicate using the standardized PROFIBUS DP (Decentralized Periphery) communication profile which defines the rules governing communication. At the heart of the communication profile is what is known as the master/slave concept, whereby a master (active communication peer) polls the associated slaves (passive communication peers) cyclically. When polled, a slave will react by sending a response frame to the polling master. A request frame contains the output data, e.g., setpoint speed of a drive, and the associated response frame contains the input data, e.g., the latest measured value from a sensor. In one bus cycle, the master polls, e.g., exchanges I/O data with, all associated slaves. This polling cycle is repeated as fast as possible.

In parallel with this type of communication, which is described as cyclic and supports the regular exchange of input and output data between a master and its slaves, parameter data, e.g., device settings, can also be transmitted via PROFIBUS. This action is initiated by the master (typically under user program control) between I/O cycles to read and/or write slave parameter data. This type of communication is referred to as acyclic communication.

There can be more than one master on a PROFIBUS system. In such systems, access rights are passed from one master to the next (token passing).

In order to meet the specific requirements of the various fields of application in the best ways possible, the PROFIBUS communication system has been expanded beyond its basic functionality to include a number of additional levels supporting special functions. There are currently three such protocol levels: DP-V0, DP-V1 and DP-V2.

The major features of the three are as follows:

- DP-V0 supports the basic functionality of the PROFIBUS protocol. In particular, this includes cyclic I/O communication and diagnostic reporting.
- DP-V1 adds optional functions for acyclic communication and alarm handling (enhancements to diagnostic reporting) to the PROFIBUS protocol.
- DP-V2 adds optional functions to the PROFIBUS protocol which are needed particularly in the field of drive control. These include functions for producer-consumer communication between slave devices, time synchronization and time stamping.

Field devices for process automation are typically slave devices which support the basic function of the PROFIBUS communication protocol (DP-V0) and are also capable of acyclic communication for the reading/ writing of device parameters (DP-V1).

3.1 Device classes

PROFIBUS devices can be categorized into three device classes:

Class 1 PROFIBUS DP master

A class 1 DP master (DPM1) is a master which uses cyclic communication to exchange process data with its associated slaves.

Class 1 masters are usually integrated into a programmable logic controller or form part of the automation station on a process control system.

Class 2 PROFIBUS DP master

A class 2 DP master (DPM2) was originally defined as a master to be used as a tool in the context of PROFIBUS device and 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 acyclic communication over what is known as the MS2 channel.

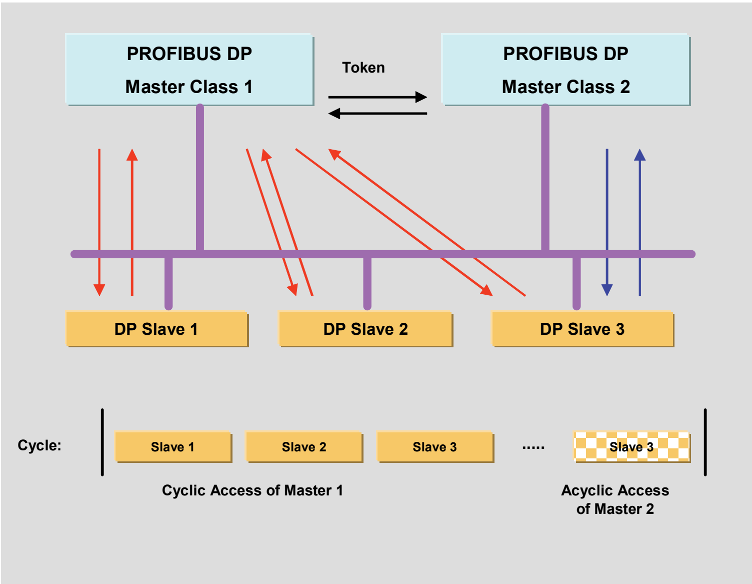

Figure 7: Cyclic and acyclic communication on DP-V1

Class 2 masters are usually part of an engineering station used for device configuration. A DPM2 does not have to be permanently connected to the bus system.

PROFIBUS slave

A PROFIBUS slave is a passive communication peer which reacts to polling by the master by sending a response frame. 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.

There are two different types of slave devices, compact devices and modular 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 configured to satisfy the specific I/O requirements of the user. Compact devices have a fixed I/O configuration – comparable to a modular device with one permanently installed module.

Slave devices for process automation may have discrete or word I/O. The majority of such devices provide measured values as input(s), with some being single-variable and some being multi-variable devices. Multi-variable devices can be thought of as modular devices on which, rather than being physically present, the individual modules simply exist in the device software (virtual modules). Access to the associated input and output data, e.g., measured values, setpoints, etc., are activated when cyclic communication is established. The process I/O data (virtual modules) associated with a process automation slave device are specified in the 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 not always possible to unequivocally categorize physical devices into the functional classes outlined above.

3.2 Configuring a PROFIBUS system

When a PROFIBUS system is configured, slaves with which the master is to communicate cyclically are assigned to a class 1 PROFIBUS DP master. During the configuration process, master and slave addresses are assigned, the bus parameters are defined, the types and numbers of modules (in the case of modular slaves) are specified, user-selectable parameter choices are made, etc.

PROFIBUS protocol message frames have a source and target address by means of which the sender and receiver can be uniquely identified. The PROFIBUS device address range runs from 0 to 126 and, within a single PROFIBUS network, device addresses can only be assigned once. Broadcast address 127 can be used to address multiple slaves simultaneously. The device address can be set using the physical address switches on the device or the PROFIBUS message for address setting, e.g., sent from the configuration tool. The physical address assigned to the device must match the address assigned to the device in the configuration setup. If a DP/PA link is being used as the coupler, it has a slave address on the RS485 side and a master address on the MBP side. Addresses on the RS485 side are independent of those on the MBP side, i.e., the two sides have separate address spaces. Rather than being limited by the number of available addresses, the scope of a PROFIBUS PA system is usually restricted by physical properties such as cable lengths and device current consumption (see Chapter 2).

Major bus parameters are transfer rate, watchdog time, slot time, and target token rotation time. As PROFIBUS masters usually have an RS485 interface, the transfer rate can be set to a value between 9.6 kbps and 12 Mbps. Although most modern couplers can operate at any transfer rate on the RS485 side, some older models only supported a fixed rate of 93.75 kbps and/or 45.45 kbps and sometimes required that the bus parameters be modified to manufacturer-defined values. The slave device's watchdog is used in monitoring cyclic communication and must be set significantly higher than the time required for one bus cycle. If a slave does not receive a request frame for a period of time longer than the set watchdog time, it will revert to its initial, power-up state and cyclic communication will have to be reestablished. If the master does not receive a valid response from a slave within the configurable slot time, it will resend the request frame as many times as it can up to the maximum retry limit. The target rotation time is the configuration tool-calculated time for the token to traverse the token ring. It should be set to the same value on all masters in a multi-master system. A master calculates its own token holding time by taking the difference between the target token rotation time and the measured rotation time.

