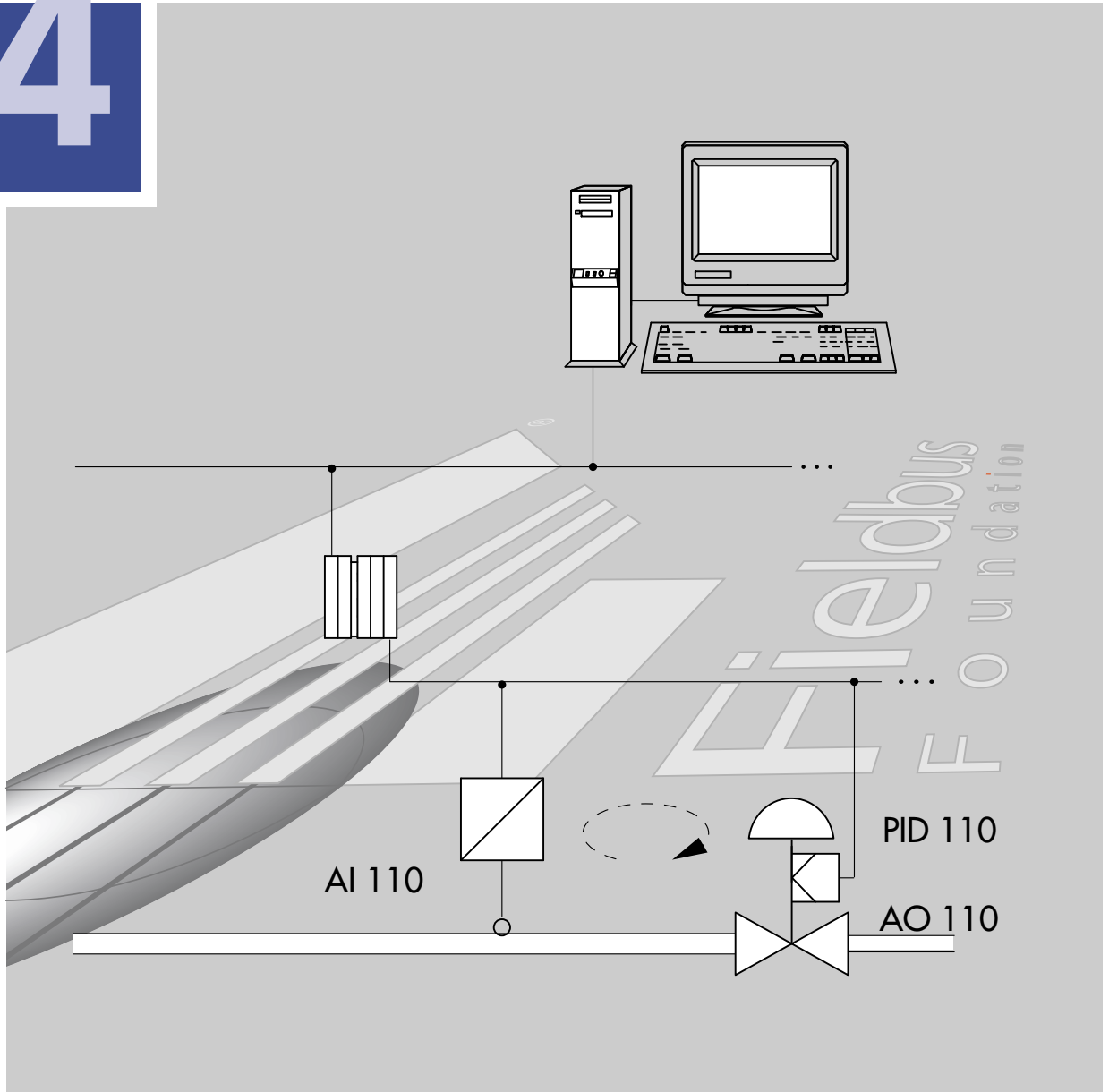


FOUNDATION Fieldbus

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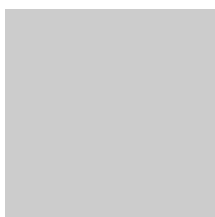
Part 4 Communication





Technical Information

- Part 1: Fundamentals
- Part 2: Self-operated Regulators
- Part 3: Control Valves
- Part 4: Communication
- Part 5: Building Automation
- Part 6: Process Automation



Foundation Fieldbus

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CONTENTS

Introduction

The FOUNDATION fieldbus can be flexibly used in process automation applications. The specification supports bus-powered field devices as well as allows application in hazardous areas. The Fieldbus FOUNDATION's slogan '... dedicated to a single international fieldbus' expresses the organization's claim to establishing an international, interoperable fieldbus standard.

**fieldbus for process
automation applications**

Fieldbus technology replaces the expensive, conventional 4 to 20 mA wiring in the field and enables bidirectional data transmission. The entire communication between the devices and the automation system as well as the process control station takes place over the bus system, and all operating and device data are exclusively transmitted over the fieldbus (see also Lit./4/).

The communication between control station, operating terminals and field devices simplifies the start-up and parameterization of all components. The communication functions allow diagnostic data, which are provided by up-to-date field devices, to be evaluated.

The essential objectives in fieldbus technology are to reduce installation costs, save time and costs due to simplified planning as well as improve the operating reliability of the system due to additional performance features. Fieldbus systems are usually implemented in new plants or existing plants that must be extended. To convert an existing plant to fieldbus technology, the conventional wiring can either be modified into a bus line, or it must be replaced with a shielded bus cable, if required.

**fieldbus technology
saves time and reduces
costs**

Note: To ensure troublefree operation, the communication system must be designed and configured by experts. For this purpose, a variety of assistance as well as comprehensive documentation can be obtained. This Technical Information does not claim to replace this type of support, but aims at explaining the basic principle of operation of the FOUNDATION fieldbus as well as its special characteristics to users, who have an interest in this technology.

It must also be noted that the FF specification is not yet completed at this stage – November 1999 – so that the facts presented here can be subject to future changes.

Historical development

In 1992 an international group, the ISP – ‘Interoperable Systems Project’, was founded with the intention to create an internationally uniform fieldbus standard for use in hazardous environments. At the same time, the manufacturers and users of the French FIP (Flux Information Processus; previously: Factory Instrumentation Protocol) established the international user organization WorldFIP. Together with the FIP North America, they were a strong counterweight to the ISP consortium.

Fieldbus FOUNDATION emerged from ISP and WorldFIP

In 1994, for technical, economic and political reasons, the ISP and the WorldFIP merged to form the Fieldbus FOUNDATION. The aim of the Fieldbus FOUNDATION was and is to create a single, international fieldbus standard for hazardous environments which will find widespread use as IEC standardized fieldbus. The same goal is pursued by the PROFIBUS user organization with its PROFIBUS PA fieldbus. While the PROFIBUS PA has its roots and its largest user community in Europe, the FOUNDATION fieldbus manufacturers and users are concentrated in America and Asia.

same bus design as PROFIBUS-PA

The Fieldbus FOUNDATION utilized some elements from the FIP for the specification of their FOUNDATION fieldbus (FF) as well as – similar to PROFIBUS PA – details from the ISP specification. This is why the physical bus design of both fieldbus systems is the same. Also, the device interface for application, which is based on function blocks, exhibits many common features. This is due to the fact that both systems have similar ambitions. However, when taking a closer look and comparing the system functions, it can be seen that there are also great differences (see also Lit. /6/).

User organization

The Fieldbus FOUNDATION is an independent not-for-profit organization which aims at developing and maintaining an internationally uniform and successful fieldbus for automation tasks, the FOUNDATION fieldbus. Members include users and manufacturers of field devices and automation systems. The Fieldbus FOUNDATION incorporates various workshops which are responsible, among others, for technical support, marketing and support of the members.

independent not-for-profit organization

Approval of devices

The Fieldbus is an open bus standard which enables devices of different manufacturers to be integrated in one system and, if required, interchanged (interoperability). This is only feasible when all the devices exactly meet the specification. Devices approved by the Fieldbus FOUNDATION are a guarantee for the user and the manufacturer that they comply with the specification.

approval confirms compliance with the specifications



Fig. 1: Logo of Fieldbus FOUNDATION members

Performance features

important characteristics

The FOUNDATION fieldbus provides a broad spectrum of services and functions compared to other fieldbus systems:

- ▶ intrinsic safety for use in hazardous environments
- ▶ bus-powered field devices
- ▶ line or tree topology
- ▶ multi-master capable communication
- ▶ deterministic (predictable) dynamic behavior
- ▶ distributed data transfer (DDT)
- ▶ standardized block model for uniform device interfaces (interoperability, interchangeability)
- ▶ flexible extension options based on device descriptions

The characteristic feature of distributed data transfer enables single field devices to execute automation tasks so that they are no longer 'just' sensors or actuators, but contain additional functions.

predefined function blocks

For the description of a device's function(s) and for the definition of a uniform access to the data, the FOUNDATION fieldbus contains predefined function blocks (see 'User application' on page 29). The function blocks implemented in a device provide information about the tasks the device can perform. Typical functions provided by sensors include the following:

sensors

'Analog Input' or
'Discrete Input' (digital input).

