00 Introduction to fieldbus technology

00.1 Industry-standard solutions for automation from HARTING

Present day and future automation solutions are evolving from being isolated applications solutions towards becoming industrialised networks. Whereas on the one hand offices are becoming ever more entwined with the production side, on the other hand, widely distributed automation sub systems are increasingly being installed. In order to combine both of these areas, IT-based systems are, in addition to the traditional fieldbus technology, gaining in importance.

User demands for openness, all-round integration and straightforward control require high-performance devices and industry-standard network concepts. Hereby the customer benefits from savings in time and costs for planning, building, operating and maintaining his machines and plant.

Apart from easy installation, network topology, cabling and connection concepts are considered to be among the more important criteria for the evaluation and therefore the acceptance of network products for use in industry.

HARTING combines the competences of the world's leading manufacturer of industrial connections with networking competence to turn these customer requirements into actual solutions. This competence is underscored by HARTING's active participation in influential committees and working groups for standardisation. Starting with its classic connectors, HARTING creates comprehensive system solutions as well as network components to build industrial networks from a single source. These include, amongst others:

- Connectors
  in robust designs and workmanship capable of standing up to industrial conditions as well as including technical features that correspond to industry requirements to suit various demands, for example, EMC requirements
- Network components
  combine the characteristic features of connectors and an optimum harmony with industrial topologies
- Networks
  fulfil user requirements with the use of optimum components

00.2 General information about fieldbus

It is necessary in the course of advancing automation and decentralisation of measurement, sensor and drive technologies to create multi-vendor, open communication standards, which can link the different devices from various manufacturers and guarantee cross-system communication. This will result in remote sensors and actuators becoming ever more 'intelligent'; thus, communication will increasingly flow in both directions:

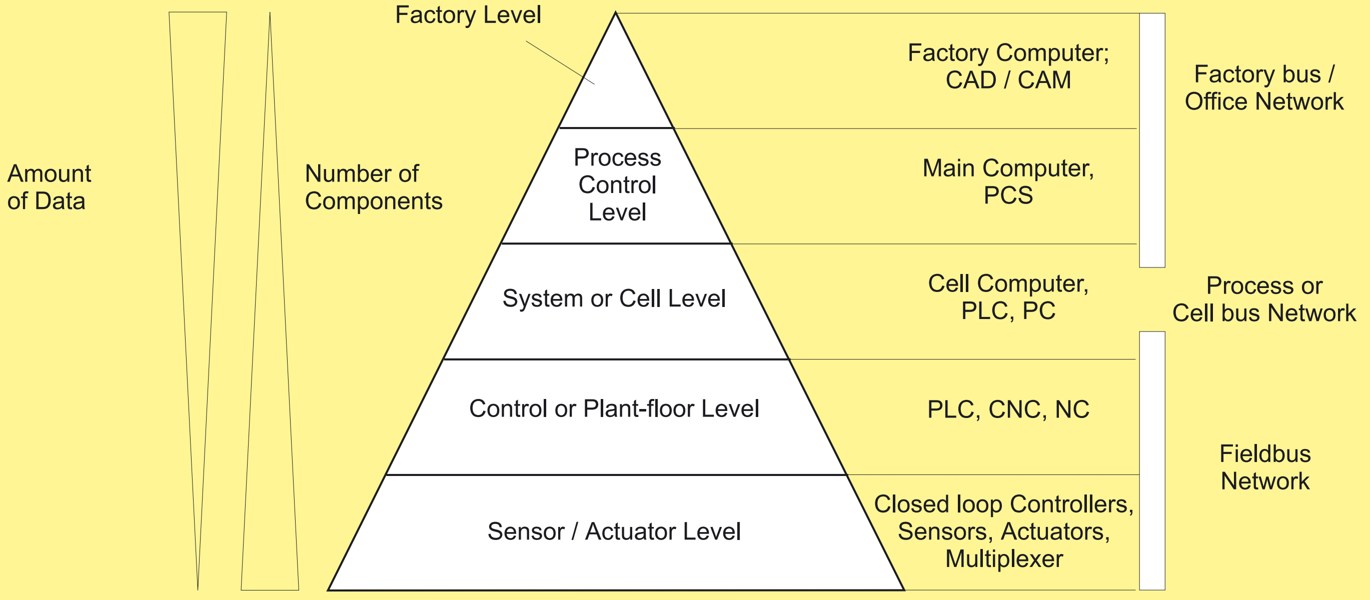
- From the PLC (transmitter) to the sensors / actuators (receivers)
- From the sensors / actuators (transmitters) to the PLC (receiver)