In the case of modular slaves, the individual slave modules must be configured. The configured modules should match slot-for-slot those which are physically present in the device. In the case of PROFIBUS PA slaves, the slave will have a default, power-up configuration of virtual modules. The types and numbers of virtual modules are either profile- or manufacturer-specified depending upon whether the device is operating in profile- or manufacturer-identifier mode. The configured modules determine the size and format of any I/O data exchanged during cyclic communication.

A configuration tool (usually provided by the manufacturer of the class 1 PROFIBUS DP master) is used for building a bus description. The configuration tool takes the device-specific properties, e.g., the transfer rates supported or the available modules, from the device master file (GSD) of a slave device. This is an ASCII file describing the communication-specific and I/O properties of a PROFIBUS device that is provided by the device manufacturer.

3.3 Cyclic communication

Once the configuration (bus description) has been loaded into the class 1 master with the help of the configuration tool, the master establishes cyclic communication with the specified slave devices via the MS0 channel. During this 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., watchdog time and PROFIBUS ID number, are transferred to the slave and checked. The ID number is unique for each device type and is assigned by PI (PROFIBUS & PROFINET International). Cyclic communication can only take place if the ID number from the configuration matches the ID number stored in the slave.

Next, the description of the configured I/O modules is transferred to the slave and checked. Cyclic communication can only be established if the modules which are physically present match those specified in the configuration or, in the case of PA devices, if the device can assign virtual modules to match the configuration received.

Successful establishment of I/O data communication is then verified via the requested diagnostics data. Invalid parameter or configuration data is indicated by corresponding error indicators in the standard PROFIBUS diagnostics. If both the parameter and configuration data are valid, the master will initiate cyclic I/O data communication with the slave device.

PROFIBUS diagnostics comprises both the required standard diagnostics and the optional extended diagnostics. The latter contains device-specific diagnostic data, for example, analog over-voltage, operating temperature exceeded, output short circuit, etc. Any changes in device-specific diagnostics data will be indicated by a flag in the response frame during cyclic communication. The master will respond accordingly in the next bus cycle by polling for the diagnostic data instead of the process data.

A DP slave can only enter into cyclic data exchange with one DPM1. This ensures that a slave can only receive output data from one master, thereby avoiding inconsistent output control.

3.4 Acyclic communication

A key part of the acyclic data exchange process is the writing or reading of device parameters on demand by a master. These device parameters can be used to tailor the configuration of a field device to exactly match the application requirements. Two different channels, MS1 and MS2, exist for acyclic communication. An acyclic communication link between a master and a slave (MS1 link for short) can only be established if cyclic data exchange is taking place between that master and the slave.

Since a slave can exchange cyclic I/O data with only one master at a time, it follows that a slave can only have one MS1 link. If supported by the device (indicated in the GSD file), the MS1 link is established when cyclic communication is established with the device.

It is possible for a slave to have an MS2 link with a number of masters simultaneously. Each MS2 connection must be established explicitly by a master. Each MS2 connection has its own time monitoring mechanism and will be closed if it is not used for a set period of time. Unlike cyclic communication, a configuration based on the device master file is not required for acyclic communication. Typically, the address of the device is all that is needed to establish an MS2 link from the master.

Device parameters are addressed in a slave device by means of slot number and index. The virtual or physical “slot” is identified by a slot number (0 – 254) on a modular device. On PA devices a slot addresses a function block (see Chapter 4). An “index” (0 to 254) into the slot addresses a parameter of the function block.

Devices conforming to PA profile 3.0 and higher must support an MS2 channel, although the MS1 channel is optional. In practice, very few PA profile devices implement an MS1 channel. Therefore, the MS2 channel is used almost universally for acyclic data transmission in process automation devices.

4. The PA profile

The PROFIBUS profile for PA devices standardizes the core functionalities of devices in process automation. Process devices are categorized into individual device classes with functionality as described in detail by the profile. Users benefit from the common manufacturer-independent core functionality of the devices in a device class due to the identical way in which those devices operate. A generic, profile-specific device driver (see Chapter 5) can be used to integrate a device of this type into a control/asset management system and operate it within the functional scope specified in the profile, i.e., in profile mode, without the need for manufacturer-specific drivers.

4.1 Structure

The PA profile is structured according to the functional classification of the process automation devices.

Part 1 contains the basic specifications. In this part, the device model illustrated below is based on function blocks. The standard parameters available in each block are defined and the basic functions, e.g., saving and transfer of a linearization table, are specified. Part 1 also contains tables with codes for manufacturer names, technical units of measurement, etc.

Part 2 describes the PROFIBUS-specific properties of a process device and the relationship between the profile and the PROFIBUS communication protocol. Specifications to be made by the manufacturer from the point of view of the PROFIBUS protocol are indicated here for the benefit of process device uniformity. These include, for example, specific configuration bytes for each device class. This ensures that in the context of manufacturer-independent cyclic I/O data exchange, PA devices in the same class communicate using the same data formats. The data format specified for transmitters and actuators consists of five bytes. The first four bytes contain the measured or manipulated value as a 32-bit floating point number and the fifth byte, the status byte, provides information about the quality of the measured value. Part 2 also contains specifications regarding uniform support of any optional PROFIBUS communication services, a specification of the encoding of device-specific diagnostic information and a list of the communication services which must be used to transfer the parameters specified in the protocol.

Parts 3 to 8, also referred to as data sheets, provide very detailed specifications for the functionalities of transmitters, devices with digital inputs, devices with digital outputs, actuators, analyzers, and multi-variable devices.

The remaining parts of the profile deal with the functionality of the individual process device classes. In addition to this division, the profile also draws a distinction between class A and class B devices. A class B device has additional functions not supported by a class A device.

4.2 Block model and signal flow

The PA profile uses what is known as a block model to describe device functionality. The model encapsulates individual functions in blocks and then represents the overall function of a device by means of links between these blocks. These function blocks describe the flow of the measured/actuating signal within the device, i.e., how it is processed from sensor to fieldbus interface or from fieldbus interface to physical actuator.

Figure 8 illustrates signal flow and function blocks using the example of a transmitter. The digital sensor signal is processed initially in an associated transducer block (TB). Structured according to various measured variables and measurement principles, the transmitter-specific part of the profile describes the functionality and associated parameters of the transmitter. Examples of TB functions, for example, include the conversion of the sensor value via linearization characteristics (which may depend on the sensor used or the properties of the process), the selection of the measurement unit or interference compensation.