Control valves usually contain the following function blocks:

control valves

'Analog Output' or
'Discrete Output' (digital output).

The following blocks exist for process control tasks:

- ‘Proportional/Derivative’ (PD controller) or
- ‘Proportional/Integral/Derivative’ (PID controller).

control processes

If a device contains such a function block, it can control a process variable independently.

The shift of automation tasks – from the automation level down to the field – results in the flexible, distributed processing of control tasks. This reduces the load on the central process control station which can even be replaced entirely in small-scale installations. Therefore, an entire control loop can be implemented as the smallest unit, consisting only of one sensor and one control valve with integrated process controller which communicate over the FOUNDATION fieldbus (see Fig. 2).

**flexible, decentralized
process control**

The enhanced functionality of the devices leads to higher requirements to be met by the device hardware and comparably complex software implementation and device interfaces.

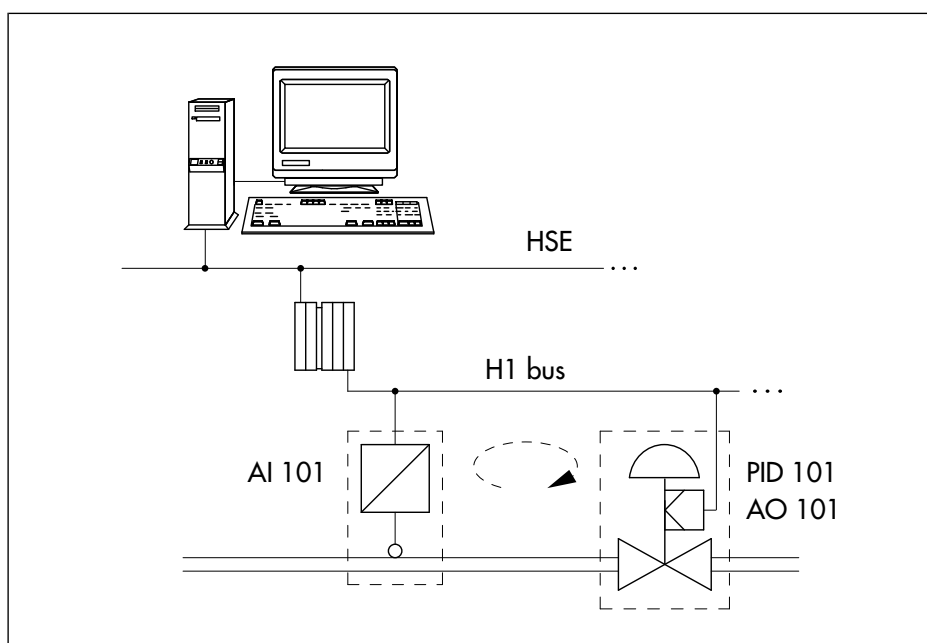


Fig. 2: Complete control loop based on the FOUNDATION fieldbus

Layered communications model

The FOUNDATION specification is based on the layered communications model and consists of three major functional elements (Fig. 3a):

- ▶ Physical Layer
- ▶ Communication "Stack"
- ▶ User Application

The User Application is made up of function blocks and the device description. It is directly based on the Communication Stack. Depending on which blocks are implemented in a device, users can access a variety of services.

system management

System management utilizes the services and functions of the User Application and the application layer to execute its tasks (Figs. 3b and 3c). It ensures the proper cooperation between the individual bus components as well as

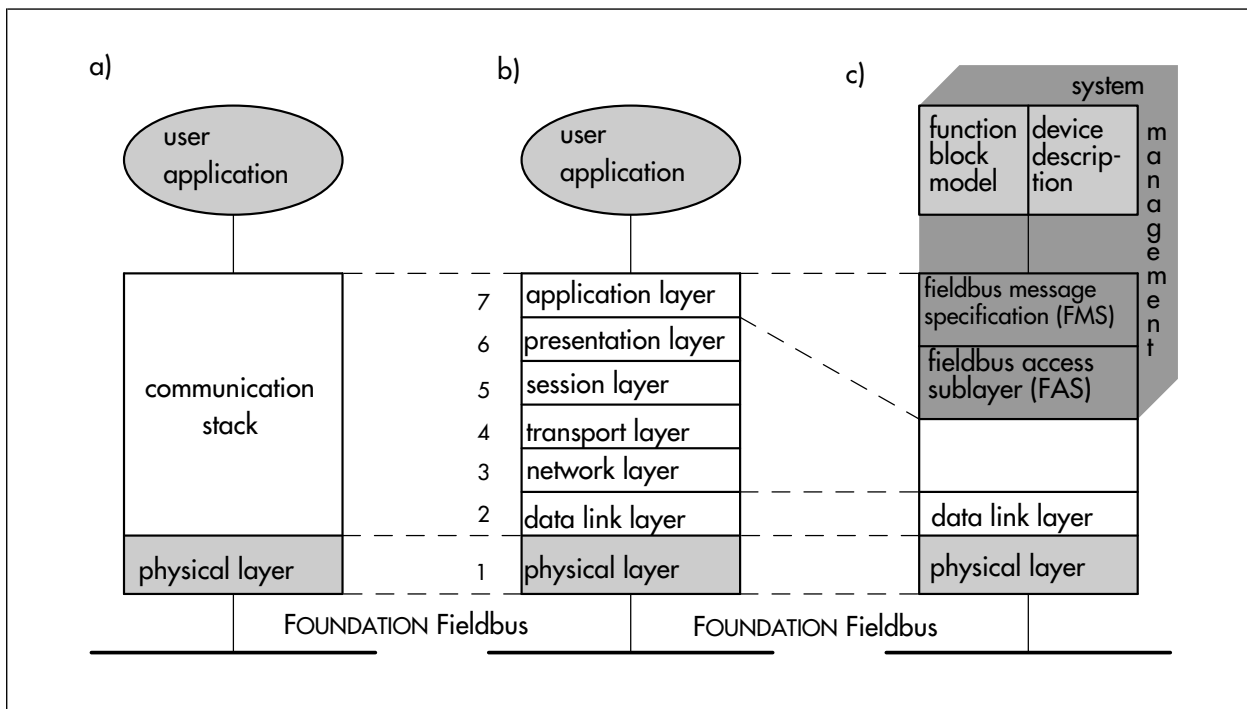


Fig. 3: Structure and description of the FF communication layers

synchronizes the measurement and control tasks of all field devices with regard to time (see page 35).

The FOUNDATION fieldbus layered communications model is based on the ISO/OSI reference model. As is the case for most fieldbus systems, and in accordance with an IEC specification, layers three to six are not used. The comparison in Fig. 3 shows that the Communication Stack covers the tasks of layers two and seven and that layer seven consists of the Fieldbus Access Sublayer (FAS) and the Fieldbus Message Specification (FMS) (see page 26 and Lit. /3/).

**fieldbus specification
based on ISO/OSI com-
munication model**

Physical layer

The specification of the FOUNDATION Fieldbus is not yet completed at this stage. However, it is certain that the topology of a FF system complies with the IEC Fieldbus model in many aspects.

IEC fieldbus The IEC fieldbus solves pending communication tasks by using two bus systems, the slow, intrinsically safe H1 bus and the fast, higher-level H2 bus with 1 to 2.5 MBit/s (see IEC fieldbus model /Lit. 4/).

FOUNDATION fieldbus The physical design of the H1 bus of the FOUNDATION fieldbus complies exactly with the specifications of the IEC fieldbus model. The specification of the H2 bus is not yet completed and the publication of the preliminary specification (PS) has been announced. However, it is certain that the High Speed Ethernet (HSE) will be used (Fig. 4).