Quality and safety reasons dictate that the transmission speeds of signals and messages will become more and more crucial for maintaining certain demands (for example, diagnostics, troubleshooting, safety-related data transmissions).

And last but not least, the introduction of fieldbus technology will decisively lower wiring overheads as well as the susceptibility to faults of the connections between the field devices and the higher-level controls and systems.

00.3 The automation pyramid

Based on the amount and number of the required components, the information to be transmitted within the different levels of a system can be portrayed in the form of a pyramid:



The automation pyramid

Bus systems provide the means for communication within the individual levels as well as between the different levels. That said, the following applies: the higher the level is, the slower the rate of transmission, but the greater the amount of data to be transmitted.

The sensor / actuator level (field level)

In this the lowest of the levels, sensors and actuators are used to control production and manufacturing processes.

Process-related data is for example:

- Liquid level
- Pressure
- Temperature
- Flow rate
- End positions
- Rotational speeds
- Control status
- …

This data is read-in and processed at the field level. In addition to the normal process data, safety- and quality-relevant data is also read-in, processed and transmitted. Amongst other, these include alarm values, run times, analysis values and so forth.

Data exchange takes place predominantly between different levels, and only seldom between the devices within the same level. For example, setpoint values are transmitted from, and actual measured values are transmitted to a higher-level controller.

PROFIBUS, CANopen, DeviceNet and AS-Interface are known fieldbus protocols used at the field level as well as for communicating to the control level.

The control or plant-floor level

This control is positioned on the second level. Amongst others, the tasks covered by this level are:

- Conditioning and processing the data received from the assigned sensors and actuators on the field level.
- Administering several control and regulating modules
- Carrying out automation and control tasks
- Routing certain data to the system level
- Visual display of data
- ...

Typical devices for this level are, for example, programmable logic controllers (PLC) and regulators or CNC modules.

Data exchange takes place both between and within the levels. For example, setpoint values are transmitted from a higher-level controller to the lower-level sensors and actuators.

This data can equally be transmitted between the individual PLC modules within this level.

PROFIBUS, CANopen and DeviceNet are the fieldbus systems used for the control level. PROFIBUS, CANopen, DeviceNet and Industrial Ethernet provide the link to the system level.

The control system or cell level

This level is responsible for the monitoring, control and regulation of several processes. The tasks covered by this level are:

- Conditioning and processing the data received from the assigned controllers and regulators from the control level
- Administering several control and regulating modules
- Carrying out higher-level automation and control tasks
- Routing certain data to the process control level
- Central point for visualisation of selected data
- …

Typical examples of such devices are: programmable logic controllers (PLC) and PCs.

Data exchange takes place both between and within the levels. For example, setpoint values are transmitted from a higher-level management system to the lower-level PLCs. This data can equally be transmitted between the individual PLC modules within this level.

Industrial Ethernet is the fieldbus increasingly being used on the system level as well as for communication to the process control level. PROFIBUS, CANopen and DeviceNet are also utilised.

The process control level and factory level

These two levels serve predominantly to control larger systems or factory operating areas as well as higher-level planning and control of the entire production.

These two levels are of less relevance as far as fieldbus systems are concerned. On the process control level, Industrial Ethernet can be used for user-specific applications.

00.4 The layer model

The 'Open Systems Interconnection Reference Model' (abbrev.: OSI Model) came into being in 1983 based on the experienced gained from using and developing TCP/IP as a standard for office communication.

This reference model describes the OSI environment very abstractly. At least two open systems make up the OSI environment, these being connected to one another by means of a physical medium for the exchange of data. Having said that, each of these systems is an autonomous entity that can independently process and transmit data.