The TB's output signal (primary value) is then transferred to the input of an analog input function block (AI), where the measured value is processed independently of the specific measurement procedure. If this process does not result in a correct value, the AI function block will automatically switch to a preset substitute value

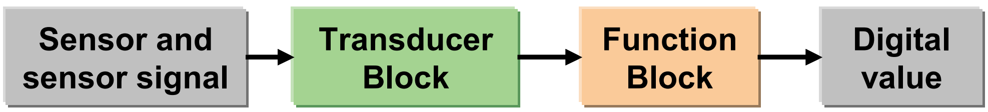

Figure 8: Functional structure of PA devices

or to the last valid measured value. The measured value is subject to continuous limit value monitoring. If it undershoots or overshoots these limits, the alarm information will be set accordingly and a limit violation will be indicated in the associated status byte. Simulation mode disconnects the AI from the TB and a specified simulation value is processed by the AI.

The measured value made available at the AI output is determined by the setting of the channel parameter in the AI; it assigns the AI to a TB and can - on devices with multiple sensors - be converted to a different TB.

In addition to transducer and input/output blocks, every PA device features an implementation of what is known as the physical block (PB). It is not part of the signal flow but contains information about the device itself, e.g., manufacturer code, serial number, installation date and diagnostic information. A complete overview of a PA device in the block model including data flows via the three data channels MS0, MS1 and MS2 appears in Figure 9. For more detailed information, see the book titled “Profibus PA" referenced in Chapter 9.

4.3 Device parameters

The individual data sheets of the PA profile define a set of profile parameters for each device class. Each of these parameters is associated with a function block. Depending on the type of parameter, a distinction is made between input, output and internal FB parameters.

Input parameters can be assigned their value by the output parameters of another block or by the user. Input parameters are used to adapt device functionality to a specific application. They can usually be set by a central station on PROFIBUS and saved there for archival and documentation purposes.

FB output parameters can be linked to the input parameters of other blocks. They can also be read via PROFIBUS, e.g., in order to provide information about the current status of the device.Block-internal parameters are assigned values used in internal FB calculations and can usually only be read via PROFIBUS.

Where profile parameters are concerned, a distinction is made between parameters which must be supported by every profile device in the associated class and parameters which are optional. Furthermore, the manufacturer of a device is free to implement other parameters in a device, e.g., in order to support the execution of a manufacturer-specific device function. Every block also has fixed, standard parameter components, e.g., the type of block and the device class. The PA profile specifies the function blocks which must be implemented for each device class. In addition to the functional description of the function block, a list of associated block parameters is also specified. This list contains the sequence of the parameters as well as their attributes, e .g., data type, length, read/write access rights, input/output or internal parameters, memory characteristics and information about whether the parameter is required or optional. The profile also specifies whether a parameter can only be transferred acyclically or both cyclically and acyclically. Typically, only individual output parameters associated with an analog input and digital input block or input parameters associated with an analog output and digital output block are communicated.

Parameter addressing is accomplished using the slot and index model specified for acyclic reading and writing. The profile only defines the relative position (relative index) of a parameter within the block. The number and types of implemented blocks, the slot and index of the first parameter, as well as the number of parameters per block are all encoded in the directory object (DO) which can be read from slot 1, index 0 and following indices on all PA devices.

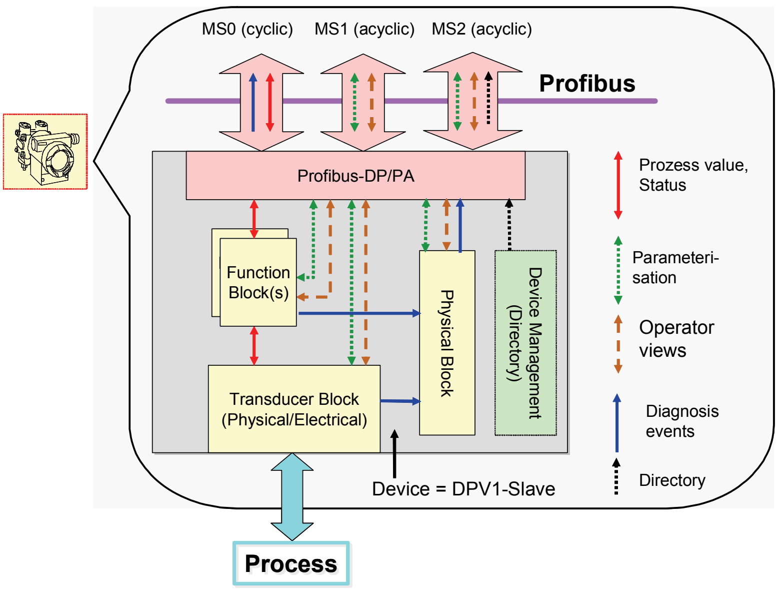

Figure 9: PA device represented in the block model

4.4 Operating profile devices

The uniform, core functionality of PA devices in a device class significantly facilitates the integration of PA devices into control systems/plant asset management systems. Device-independent drivers (profile GSD, profile EDD and profile DTM) mapping the functionality specified in the profile enable devices to be operated without device-specific drivers. Cyclic data traffic can be configured with a profile GSD. A profile GSD can be used to facilitate the operation and interchange of devices in the same class from different manufacturers. In order for this to be possible, the ID number of the device must be set to the profile ID number (parameter ID number selector in the physical block). Profile GSDs can be obtained from the PI Web site (www.profibus.com).

4.5 PROFIBUS in safety-related applications

Automation equipment having an effect on or safeguarding plant safety is subject to strict approval requirements in respect of the safe performance of its safety function. These requirements are not simply restricted to automation devices such as sensors, actuators and controllers but also extend to the communication system connecting these devices.

The PROFIsafe profile increases the transmission safety of the PROFIBUS protocol and has been officially approved for applications up to Safety integrated Level 3 (SIL 3).

With PROFIsafe, PROFIBUS was the first communication standard to have a communication layer developed in accordance with the requirements of international standard IEC 61508 and, therefore, supporting the transmission of safety-related and non-safety-related communication data via the same communication medium. The implementation of the PROFIsafe profile is independent of both the physical transmission technology and the application layer. This means that the PROFIsafe technology is equally compatible for use on process devices with the PA profile and for factory automation devices.