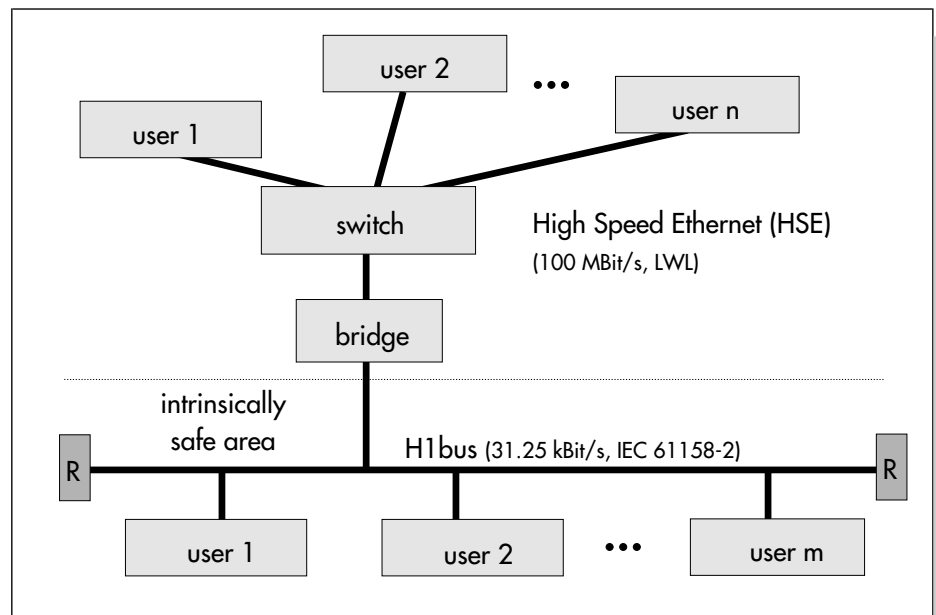


Fig. 4: Structure of the FOUNDATION fieldbus

H1 bus

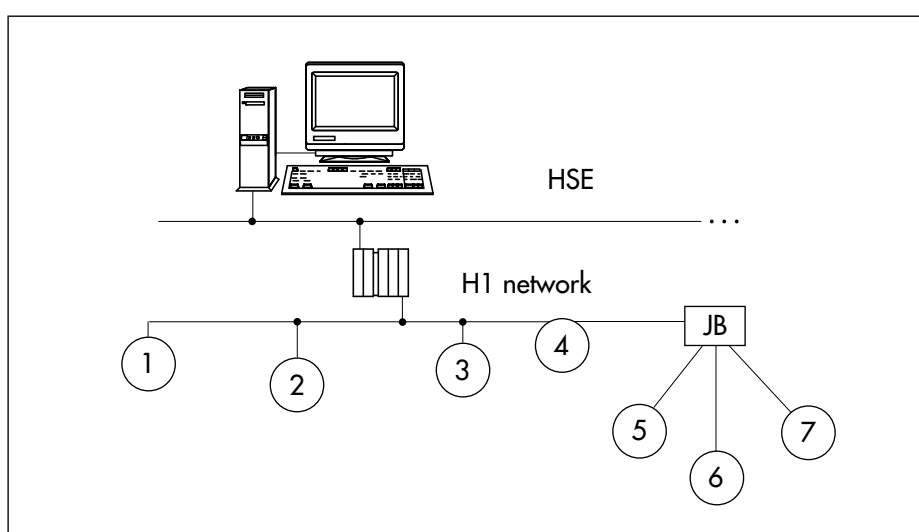
The following summary gives a brief overview of the basic values and features of the H1 bus. For more details, refer to the various 'Application Guides' of the Fieldbus FOUNDATION (e.g., AG 140, AG 163).

The H1 bus specification is based on the IEC 61158-2 (see Lit./2/):

- ▶ Manchester coding is used for data transfer. The data transfer rate is 31.25 kBit/s.
- ▶ Proper communication requires that the field devices have enough voltage. Each device should have minimum 9 volts. To make sure that this requirement is met, software tools are available which calculate the resulting currents and terminal voltages based on the network topology, the line resistance and the supply voltage.
- ▶ The H1 bus allows the field devices to be powered over the bus. The power supply unit is connected to the bus line in the same way (parallel) as a field device. Field devices powered by supply sources other than the bus, must be additionally connected to their own supply sources.
- ▶ With the H1 bus it must be ensured that the maximum power consumption of current consuming devices is lower than the electric power supplied by the power supply unit.

**H1 specification
based on IEC 61158-2**

**bus powered
field devices**



**1..7: field devices
JB: junction box**

Fig. 5: Mixed topology for an H1 network

No. of devices	1 device per spur	2 devices per spur	3 devices per spur	4 devices per spur
25-32	1 m	1 m	1 m	1 m
19-24	30 m	1 m	1 m	1 m
15-18	60 m	30 m	1 m	1 m
13-14	90 m	60 m	30 m	1 m
1-12	120 m	90 m	60 m	30 m

Fig. 5: Length of spurs

spurs via T-connector

- ▶ Network topologies used are usually line topology or, when equipped with junction boxes, also star, tree or a combination of topologies (Fig. 5). The devices are best connected via short spurs using tee connectors to enable connection/disconnection of the devices without interrupting communication.
- ▶ The maximum length of a spur is limited to 120 meters and depends on the number of spurs used as well as the number of devices per spur (Fig. 6).
- ▶ Without repeaters, the maximum length of an H1 segment can be as long as 1900 meters. By using up to four repeaters, a maximum of 5*1900 m = 9500 m can be jumpered. The short spurs from the field device to the bus are included in this total length calculation.

	Type A	Type B	Type C	Type D
Cable description	shielded twisted pair	single or multi-twisted pair with an overall shield	multi-twisted pair without shield	multi-core, without twisted pairs, without shield
Size	0.8 mm ² (AWG 18)	0.32 mm ² (AWG 22)	0.13 mm ² (AWG 26)	1.25 mm ² (AWG 16)
Max. length incl. spurs	1900 m	1200 m	400 m	200 m

Fig. 6: Fieldbus cable types and maximum bus lengths

- ▶ The number of bus users per bus segment is limited to 32 in intrinsically safe areas. In explosion-hazardous areas, this number is reduced to only a few devices due to power supply limitations (see EEx-i instrumentation below).
- ▶ Various types of cables are useable for fieldbus (Fig. 7). Type A is recommended as preferred fieldbus cable, and only this type is specified for the maximum bus length of 1900 m.
- ▶ Principally, there need to be two terminators per bus segment, one at or near each end of a transmission line.
- ▶ It is not imperative that bus cables be shielded, however, it is recommended to prevent possible interferences and for best performance of the system.

**limited electrical power
in ex areas**

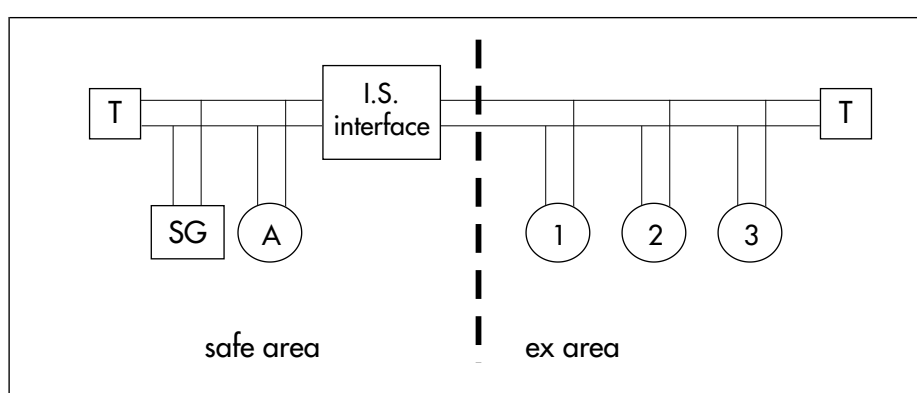
**two terminators per
bus segment**

- EEx-i instrumentation

The H1 bus can be designed intrinsically safe (Ex-i) to suit applications in hazardous areas. This requires that proper barriers be installed between the safe and the explosion hazardous area (Fig. 8). In addition, only one device, the power supply unit, must supply the fieldbus with power. All other devices must always, i.e. also when transmitting and receiving data, function as current sinks.