According to OSI specifications, data exchange takes place in an open system in accordance with formal rules of communication, which were developed in accordance with the OSI reference model.

In order to be able to use the OSI reference model on a system, the system has to be divided up into two categories.

- Into data processing to perform a certain task

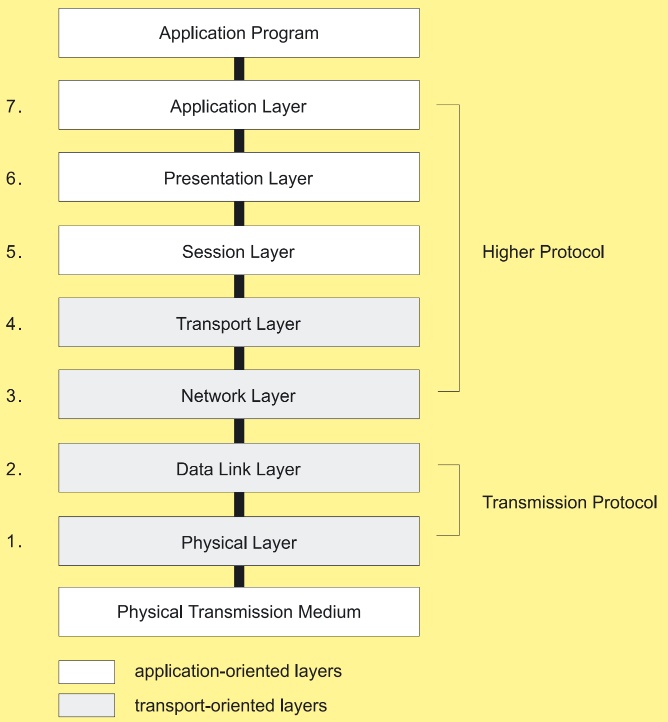
and

- Into the communication system solely responsible for transmission of data

The rules applied to the system of communication are called protocols. These rules require that the messages using this communication to exchange data between the individual stations must be able to be subdivided into four different types:

- Request
- Indication
- Response
- Confirmation

The OSI Reference Model is divided up into 7 layers. Each layer contains at least one instance specifying particular network functions. This instance can be compared with an independently functioning software module that carries out special tasks with the assistance of neighbouring instances.



The OSI Reference model

The tasks and functions are assigned to the individual layers as follows:

Layer 1: Physical Layer

Layer 1 (bit transmission layer) manages the physical medium for transmitting the individual bits of the telegram messages. This includes defining the transmitting medium (electrical cable, fibre-optic cable), connector assignment, type of modulation, transmission rate, signal level as well as further physical parameters such as the length of cable and more.

Layer 2: Data Link Layer

Layer 2 is responsible for the bus access procedure as well as the fail-safe transmission of data packets from the transmitter to a receiver or several receivers (Multicast) or to all receivers (Broadcast).

Layer 3: Network Layer

Layer 3 supports the search and use of suitable transmission routes between the transmitter and receiver through the network, possibly via a communication PC.

Layer 4: Transport Layer

Layer 4 is responsible for the control of and error-free, logical delivery of telegrams.

Layer 5: Session Layer

Layer 5 (communication layer) establishes, manages, synchronises and terminates communication between the participating stations of a bus communication.

Layer 6: Presentation Layer

Layer 6 is responsible for character coding and conversion of data, monitor and file formats in a suitably readable form for the corresponding computer.

Layer 7: Application Layer

Layer 7 provides interactive services, such as writing and reading, for other network users. In doing so it provides an interface to the user programmes in PLC, PC and control systems.