PROFIsafe has four ways of detecting data transmission errors:

- Sequence numbering
- Time monitoring
- Unique identification of communication peers
- Cyclic redundancy check (CRC)

These safety measures are implemented in the device software in the form of a safety layer superimposed on the PROFIBUS protocol, which remains unchanged. The safety layer checks the additional safety-related data received during cyclic data exchange, indicating errors when any are detected. In the sending of data, the safety layer generates the safety-relevant data.

The device parameters transferred during acyclic communication are not subject to the data safety mechanisms specified in the PROFIsafe protocol. In order to meet the requirements of functional safety with respect to device parameters, Appendix 1 of the PA profile (“Amendment 1, PROFIsafe for PA Devices”) specifies a procedure for starting up PA devices under acyclic communication conditions. As part of this procedure, the safety-related device parameters have a checksum generation performed both in the device and in the configuration tool. Only when both checksums match can the device be operated in a safety-related application with its current settings. It is not possible to change device settings during safety-related operation.

In process automation, safety-related applications must take into consideration issues that go far beyond functional safety.

- The required high availability of the sensors affects the details and sequence of device development and
- The term or property known as "proven performance" (IEC 61511) is of great significance in this respect. User guidelines such as the NAMUR recommendations NE 79 and NE 97 define requirements in this respect.

It was already common practice in the use of 4-20 mA technology to use “proven-in-use” field devices for safety applications. In order to facilitate such use for more complex fieldbus communication, "proven-in-use" devices can be provided with a bus interface and an "on/off" PROFIsafe layer. This allows users to continue to rely on one and the same device type for standard or safety applications.

4.6 Functions for device identification and maintenance support (I&M)

Identification and maintenance functions (I&M for short) describe a concept for identifying PROFIBUS devices and accessing device-specific information online via the Internet. I&M parameters describe device-identifying parameters such as manufacturer code, serial number, order number, hardware and software version. Both the format of the parameters and the communication services used to read them are identical for all PROFIBUS devices. An operator tool accessing I&M parameters can then use the manufacturer code to access the device manufacturer's Web site. The assignment between manufacturer code and Web URL is published on PI's Web site and used by the operator tool. Other

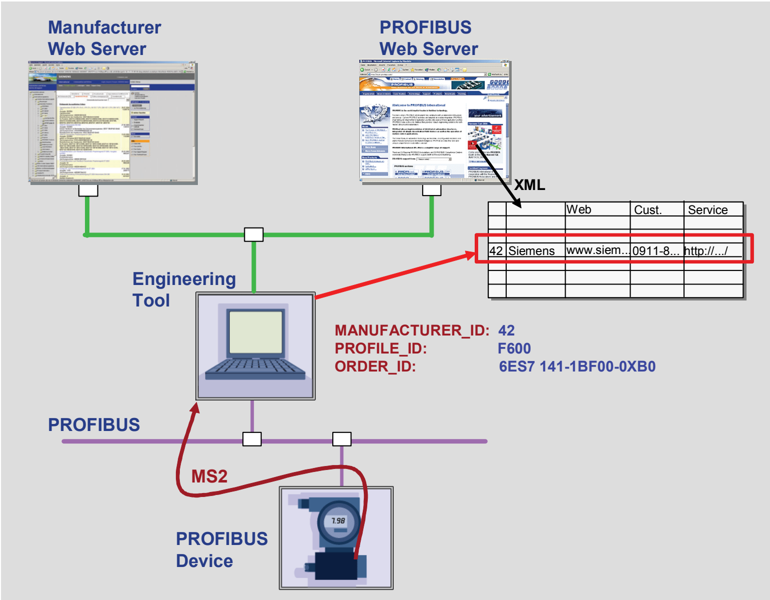

Figure 10: I&M functions supporting asset management

I&M parameters and parameters from the context of the operator tool are used by the tool in accordance with specific regulations in Web URLs to facilitate dedicated access to device-specific online information such as device documentation, GSD files or replacement parts. In this respect, I&M functions affect not only the functionality of the PROFIBUS device but also create a concept spanning the functionality of operator tools, the content of Web URLs and the provision of information on a Web site.

Appendix 3 of the PA profile ("Amendment 3, Identification and Maintenance Functions") describes the relationship between I&M parameters and their corresponding profile parameters (usually physical block parameters), thereby linking the I&M specification with the PA profile. I&M functions are specified independently of the profile for all PROFIBUS devices supporting an acyclic communication channel.

4.7 Device diagnostics

Consistent "diagnostics" of machines, systems and automation devices provides huge potential for savings in the context of their operation, maintenance and repair. "Intelligent" field devices provide good requisite conditions since, in addition to measured and manipulated variables, they are also able to provide operational status information, e.g., remaining wear margin, number of operating hours or even process-specific states. This type of status and diagnostic information must be unambiguous to provide a basis for making relevant and sound decisions.

In principle in an automation system, there are three possible users of field device information: the controller, the system operator, e.g., for availability and validity of process values, and maintenance/ service personnel, e.g., for location and cause of faults needed for equipment replacement.

Adaptation to VDI/VDE and NAMUR

Device-specific diagnostics and its targeted distribution to various users without additional measures having to be taken is a very attractive feature of fieldbus technology in comparison with conventional analog signal transmission. The PA profile makes provision for a diagnostics capability of this type (see "Amendment 2, Condensed Status and Diagnostic Messages"). In terms of content, specific care was taken to ensure compatibility with the requirements of VDI/VDE 2650 and its NAMUR equivalent NE107, closing a significant information gap between fieldbus and control technology.

VDI/VDE Guideline 2650 Sheet 1 and its NAMUR equivalent, recommendation NE107, require that the diagnostics information provided by the field device be categorized into what are known as "status signals" which must be made available permanently by the device. The four status signals are analogously:

Function check (C):
Output signal temporarily invalid (e.g. frozen) due to ongoing work on the device.

Maintenance Request (M):
Although the output signal is still valid, the wear margin is almost exhausted or, due to application conditions, e.g., caking, a function will soon be restricted.

Out of Specification (S):
The device is operating outside of its specification, e.g., the permissible physical measurement range has been exceeded, and/or is operating under process conditions which may lead to deviations from measured values or setpoints, e.g., bubbling in the context of flow measurements.

Failure (F):
Output signal invalid due to malfunction in the field device or its peripherals.

PA devices transfer the measured value status cyclically together with the process value in the form of easy-to-interpret information about the state of the field device. There are four specific values corresponding to the four status signals listed above.

Parameterization for the current application

The assignment of diagnostic events to a specific measured value status is often only possible subject to the evaluation of the measurement point with regard to the specific application. For example, volume build-up on a level limit switch would typically be assigned to the "Maintenance" status signal. However, in another specific process application, volume build-up might relate to a known, process-specific build-up which will be removed during the next cleaning cycle. In this case, the "Out-of-Specification" status signal would be more appropriate.