**only one power
supply unit**

Since the capacity of electrical lines is limited in intrinsically safe areas depending on the explosion group – IIB or IIC – (see Fig. 9), the number of de-



T: terminator
I.S. intrinsically safe barrier
SG: power supply unit
A: field device in safe area
1...3: intrinsically safe field devices

Fig. 7: Elements for the intrinsically safe H1 bus

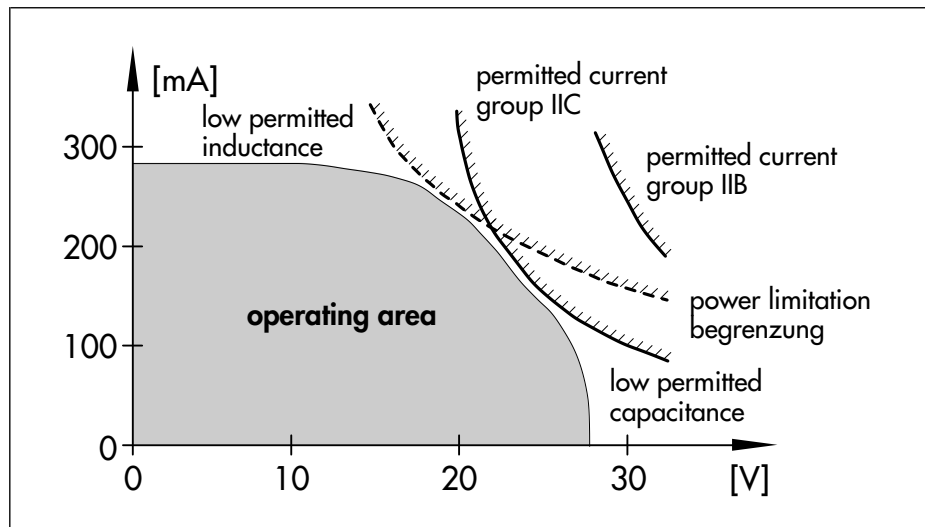


Fig. 8: Limited operating area for Ex-i IIB and IIC installations (including a safety factor of 1.5)

vices that can be connected to one segment depends on the effective power consumption of the used devices.

intrinsic safety requirements must be met during planning and installation

Since the FOUNDATION fieldbus specification is not based on the FISCO model (see Lit./4/), the plant operator himself must ensure that intrinsic safety requirements are met when planning and installing the communications network. For instance, the capacitance and inductance of all line segments and devices must be calculated to ensure that the permissible limit values are observed (Fig. 10).

Group	Co (Ca)	Lo (La)
IIC	165 nF	0.35 mH
IIB	1.14 µF	1.04 mH

Fig. 9: Capacitance and inductance limit values for installation of Ex-i instrumentation

High Speed Ethernet (HSE)

The HSE is based on standard Ethernet technology. The required components are therefore widely used and are available at low costs. The HSE runs at 100 Mbit/s and cannot only be equipped with electrical lines, but with optical fiber cables as well.

**standard available
Ethernet technology**

The Ethernet operates by using random (not deterministic) CSMA bus access. This method can only be applied to a limited number of automation applications because it requires real-time capability. The extremely high transmission rate enables the bus to respond sufficiently fast when the bus load is low and devices are only few. With respect to process engineering requirements, real-time requirements are met in any case.

**real-time requirements
can be met**

If the bus load must be reduced due to the many connected devices, or if several HSE partial networks are to be combined to create a larger network, Ethernet Switches must be used (see Fig. 4). A switch reads the target address of the data packets that must be forwarded and then passes the packets on to the associated partial network. This way, the bus load and the resulting bus access time can be controlled to best adapt it to the respective requirements.

Bridge to H1-HSE coupling

A communications network that consists of an H1 bus and an HSE network results in a topology as illustrated in Fig. 4. To connect the comparatively slow H1 segments to the HSE network, coupling components, so-called Bridges, are required. Similar to HSE, the specification of this bus component has not been completed up to now.

**coupling components
required**

A Bridge is used to connect the individual H1 buses to the fast High Speed Ethernet. The various data transfer rates and data telegrams must be adapted and converted, considering the direction of transmission. This way, powerful and widely branched networks can be installed in larger plants.

**adaptation of various
data rates and
telegrams**

Communication stack

The field devices used with the FOUNDATION fieldbus are capable of assuming process control functions. This option is based on distributed communication which ensures that

distributed communication

- ▶ each controlling field device can exchange data with other devices (e.g. reading measuring values, forwarding correction values),
- ▶ all field devices are served in time ('in time' meaning that the processing of the different control loops is not negatively influenced),
- ▶ two or more devices never access the bus simultaneously.

central communication control

To meet these requirements, the H1 bus of the FOUNDATION fieldbus uses a central communication control system.

Link Active Scheduler – LAS

The Link Active Scheduler (LAS) controls and schedules the communication on the bus (see page 19: Communication control). It controls the bus activities using different commands which it broadcasts to the devices. Since the LAS also continuously polls unassigned device addresses, it is possible to connect devices during operation and to integrate them in the bus communication.

Devices that are capable of becoming the LAS, are called 'Link Master'. 'Basic devices' do not have the capability to become LAS.

fail-operational design

In a redundant system containing multiple Link Masters, one of the Link Masters will become the LAS if the active LAS fails (fail-operational design).

Communication control

The communication services of the FF specification utilize scheduled and unscheduled data transmission. Time-critical tasks, such as the control of process variables, are exclusively performed by scheduled services, whereas parameterization and diagnostic functions are carried out using unscheduled communication services.

**scheduled or
unscheduled data
transmission**

- Scheduled data transmission

To solve communication tasks in time and without access conflicts, all time-critical tasks are based on a strict transmission schedule. This schedule is created by the system operator during the configuration of the FF system.

**time-critical tasks
with a strict trans-
mission schedule**

The LAS periodically broadcasts a synchronization signal (TD: Time Distribution) on the fieldbus so that all devices have exactly the same data link time. In scheduled transmission, the point of time and the sequence are exactly defined. This is why it is called a deterministic system.

Fig. 11 presents the schedule for a system with two sensors and two control valves. The schedule determines when the devices process their function blocks (AI, AO, PID) and when it is time to transmit data.

Each activity to be executed has been scheduled for a certain time. This time is defined by an offset value which reflects the delay referred to the start of the schedule.

Based on this schedule, a transmission list is generated which defines when a specific field device is prompted to send its data. Upon receipt of the mes-

**transmission list for
“publisher and
subscriber” method**

Device	Type	Action	Offset
1	Sensor	Execution AI (1) Transmission AI (1) of data	0 20
2	Sensor	Execution AI (2) Transmission AI (2) of data	0 30
3	Control valve	Execution PID (3) Execution AO (3)	40 62

Fig. 10: Schedule for processing function blocks

sage, the respective device ('publisher') broadcasts the data in the buffer to all devices on the fieldbus which are configured to receive the data ('subscriber'). This type of data transmission is therefore called the 'publisher-subscriber' method.

The LAS cyclically transmits the data according to the list for all data buffers in all devices. Each cyclical data transmission is explicitly activated by the LAS (Fig. 12):

cyclical data transmission

- ▶ If a device (e.g. device 1: Sensor) is prompted to publish its measured data, the LAS issues the Compel Data (CD) command to the device.
- ▶ Upon receipt of the CD, the device publishes the data in the buffer.
- ▶ The 'subscribers' of this message (e.g. device 3: Control valve) can read and evaluate this data accordingly.

separate schedule for system management

Each field device receives a separate schedule. This enables system management to know exactly what task is to be executed when and when data must be received or sent.

Example: For the above mentioned schedule, the following time sequence of actions results as shown in Fig. 13.

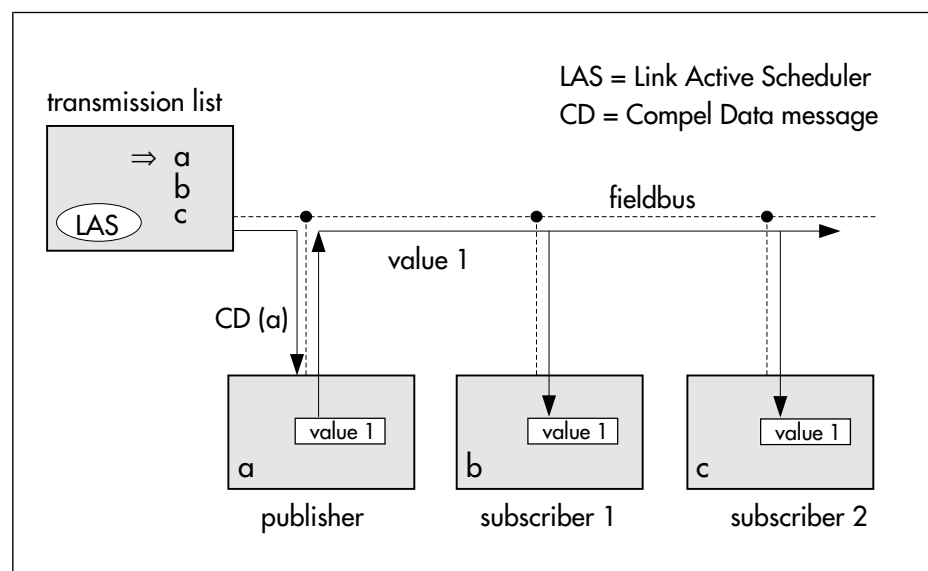


Fig. 11: Scheduled data transmission according to the transmission list

- ▶ at zero time, sensors (1) and (2) start their measurements;
- ▶ at time 20, the LAS prompts the sensor (1) to send its measuring data so that it can be read by the PID controller of the associated control valve (3);
- ▶ at time 30, the LAS prompts the sensor (2) to send its measuring data so that it can be read by the PID controller of the associated control valve (4);
- ▶ at time 40, both control valves are processing their PID function blocks;
- ▶ at time 57, control valve 4 starts its travel process;
- ▶ at time 62, control valve 3 starts its travel process;
- ▶ at 140 time increments, the same actions are repeated.