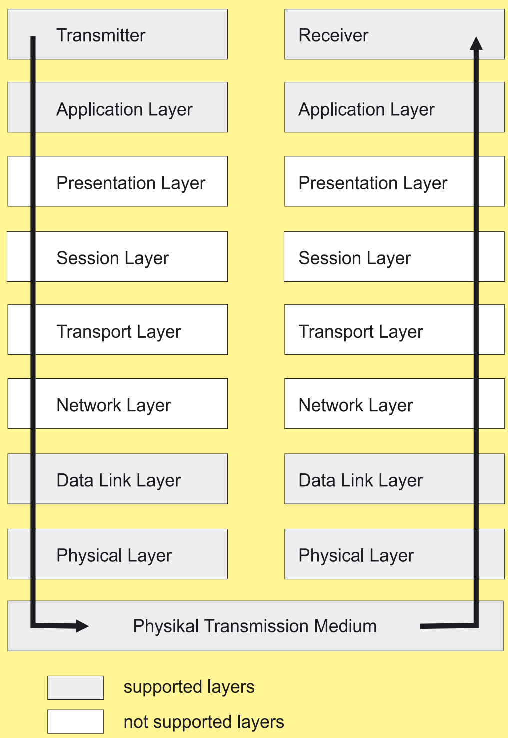
Using the OSI Reference Model

Layers 1 to 4 are responsible for the transmission of data between stations within the network. Layers 5 to 7 coordinate the interaction between the bus system and the user program of the computer in the respective station.

The structure of the layers applies only to the internal sequence of communication. It has nothing to do with the control levels of automation engineering.

Generally speaking, only the layers 1, 2 and 7 need be considered for industrial communication purposes by means of fieldbus systems. These layers are reduced even further for individual fieldbus systems (for example, PROFIBUS-DP or AS-Interface) in order to achieve increased transmission speeds.

The following figure depicts a typical route taken by a message from the transmitter to the receiver.



Example of message transmission by means of the OSI Reference Model

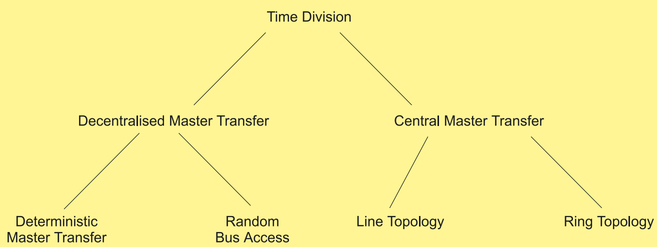
00.5 Classifying the fieldbus systems

Serial fieldbus systems are based on a time-division multiplex method. That means that the communicating partners must divide up the transmitting time between themselves, because only one station can occupy the bus for transmission purposes at a given time.

The classification of the fieldbus systems can be made according to various aspects:

- According to access procedures
- According to topology
- According to bus access protocols

The link between the individual aspects is depicted in the following figure:



Classifying the fieldbus systems

Fieldbus systems with decentralised master transfer

The master function of a bus system employing a decentralised master transfer mechanism is distributed between several stations. In this case, a distinction is drawn between the differing access mechanisms:

Deterministic master transfer

Certain stations, the masters, are each permitted to transmit (token holders) for a defined time. Once this defined time has elapsed, the token, which provides the necessary authority to transmit, is passed on to the next master making it the active master. A logical ring is built up between the masters so that this process can be applied independently of the network topology. This process is known under the name of 'Token Passing'.

Typical fieldbus systems that function according to this principle are:

- PROFIBUS-FMS (Fieldbus Message Specification)
- PROFIBUS-DP (Decentralized Peripherals)
- others

Random bus access

The bus assignment is not made according to a predefined concept. That means that all stations have the same rights and are always ready to receive messages. Where necessary, they can begin to transmit messages when the bus is not occupied. The access procedure used is called CSMA (Carrier Sense Multiple Access).

The advantage of this access procedure is the event-controlled communication.

Typical fieldbus protocols that function according to this principle are:

- CANopen
- DeviceNet
- others

Fieldbus systems with central master transfer

In a bus system operating a centralised master transfer mechanism the master transfer function is fulfiled by one station only, which is defined as the master terminal. The master terminal cyclically queries all of the other network stations (slaves). The slaves are only permitted to transmit information following a request from the master.

With this form of data transfer, a distinction is drawn between the different topologies:

Line topology

Several stations are connected to a bus trunk cable by means of a stub line. The tree topology is an extended form of the line topology. The maximum length of such a cable is restricted by its electrical characteristics.