In order to adapt the assignment of diagnostic events to measured value status in line with specific application conditions, the concept also supports an option to adapt the "Diagnostic event - Measured value status" assignment made by the manufacturer via parameterization.

More detailed diagnostic information

The two guidelines cited above also propose going beyond the scope of the classification of a diagnostic event as described and making available additional and more detailed diagnostic information. This in turn makes it possible, by means of appropriate functions in the control system or plant asset management system (PAMS), to provide information on an individual basis to various addressees, e.g., operators and maintenance personnel, via parameterization.

The new diagnostics concept of PROFIBUS PA is a decisive step on the road to comprehensive asset management and a significant shift from preventive or reactive maintenance to proactive maintenance or condition monitoring. This provides a huge potential for cutting costs, since field devices susceptible to wear, e.g., actuators or ph value analyzers, can be virtually fully utilized since necessary service operations can be scheduled in line with the production schedule and/or regularly scheduled downtimes.

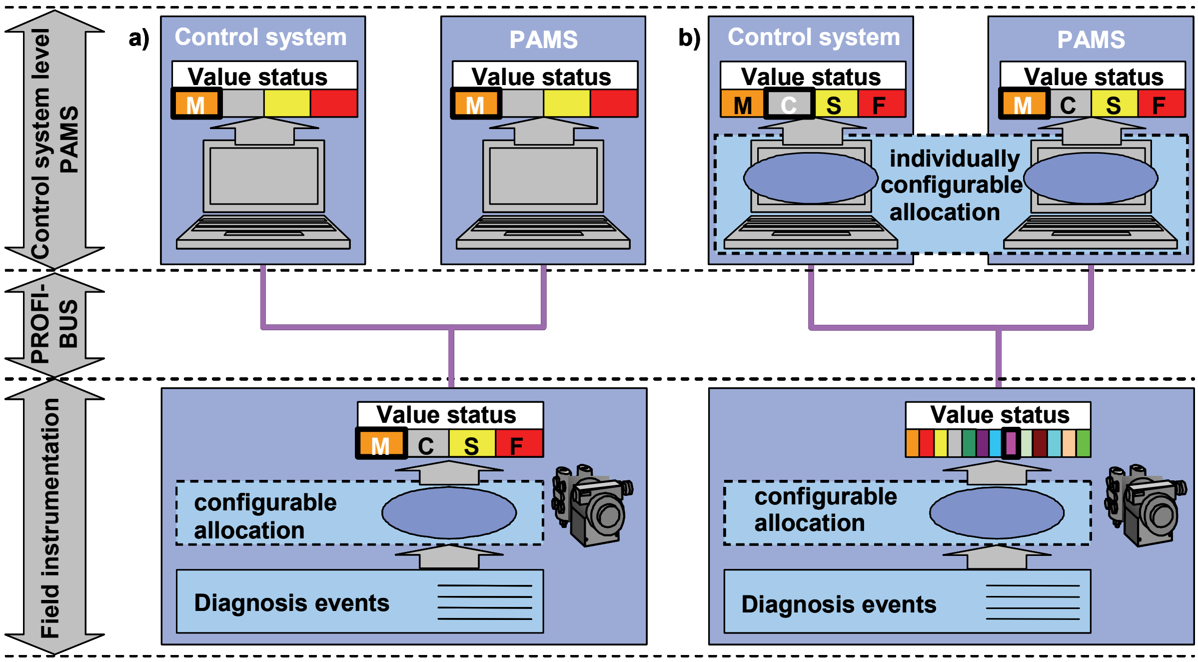

Figure 11: Assignment of a diagnostic event to a value of measured value status

5. Device integration

A particular advantage of PROFIBUS is its openness, which in turn brings with it compatibility across 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 available HMIs. Standards for the central 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 respect 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 sections can be used in conjunction with PROFIBUS.

5.1 General Station Description (GSD)

The GSD is provided by the device manufacturer and is the electronic data sheet for the communication properties of any PROFIBUS device. It is standardized in ISO 15745 and supplies all information necessary to specify the cyclic I/O communication with a PROFIBUS master and for the configuration of the PROFIBUS network. A GSD file is in the form of a text-based description. It contains key information about the device, e.g., communication baud rates supported, possible I/O configurations, any special features supported and possible device diagnostics provided (if included by the vendor). The GSD alone is sufficient to specify the cyclic I/O data exchange of measured values and manipulated variables between field device and automation system.

5.2 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 to support the engineering system in handling the parameterization, service, maintenance, and diagnostics of the devices. The Electronic Device Description Language (EDDL), standardized in IEC 61804-2, is used for this purpose. It has been further developed by the ECT (EDDL Cooperation Team), a cooperative effort including PI, the HART Communication Foundation, the Fieldbus Foundation and the OPC Foundation.

An EDD is a text-based device description which is independent of an engineering system's OS. It provides a description of the device functions handled by acyclic communications, including any graphics-based functions. It also provides device information such as order data, materials, maintenance instructions, etc.

The EDD provides the basis for the processing and display of device data by 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 device or manufacturer.

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

Sharing the principles of the GSD and EDD technologies but executable-software-based rather than description-based, FDT/DTM technology created a method of device integration permitting a variety of different devices from all manufacturers to be integrated and managed using a single piece of operator software. The DTM is an executable software component communicating with the engineering system via the FDT interface. The ongoing development of FDT/DTM technology is in the hands of the FDT Group and is subject to international standardization (IEC 62453).

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 in a device-specific fashion by the manufacturer and contains a separate user interface for each device. DTM technology is very flexible in terms of how it can be configured.
The FDT interface is a manufacturer-independent, 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.

6. System technology

6.1 Paradigm shift in process automation

Process automation is characterized by a number of specific features which determine the use of automation technology to a significant extent: the service life of systems is frequently more than 20 years; such systems often feature high risk potential and, therefore, demand that specific safety requirements are met; the use of proven-in-use devices and systems is preferred; old and new technologies must coexist in such a way that they are functionally compatible.

This coexistence of old and new technologies is a particularly relevant requirement where communication between field devices, in-process components and control systems is concerned. The most frequently used standard for transferring measured values or manipulated variables is consistently the 4-20 mA signal, often superimposed with the HART communication technology protocol. HART (Highway Addressable Remote Transducer) is a communication system stan-dardized by the HART Communication Foundation (HCF) which supports the transmission of additional data, e.g., limit values, diagnostics data, and error messages via the 4-20 mA signal.
Where newer systems or system expansions are being installed, the use of 4-20 mA technology has given way to fieldbuses such as PROFIBUS PA or FF (Foundation Fieldbus). In order for these technologies to run side-by-side in a single system, integrated communication concepts are required.