schedule

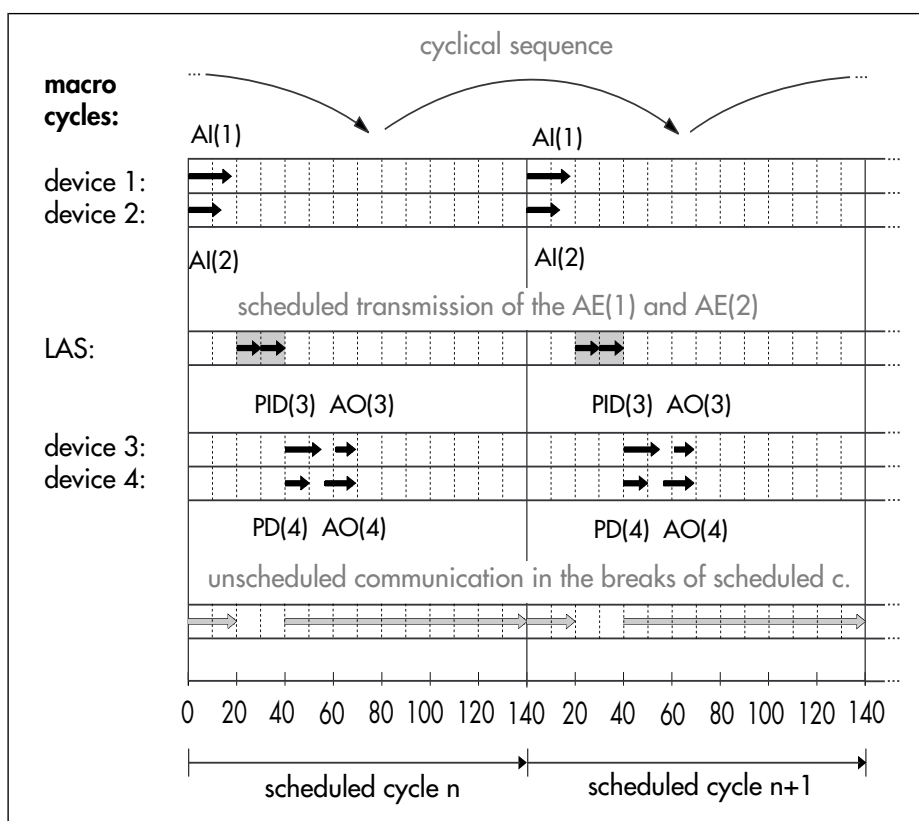


Fig. 12: Scheduled transmission and unscheduled communication

number of data transmissions considerably reduced Each control loop accesses the bus only once for a short time. Therefore, the bus could be used for many more control loops as well as for other activities. This shows that the distributed control strategy reduces the number of data transmissions over the bus to a minimum.

- Unscheduled transmission

Device parameters and diagnostic data must be transmitted when needed, i.e. on request. The transmission of this data is not time-critical. For such communication tasks, the FOUNDATION fieldbus is equipped with the option of unscheduled data transmission.

Unscheduled data transmission is exclusively restricted to the breaks inbetween scheduled transmission. The LAS grants permission to a device to use the fieldbus for unscheduled communication tasks if no scheduled data transmission is active (see Fig. 14 below).

Permission for a certain device to use the bus is granted by the LAS when it issues a pass token (PT command) to the device. The pass token is sent around to all devices entered in the 'Live List' (Fig. 14) which is administrated by the LAS. Each device may use the bus as long as required until it either returns the token, or until the maximum granted time to use the token has elapsed.

The Live List is continuously updated by the LAS. The LAS sends a special command, the Probe Node (PN), to the addresses not in the Live List, searching for newly added devices. If a device returns a Probe Response (PR) message, the LAS adds the device to the Live List where it receives the pass token for unscheduled communication according to the order submitted for trans-

**data transmission
on request**

**token passing
over the 'Live List'**

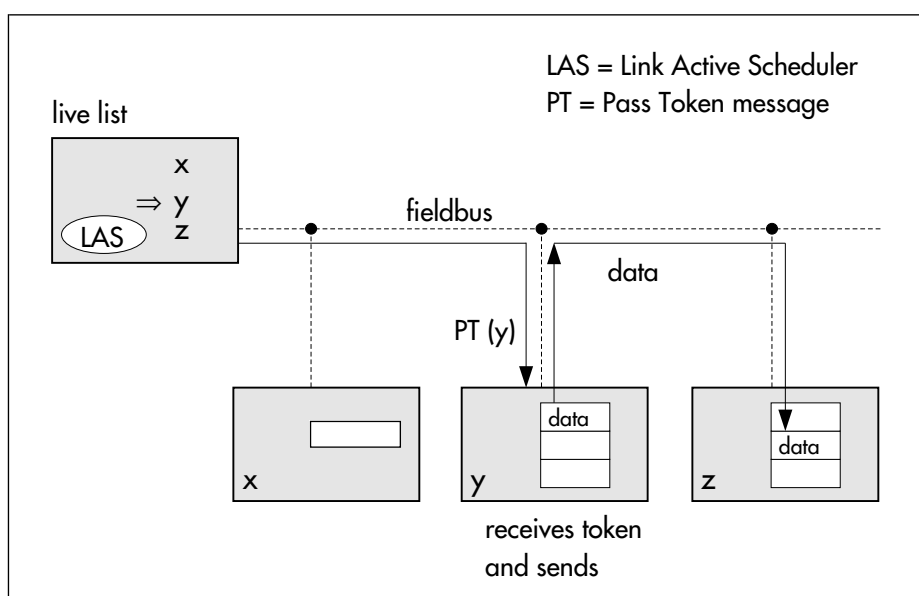


Fig. 13: Unscheduled data transmission with token

mission in the Live List. Devices which do not respond to the PT command or return the token after three successive tries are removed from the Live List.

**copy of Live List
to all Link Masters**

Whenever a device is added or removed from the Live List, the LAS broadcasts these changes to all devices. This allows all Link Masters to maintain a current copy of the Live List so that they can become the LAS without the loss of information.

- Communication schedule

The LAS follows a strict schedule (Fig. 15) to ensure that unscheduled communication using the token as well as the TD or PN commands do not interfere with the scheduled data transmission.

Before each operation, the LAS refers to the transmission list to check for any scheduled data transmissions. If this is the case, it waits (idle mode) for precisely the scheduled time and then sends a Compel Data (CD) message to activate the operation.

In case there are no scheduled transmissions and sufficient time is available for additional operations, the LAS sends one of the other commands. With PN it searches for new devices, or it broadcasts a TD message for all devices to have exactly the same data link time, or it uses the PT message to pass the token for unscheduled communication. Following this, the sequence starts all over again with the above mentioned check of the transmission list entries.

It is obvious that this cycle gives scheduled transmission the highest priority and that the scheduled times are strictly observed, regardless of other operations.

**highest priority
for scheduled
data transmission**

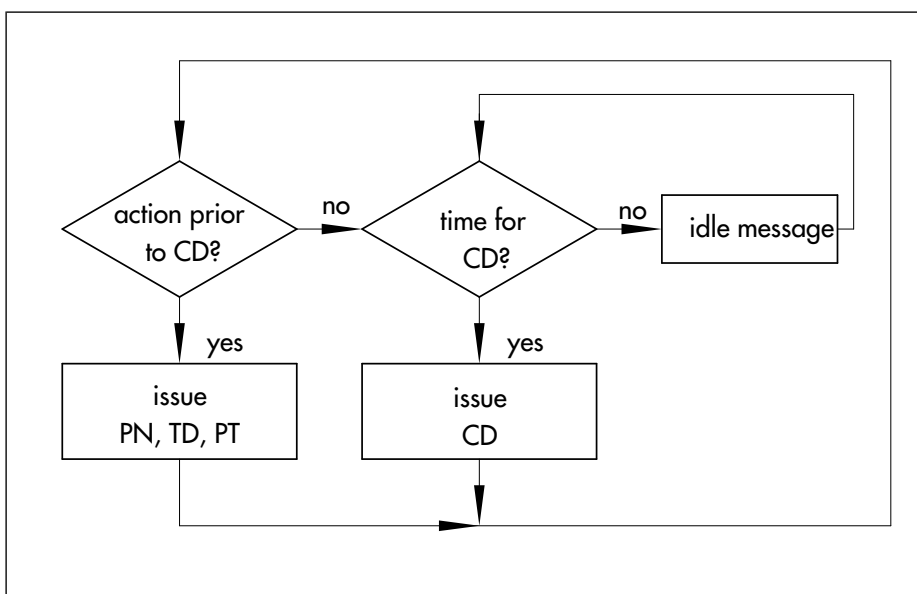


Fig. 14: LAS communication control

Application layer

interface between data link layer and user application

The Fieldbus Access Sublayer (FAS) and Fieldbus Message Specification (FMS) layer form the interface between the data link layer and the user application (see Fig. 3). The services provided by FAS and FMS are invisible for the user. However, the performance and functionality of the communication system considerably depends on these services.