Typical fieldbus systems that employ a line topology are:

- AS-Interface ASI
- others

Ring topology

Both ends of the trunk cable forming the bus system are connected to each other. That is the reason why no cable termination is required. The individual stations form a ring configuration. For data exchange purposes, both separate data telegrams from each station as well as accumulated frame telegrams are used for the transmission of master information. The accumulated frame telegrams contain data for all of the stations. Each station receives the data addressed to him, and attaches its own data to this telegram at a time determined by the master.

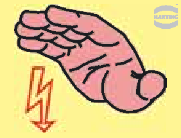
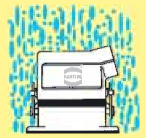
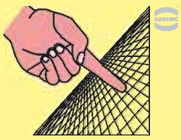
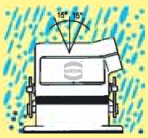
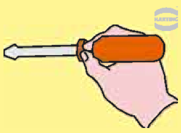
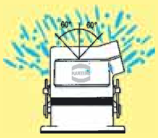
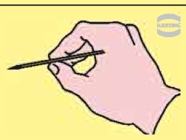
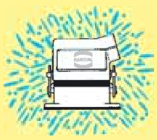
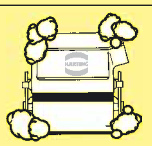
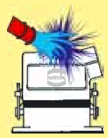
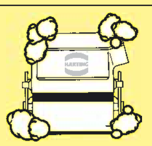
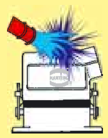
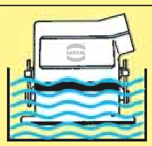
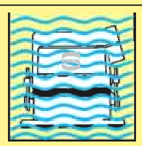
INTERBUS is a typical example of a fieldbus system that uses ring topology.

HARTING can draw on many years of extensive experience gained in achieving high protection classes for industrial environments (IP 65 and greater); all of which flows into the development of its family of devices.

The protection class for these devices is achieved with corresponding housings and covers or by the interlocking of their connections. Depending on their protection class, the devices are protected from external mechanical influences (impacts, foreign objects, dust, and accidental touch contact) as well as against ingress of moisture (water, cleaning agents, oils and other fluids).

The protection class provided by a device is defined in the standards IEC 60 529 and DIN EN 60 529, which also contain a classification of the different degrees of protection. The table below offers an overview of the protection classes. In accordance with the above-mentioned standards, the degrees of protection are indicated as follows:

Code letters (International Protection)	**First Index Figure** (Foreign bodies protection)	**Second Index Figure** (Water protection)
IP	**6**	**5**

Index figure	Degree of protection			Index figure	Degree of protection		
0	No protection		No protection against accidental contact, no protection against solid foreign bodies	**0**	No protection against water		No protection against water
1	Protection against large foreign bodies		Protection against contact with any large area by hand and against large solid foreign bodies with Ø > 50 mm	**1**	Drip-proof		Protection against vertical water drips
2	Protection against medium sized foreign bodies		Protection against contact with the fingers, protection against solid foreign bodies with Ø > 12 mm	**2**	Drip-proof		Protection against water drips (up to a 15° angle)
3	Protection against small solid foreign bodies		Protection against tools, wires or similar objects with Ø > 2.5 mm, protection against small foreign solid bodies with Ø > 2.5 mm	**3**	Spray-proof		Protection against diagonal water drips (up to a 60° angle)
4	Protection against grain-shaped foreign bodies		As 3 however Ø > 1 mm	**4**	Splash-proof		Protection against splashed water from all directions
5	Protection against injurious deposits of dust		Full protection against contact. Protection against interior injurious dust deposits	**5**	Hose-proof		Protection against water (out of a nozzle) from all directions
6	Protection against ingress of dust		Total protection against contact. Protection against penetration of dust	**6**	Protected against flooding		Protected against temporary flooding
				7	Protected against immersion		Protected against temporary immersion
				8	Water-tight		Protected against water pressure

Description according to DIN EN 60 529, IEC 60 529