PROFIBUS offers a particularly effective integrated communication solution for process automation which is essentially based on the following technologies and concepts:

- The standard PROFIBUS DP protocol
- The various profile definitions
- The "Remote I/O for PA" specification
- The "Profile for HART on PROFIBUS" specification for the integration of the large number of installed HART devices into PROFIBUS systems

The "Profile for HART on PROFIBUS" specification defines a profile which is implemented on master and slave above layer 7 and as such supports the mapping of the client/master/server model of HART onto PROFIBUS. Full compatibility with HART specifications has been assured by collaboration with the HCF in drafting the specification.

The HART client application is integrated in a PROFIBUS master and the HART master in a PROFIBUS slave, the latter serving as a multiplexer and taking over communication with the HART devices. A communication channel which works independently of the MS1 and MS2 links has been defined for the transmission of HART frames. One HMD (HART master device) can support a number of clients.

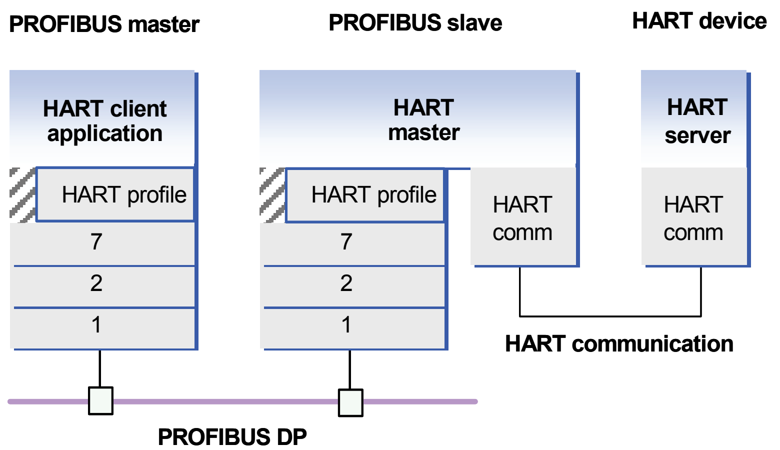

Figure 12: HART devices operating via PROFIBUS

(TCP/IP, http, SMTP, etc.) with the requirements of industrial communication (real time, determinism, etc.). In so doing, PROFINET turns the success of nearly 20 years' experience of Industrial Ethernet to its advantage. Real-time applications and non-time-critical programs (Internet browsers, e-mail clients, etc.) from the office world can run on the same network cable. The use of Ethernet results in a uniform company-wide networking technology for both office and production. The system supports communication throughout the production chain…from the delivery of materials through the various phases of the production process and beyond to packaging and dispatch.

PI has specified the PROFINET technology as the Ethernet standard for industrial automation.

Potential benefits of PROFINET

PROFINET facilitates vertical and horizontal communication from the field level to the corporate management level, thereby significantly

6.2 PROFINET in automation technology

Industrial Ethernet has been used in automation technology since the mid-eighties to network computers and controllers. Now, PROFINET provides an Ethernet-based communication system which is able to combine the benefits of office communication

simplifying the link between production processes and systems for production planning and control, e.g., manufacturing execution systems (MES) and enterprise resource planning (ERP). PROFINET uses globally established standard IT services and offers scalable real time communication for all applications in the automation sector. Both real-time and TCP/IP-based communications can run concurrently on the same cable. The technical integration of process data into the IT infrastructure of the company is thus much easier than is the case with fieldbus solutions.

PROFINET for process automation

Now that PROFINET is firmly established in factory automation, its use is being introduced in process automation too. The strengths of PROFIBUS which have served it so well over the years, e.g.., consistent communication methods for process and factory automation, the safety and drive technologies, and application profiles for all important applications have all been adopted by PROFINET.

The integration of PROFIBUS PA into PROFINET targets the protection of investments in existing PROFIBUS PA installations while also exploiting the advantages of the PROFINET technology. This is because installed PA devices can be used in PROFINET systems with no changes. To ensure the ability to integrate these devices into control systems or asset management systems, mapping onto PROFINET has been added to the PA profile.

Integration of PROFIBUS PA into PROFINET

The focus of the requirements on the use of PROFINET in process automation is the consistent integration of PROFIBUS PA into PROFINET. The proxy concept, which is responsible for conversion between the two communication systems at both the physical and communication layers, is part of this integration. This means that it remains possible to use the properties of the PROFIBUS PA transmission technology developed specifically for process automation without having to sacrifice the benefits of PROFINET technology. In addition, there are industry-specific product offerings of PROFIBUS PA-compatible process devices today that cannot be expanded short-term to offer equivalent PROFINET-compatible devices.

There are currently no plans to develop PROFINET-compatible devices for intrinsically-safe areas of process automation due to the lack of "power over the bus" solutions for Ethernet that would facilitate the intrinsically-safe supply of power to devices similar to that supported by 2-wire MBP-IS.

PROFINET as a communication medium between control systems

In addition to using PROFINET in terms of the above scenarios, PROFINET is of great importance in the exchange of data between control systems. In this respect, PROFINET in automation systems will also perform the task of a communication backbone which will interconnect PROFINET devices directly and PROFIBUS PA devices indirectly via proxy solutions.