- Fieldbus Access Sublayer (FAS)

Virtual Communication Relationship VCR

FAS services create Virtual Communication Relationships (VCR) which are used by the higher-level FMS layer to execute its tasks. VCRs describe different types of communication processes and enable the associated activities to be processed more quickly. FF communication utilizes three different VCR types as follows (Fig. 16).

transmitting input/output data of function blocks

► The Publisher/Subscriber VCR Type is used to transmit the input and output data of function blocks. As described above, scheduled data transmission with the CD command is based on this type of VCR. However, the Publisher/Subscriber VCR is also available for unscheduled data transmission; for instance, if a subscriber requests measuring or positioning data from a device.

Client/Server	Report Distribution	Publisher/Subscriber
Operator communication	Event notification, alarms, trend reports	Data publication
Set point changes Mode and device data changes Upload/download Adjusting alarm values Access display views Remote diagnostics	Send process alarms to operator consoles Send trend reports to data historians	Send actual value of a transmitter to PID block and operator console

Fig. 15: Virtual Communication Relationships of the FAS

- ▶ The Client/Server VCR Type is used for unscheduled, user-initiated communication based on the PT command. If a device (client) requests data from another device, the requested device (server) only responds when it receives a PT from the LAS.

**unscheduled
communication**

The Client/Server communication is the basis for operator initiated requests, such as set point changes, tuning parameter access and change, diagnosis, device upload and download, etc.

**basis for
operator-initiated
requests**

- ▶ Report Distribution communication is used to send alarm or other event notifications to the operator consoles or similar devices. Data transmission is unscheduled when the device receives the PT command together with the report (trend or event notification). Fieldbus devices that are configured to receive the data await and read this data.

- Fieldbus Message Specification (FMS)

FMS provides the services for standardized communication. Data types that are communicated over the fieldbus are assigned to certain communication services. For a uniform and clear assignment, object descriptions are used. Object descriptions contain definitions of all standard transmission message formats, but also include application specific data. For each type of object there are special, predefined communication services.

**communication services
are assigned to each
data type**

Object descriptions are collected together in a structure called an object dictionary. The object description is identified by its index (Fig. 17).

**access via the object
dictionary**

- ▶ Index 0, called the object dictionary header, provides a description of the dictionary itself.
- ▶ Indices between 1 and 255 define standard data types that are used to build more complex object descriptions.
- ▶ The User Application object descriptions can start at any index above 255.

standard data types

**User Application
object descriptions**

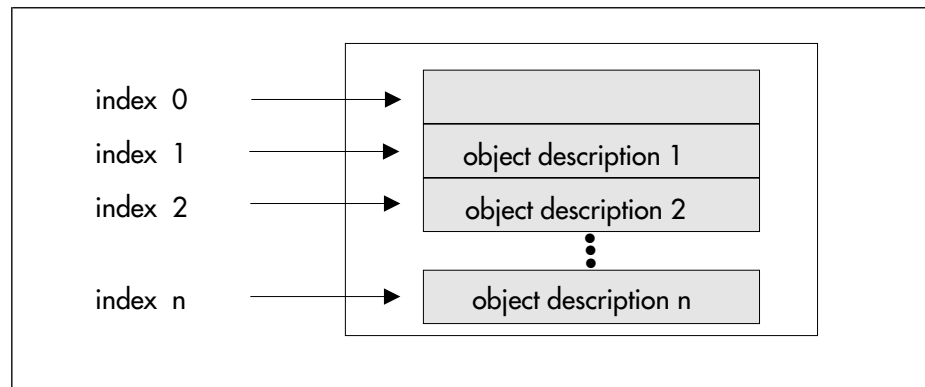


Fig. 16: Access to the object dictionary using indices

virtual field devices The FMS defines 'Virtual Field Devices' (VFD) which are used to make the object descriptions of a field device as well as the associated device data available over the entire network.

remote access to all data The VFDs and the object description can be used to remotely access all local field device data from any location by using the associated communication services.

User application

An important criterion for a fieldbus system to be accepted by the market is the interoperability of the devices. Interoperability is the capability of devices of different manufacturers to communicate with each other. In addition, it must be ensured that a component from one manufacturer can be substituted with that of another, also called interchangeability.

interoperability and interchangeability

This requires an open protocol specification which defines uniform device functions and application interfaces. Other devices on the network and application programs can use these interfaces to access the functions and parameters of the field devices. The FOUNDATION fieldbus makes these definitions based on blocks and device descriptions.

uniform device functions and application interfaces

Block model

The FOUNDATION fieldbus assigns all functions and device data to three different types of blocks (Fig. 18). The assignment depends on the device's type of function. Depending on its functionality, it is described as follows:

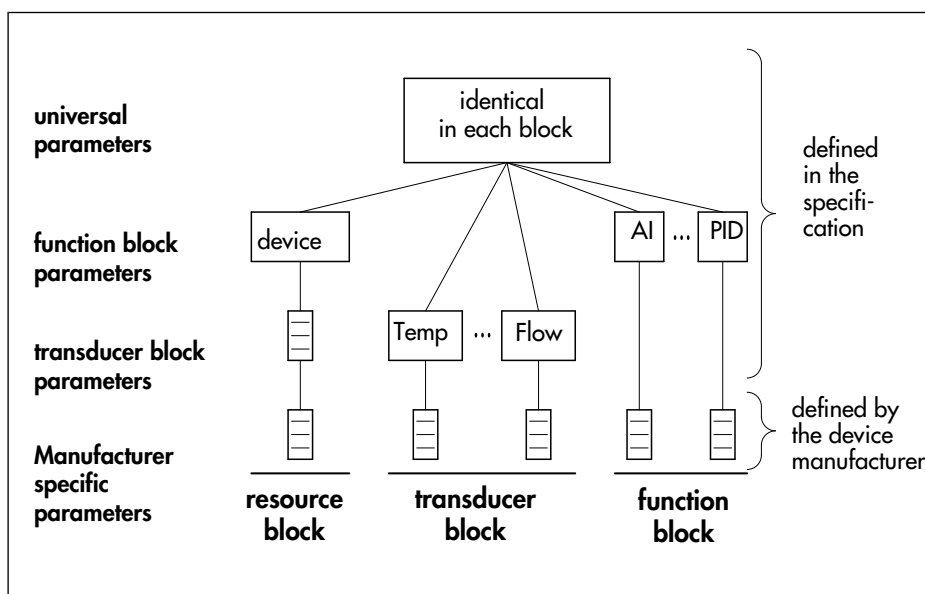


Fig. 17: Division of field device data in resource, function and transducer block

- block model elements**
- ▶ Resource block
 - ▶ One or multiple function blocks
 - ▶ Several transducer blocks, if required

resource block The resource block describes characteristics of a fieldbus device, such as the device name, manufacturer, serial number, hardware and firmware version, etc.

function block Function blocks describe a device's functions and define how these can be accessed. The transmission schedules of scheduled data transmission are based on these function blocks. Each block has a certain task including the associated inputs and outputs. Each device is equipped with one function block minimum.

The FF specification has defined sets of standard function blocks which can be used to describe all basic functions. These are listed below:

- AI: analog input
- AO: analog output
- B: bias
- CS: control selector
- DI: discrete input
- DO: discrete output
- ML: manual loader
- PD: proportional/derivative
- PID: proportional/integral/derivative
- RA: ratio

transducer block Transducer blocks expand the complexity and application possibilities of a device. Their data enables the input and/or output parameters of a function block to be influenced. They can be used to calibrate and reset measuring and positioning data, linearize characteristics or convert physical units using additional process data.

Besides the three block types, the following additional objects are defined in the block model (Fig. 19).

- ▶ So-called Link Objects define the links between different function blocks, internal to the field device as well as across the fieldbus network.
- ▶ Alert Objects allow reporting of alarms and events on the fieldbus.
- ▶ Trend Objects allow trending of function block data for access and analysis from higher-level systems.
- ▶ View Objects are predefined groupings of data and block parameter sets that can be used to view and display these quickly according to their tasks: process control, configuration, maintenance, additional information (Fig. 19).