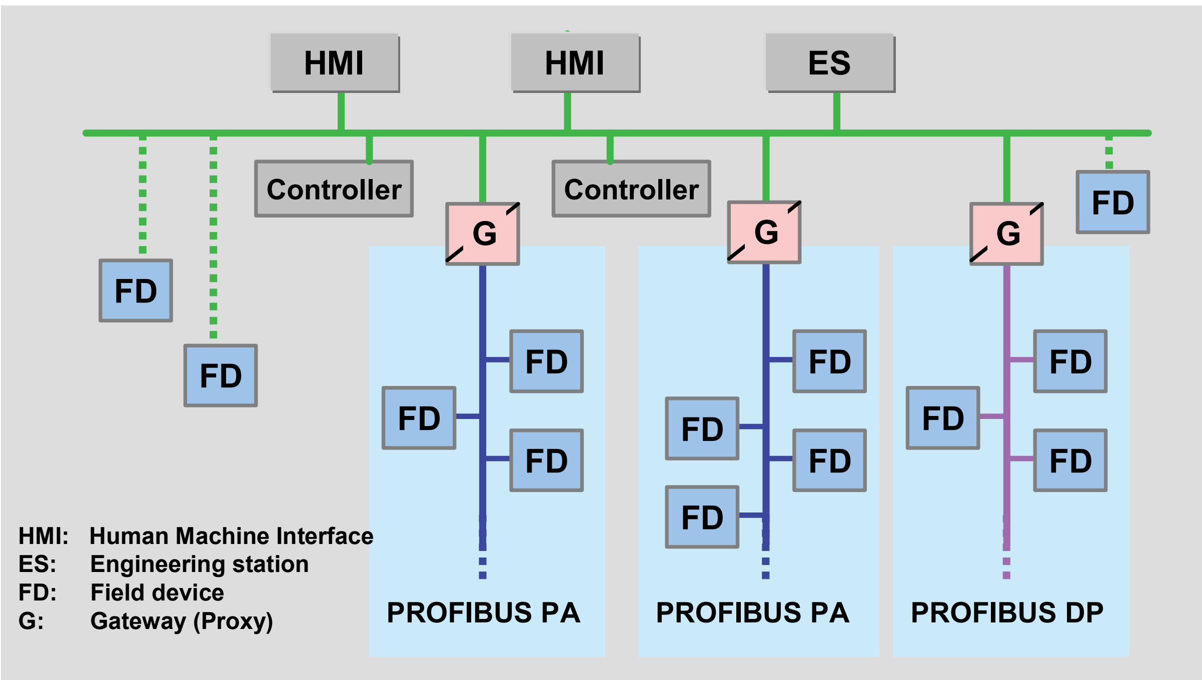

Figure 13: PROFINET-based automation system

7. Conformity and certification

For products of different types and from different manufacturers to be able to perform various tasks in the automation process correctly, they must exchange information over the bus without errors. A prerequisite for this is a standards-compliant implementation of the communication protocols and application profiles by the device manufacturers.

Certificates are issued to prove that the many devices available (which vary considerably from manufacturer to manufacturer and in terms of their functional scope) conform to the communication and profile specifications. Certificates are issued by the PI certification body on the basis of a test report from an accredited PITL. This provides the user with added peace of mind with respect to the interoperability and interchange-ability of products.

7.1 Quality control through certification

To ensure that products are developed in accordance with the standards, PI has established a quality assurance system whereby certificates are issued for products that meet the necessary requirements as indicated in a test report.

The aim of certification is to provide users with an assurance that devices from different manufacturers are capable of fault-free operation when used together. The devices are tested by independent test laboratories in accordance with the approved test procedures. This makes it possible to identify any misinterpretation of the standards by developers at an early stage so that manufacturers can take the necessary remedial action before devices are installed in the field. The test also examines the device's compatibility with other certified devices. Upon successful completion of the test, the manufacturer can apply for a device certificate.

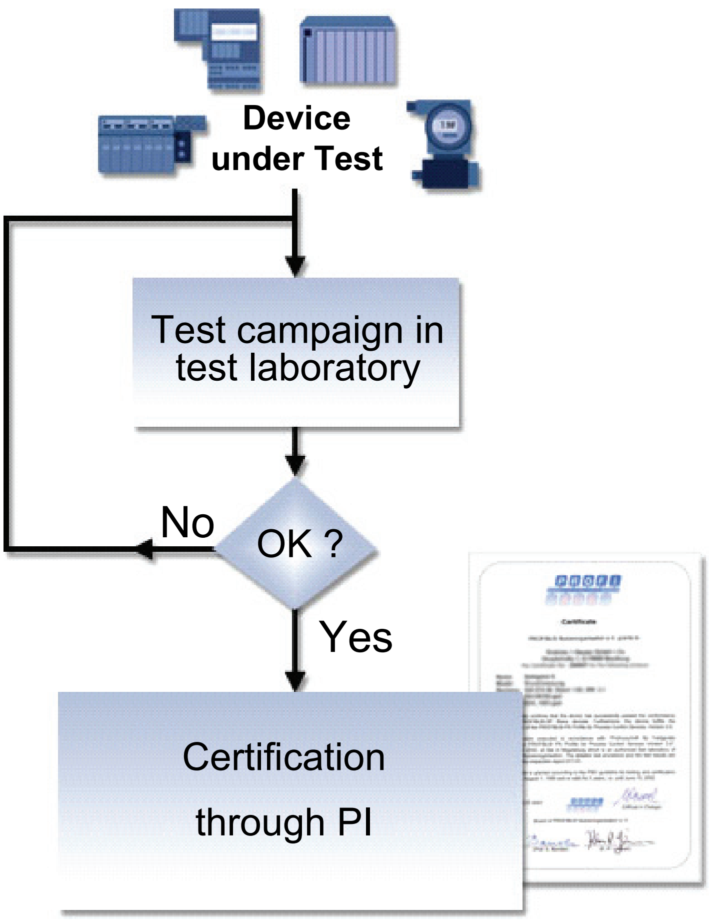

Figure 14: Test procedure for certification

The certification procedure is based on standard EN 45000. In accordance with the requirements of this standard, the test laboratories accredited by PI are not associated with any specific manufacturer. Only these accredited test laboratories are authorized to carry out the device tests that form the basis for certification.

The test procedure and sequence for certification are described in the guidelines.

7.2 PA device certification

Figure 14 shows the basic certification procedure for a PROFIBUS device (device under test). The devices undergo automated testing based on test scripts. All the results from the individual test steps are recorded automatically in the device test log. The quality system and accreditation procedure together ensure a consistent level of test quality at the PITLs.

8. User benefits

The concepts of “integration instead of user interfaces” and “One technology instead of multiple technologies” mean that PROFIBUS is able to generate significant cost reductions throughout the life cycle of a system: during planning, installation, operation and maintenance, as well as in the context of system expansions or upgrades. The provision of additional information such as diagnostics data or supplementary measured values increases system availability and productivity.

PROFIBUS integration is based on the standardized “PROFIBUS DP” communication protocol, which supports a variety of applications in factory automation and process automation as well as motion control and safety-related tasks. This integration proves its worth during planning, assembly and service while training, documentation and maintenance are required to support only a single technology. Users with “hybrid” automation tasks in particular benefit from the unique ability of the PROFIBUS technology to seamlessly integrate process-oriented and factory-oriented tasks. This is of particular relevance in the pharmaceutical and food industries.

These industry sectors also face the additional challenge of validation. The US FDA (Food and Drug Administration) has set legal quality requirements that must be met by these sectors. Accordingly, the ability of the communication system used for production to communicate electronic data with integrity must be validated. To support this quality validation process, PI has drafted a guideline describing PROFIBUS functions to support validation. The guideline is based on NE72 (NAMUR recommendation 72: “Validation of Process Control Systems“), GAMP (“Good Automated Manufacturing Practice”, UK Pharmaceutical Industry Computer Validation Forum) and FDA 21 CRF Part 11 (U.S. Food and Drug Administration 21 Code of Federal Regulations, Part 11: “Electronic Records; Electronic Signatures“).

PROFIBUS PA meets the particular requirements of process automation. It encompasses all technology components used to connect intelligent field devices to controllers, control systems and engineering stations. These include, for example,

- 2-wire transmission technology, which facilitates data transmission and power for devices even in hazardous areas using easy to handle concepts (FISCO) and
- the PA profile, which describes the transmission of measured values, diagnostics and parameters, ensuring the interoperability of many different devices.

The simple, transparent topology of PROFIBUS PA pays off as early as the planning phase. The scope of documentation can be reduced by up to 90% when compared with a 4-20 mA installation. During the commissioning phase, loop checks can be completed much more quickly, significantly reducing the total time line from planning to commissioning. Therefore, PROFIBUS is able to reduce to time to market. The flexibility of the PROFIBUS installation also makes the addition of devices, retrofitting or device replacement easier once operation is underway. Where add-ons or expansions affecting older systems are concerned, 4-20 mA devices or HART devices can be integrated into PROFIBUS installations with ease.

The PA profile describes how process devices communicate with PROFIBUS masters. In addition to process variables, status and diagnostics information, or parameters, can be transferred. The specifications of the profile ensure the interoperability of devices from many manufacturers within a single system. The best way to again a perspective of the wide and varied range of PA devices, host systems and asset management systems available on the market is to take a look at the “Online product guide” at www.profibus.com.

The new diagnostics concept defined in the PA profile paves the way for comprehensive asset management and for a shift from preventive or reactive maintenance to proactive maintenance or condition monitoring. PROFIBUS PA can, therefore, tap into enormous potential for cutting costs, since field devices susceptible to wear, e.g., actuators or ph value analyzers, can be virtually fully utilized and necessary service operations can be scheduled in line with the production schedule and/or regular downtimes.

Both PROFIBUS and PROFIBUS PA have been internationally standardized by the IEC and are the most successful and proven fieldbus technologies on the market. Supporting PROFIBUS, PI is an organization with representation at national levels, competence centers and test laboratories in all corners of the world. Users from all sectors of industry can use PROFIBUS to significantly improve their production processes and dramatically reduce total cost of ownership.

9. PI – PROFIBUS & PROFINET International

As far as maintenance, ongoing development, and market penetration are concerned, open technologies need a company-independent institution that can serve as a working platform. As for the PROFIBUS and PROFINET technologies, this was achieved by founding the PROFIBUS Nutzerorganisation e.V. (PNO) in 1989 as a non-profit interest group for manufacturers, users, and institutions. The PNO is a member of PI (PROFIBUS & PROFINET International), an umbrella group which was founded in 1995 and which now has 25 regional user organizations (RPA: Regional PI Associations) and approximately 1,400 members. Thus, it is represented on every continent and is the world's largest interest group for the industrial communications field.

9.1 Responsibilities of PI

The key tasks performed by PI are:

- Maintenance and ongoing development of PROFIBUS and PROFINET.
- Promoting the worldwide establishment of PROFIBUS and PROFINET
- Protection of the investments of users and manufacturers through influencing standardization efforts
- Representation of the interests of members to standards bodies and unions
- Providing companies with worldwide technical support through PI Competence Centers (PICCs).
- Quality control through product certifications based on conformity tests at PI test laboratories (PITL).
- Establishment of a worldwide training standard through PI Training Centers (PITC).

9.2 Technological development

PI has given responsibility for technological development to PNO Germany.

The Advisory Board of PNO Germany oversees development activities. Technological development takes place in the context of more than 50 working groups with input from more than 500 experts.

9.3 Technical support

PI supports more than 35 accredited PICCs worldwide. These facilities provide users and manufacturers with all types of advice and support. As institutions of PI, they are independent service providers and adhere to mutually recognized regulations. The PICCs are regularly audited for their suitability as part of an individually tailored accreditation process. An up-to-date list of addresses can be found on the PI Web site (www.profibus.com).

9.4 Certification

PI supports 8 accredited PITLs worldwide which assist in the certification of products with a PROFIBUS/PROFINET interface. As institutions of PI, they are independent service providers and adhere to the mutually agreed regulations. 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. An up-to-date list of addresses can be found on the PI Web site.

9.5 Training

PI Training Centers (PITCs) have been set up with the specific aim of establishing a global training standard for engineers and installation technicians. The fact that the Training Centers and the experts who are based there must be officially accredited means that quality is assured, not only with respect to the PROFIBUS and PROFINET training offered but also of the associated engineering and installation services. An up-to-date list of PITC addresses can be found on the PI Web site.

9.6 The Internet: An information hub

Up-to-date information about the PI organization and PROFIBUS and PROFINET can be found at 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.

9.7 Further reading

For more information, please refer to the book titled "PROFIBUS PA" by Ch. Diedrich and Th. Bangemann; published by the Oldenbourg Industrieverlag (ISBN 978-3-8356-3056-7).

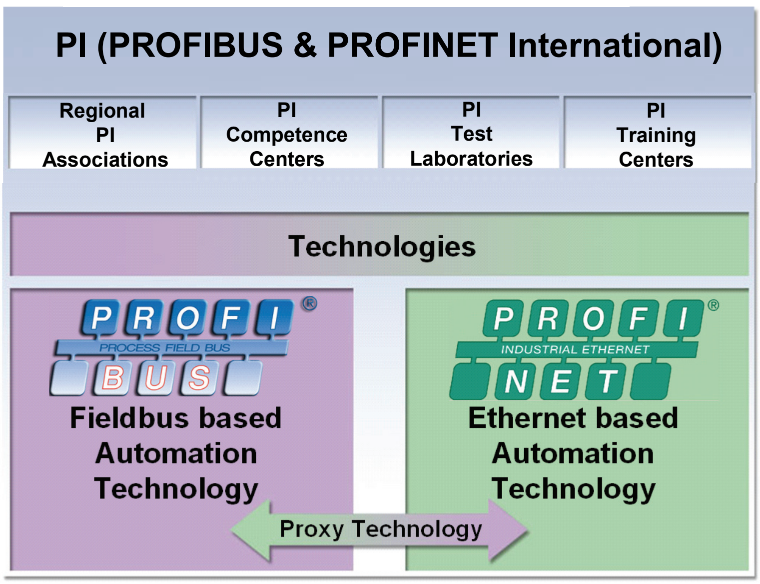

Figure 15: PROFIBUS & PROFINET International

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PROFIBUS PA technology and application

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