Link Objects in the block model

Alert Objects

Trend Objects

View Object

The grouping of parameters in Trend and View Objects accelerates access to this data. If required, the operating program simply accesses the object which contains the predefined, desired data group (Fig. 19).

parameter groups

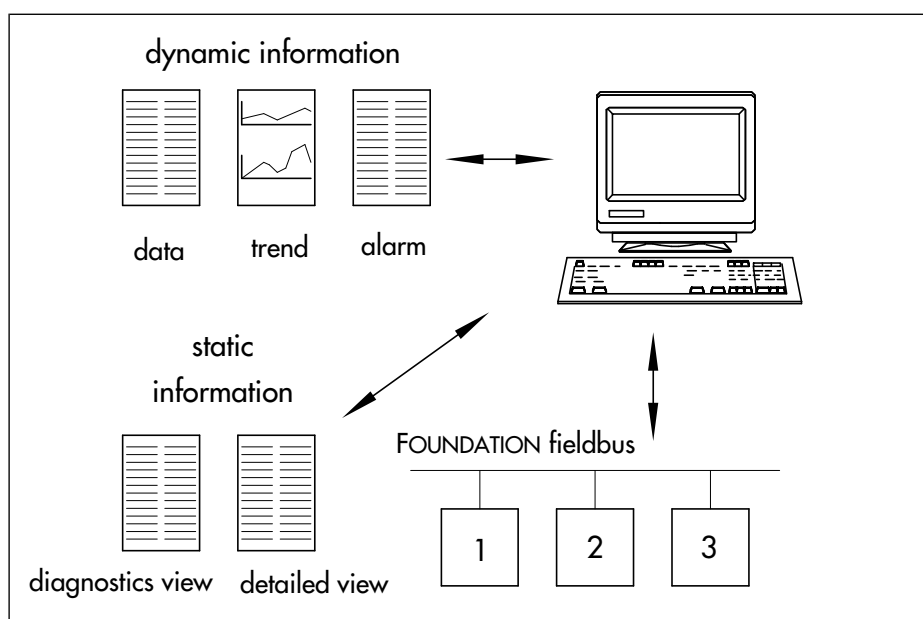


Fig. 18: View Objects group functions block data

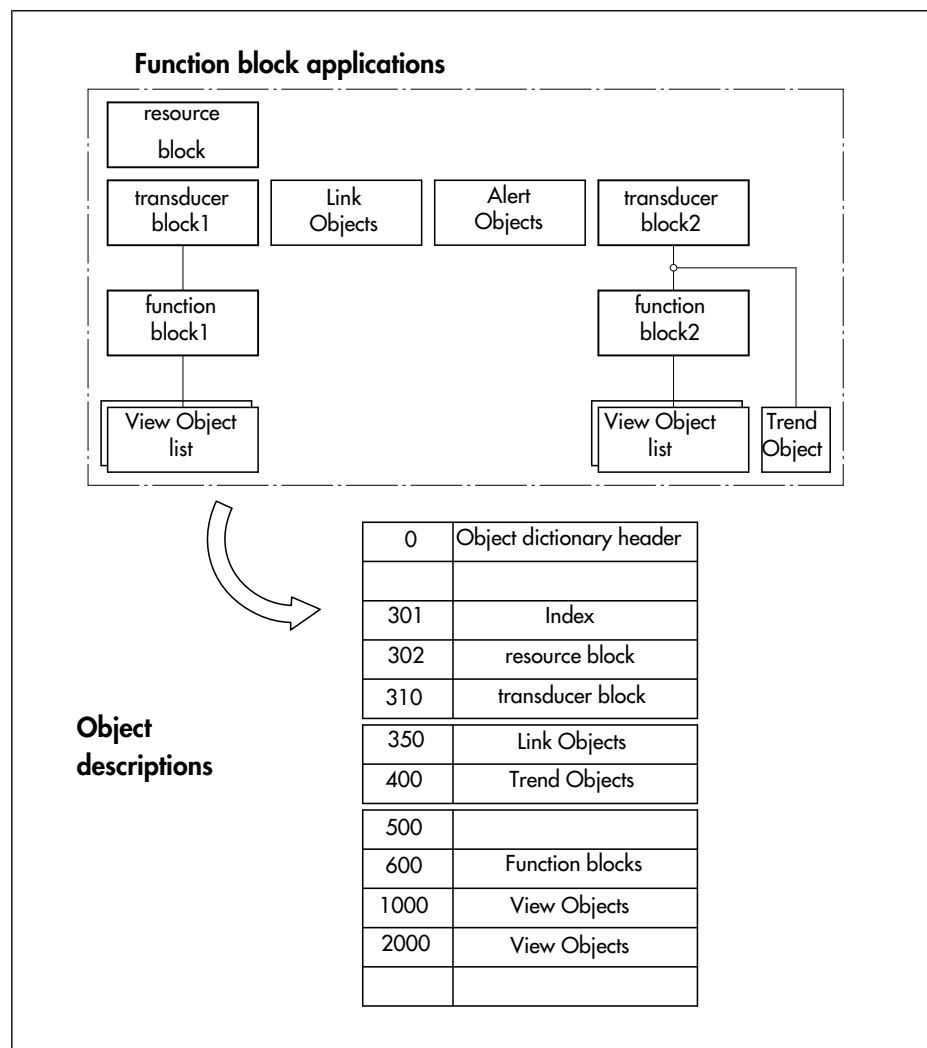


Fig. 20: Assignment of block model data to an object dictionary

The entire block model of a field device with two function blocks (e.g. AO and PID) consists of the elements depicted in Fig. 20. The data structure of the blocks is accessed via the associated object dictionary.

Device descriptions

During start-up and maintenance as well as when performing diagnostic functions, an open communication system must ensure that higher-level control computers or the control system

open communications system

- ▶ can access all field device data and
- ▶ have the proper controls to achieve this.

The device descriptions (DDs) contain the necessary information to fulfill these requirements. They provide the information needed to understand the meaning of the device data and display them correctly at the operator console.

For the basic functions of the devices, the FOUNDATION fieldbus uses different standard function and transducer blocks. For this purpose, predefined device descriptions (standard DDs) are available that can be obtained from the Fieldbus FOUNDATION (FF). FF operating devices can interpret and display the data and functions of these standard blocks as well as providing the user with them via the operating interface.

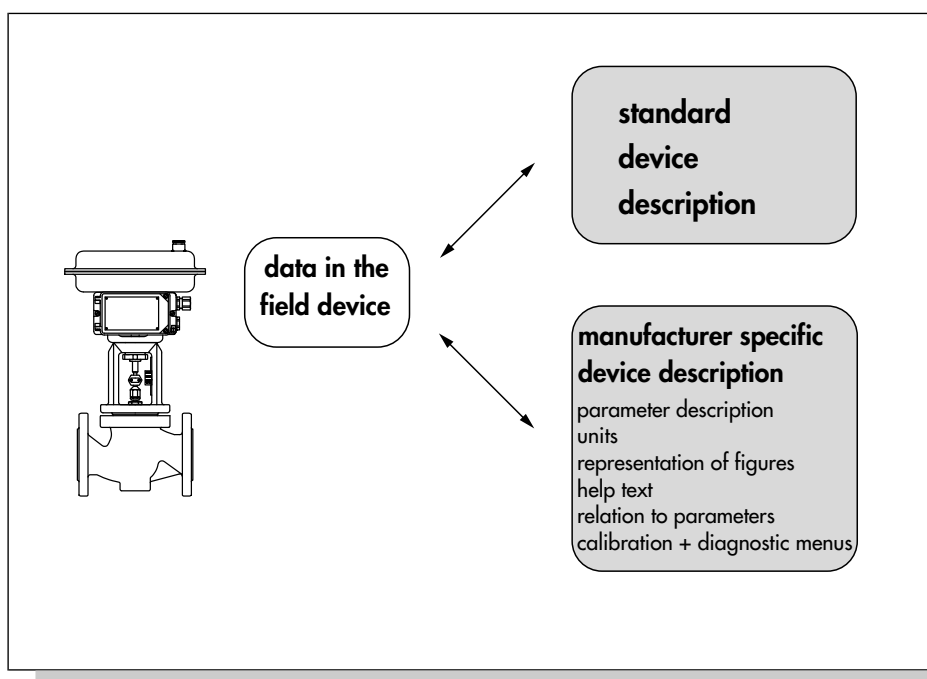


Fig. 19: Device description extends the description of all objects in the virtual field device

special device description supplied by the manufacturer

If a device supplier implements additional functions and parameters in a device, he must define the contents, access and representation in an extended device description. Only when the device manufacturer supplies a device description tailored to his product, can it be operated and applied to the full extent.

device description

The device description is written using the Device Description Language (DDL) to generate a text file (Fig. 22). This file is then converted with the help of a 'Tokenizer' and distributed on diskette or via Internet download. If the manufacturer has registered his device with the associated device description with the FF, the DD can be also be obtained there.

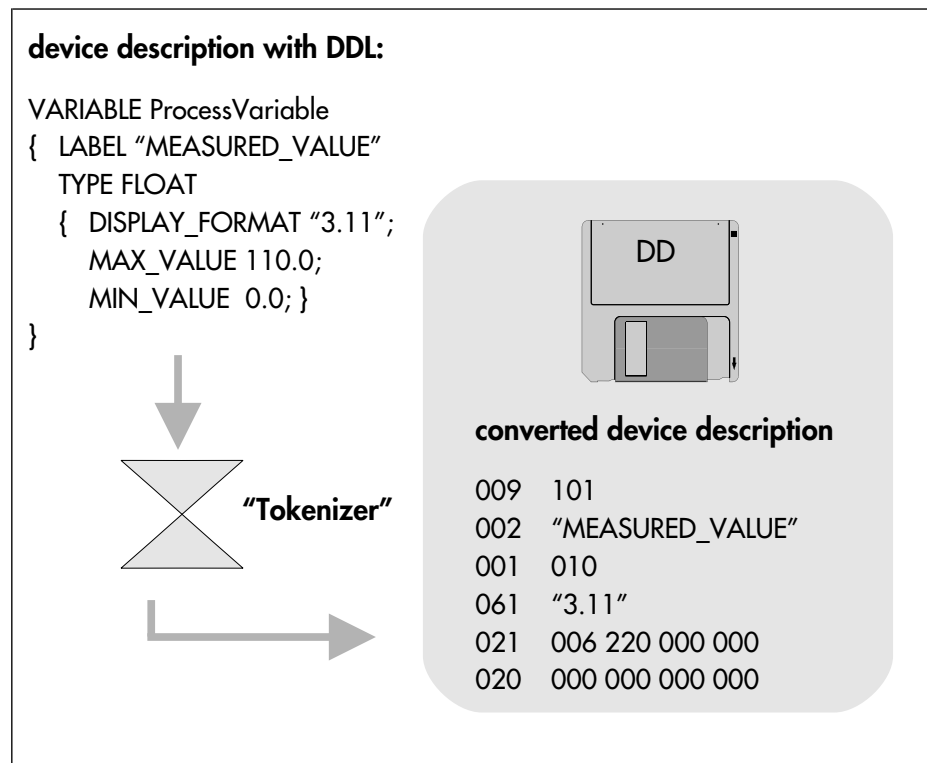


Fig. 20: Creating a device description

System management

The system management of each device has the following tasks:

- ▶ Synchronization of the relevant device activities in time, i.e. according to the predefined transmission schedule (see page 25).
- ▶ Cyclical processing of the transmission list (LAS only) within the predefined time schedule (page 19).

**system management
tasks**

Further tasks performed by system management are the following.

- ▶ Automatic assignment of the LAS function to another Link Master, if the active LAS fails.
- ▶ Application clock synchronizations.
- ▶ Automatic address assignment for new devices on the communications network.

The automatic assignment of device addresses enables a device to be assigned a unique network address while the process is active.

**automatic address
assignment**

For the software controlled address assignment, special default addresses are reserved over which the new devices can be accessed. After the internal physical device tag as well as a unique and new bus address have been assigned to the new device, it is integrated in the communications network. The 'default address' is then available again for the assignment of more devices.

System configuration

Scheduled communication as well as all fieldbus devices must be parameterized before the first start-up (Fig. 23). A configuration tool, e.g. the NI-FBUS Configurator by National Instruments, is required for this purpose.

configuration device loads the device description

The device description of all used devices must be entered into the configuration device. The software must either be able to access the DDs in predefined libraries, or they must be loaded via external data carriers (e.g. via diskette).

connection of function blocks

The configuration software determines how and with which devices the measurement and control tasks of a plant are processed by interconnecting the function blocks of the field devices. This job can be easily performed by means of a graphical user interface. All that needs to be done is to connect the inputs and outputs of the corresponding block symbols.

Fig. 24 shows an example of cascade control where the sensor output value is connected to a PID function block. This block can be implemented, for instance, in a control valve's positioner. The positioner output acts locally on the analog output of the final controlling element, so that no data has to be

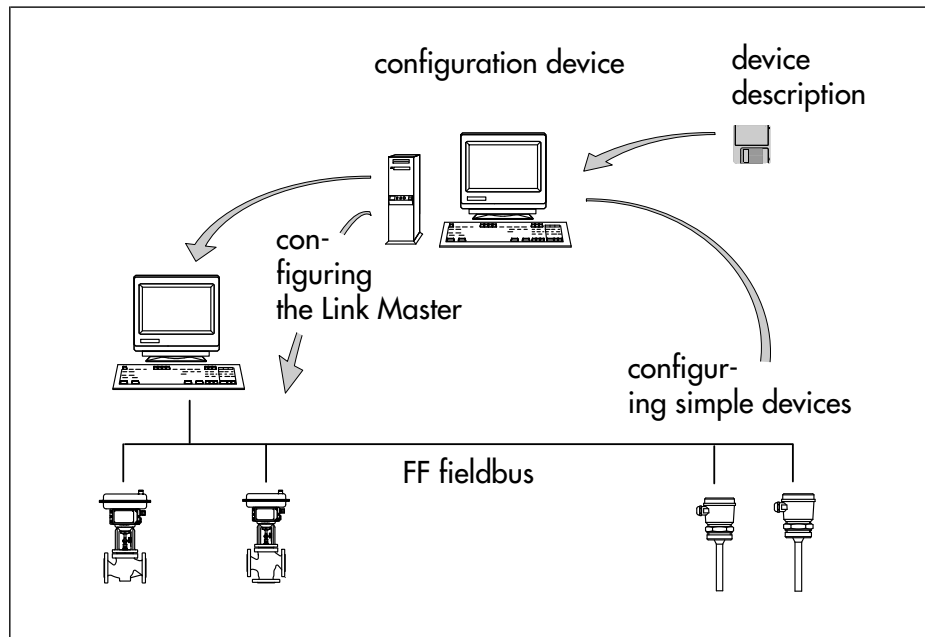


Fig. 21: System configuration by means of a configuration device

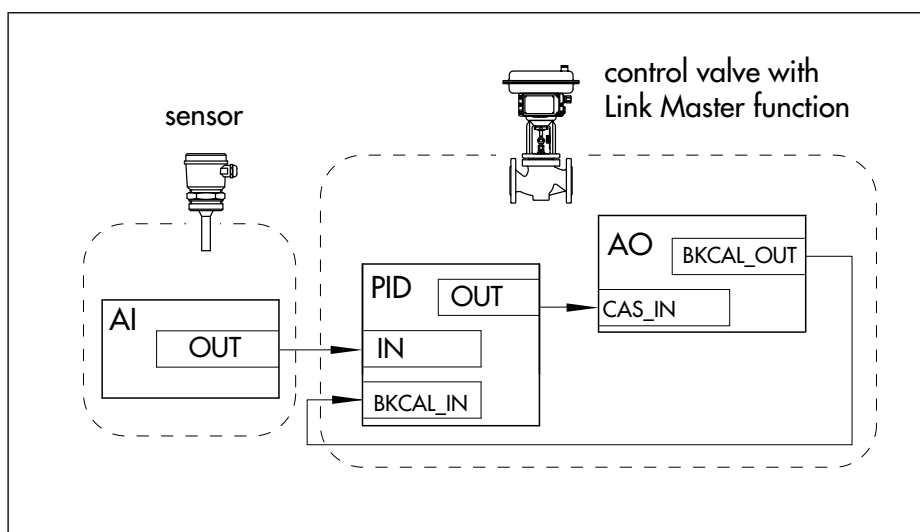


Fig. 22: Connection of function blocks for cascade control (via software)

transmitted via the fieldbus. The configuration shown corresponds to the control loop example illustrated in Fig. 2.

Besides connecting the function blocks, the network configurator also configures the individual loop execution rate. Based on this data and the wiring diagram, the configuration tool generates the information needed to control the devices and the communication.

Finally, this data is entered into the individual field devices. During this process, the LAS is configured and all Link Masters receive the current transmission list for scheduled data transmission.

The system configuration is now complete so that the system management of the LAS and of the other field devices can take control over the system.

control loop execution rate

configuration of LAS and Link Masters

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