INDUSTRIAL COMMUNICATION

Module 1

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4. ETHERNET IN INDUSTRIAL USE

5. GLOSSARY

1. BASICS OF AUTOMATION
1.1. ADVANTAGES OF AUTOMATION

- Accelerates the production cycle
- Increases product quality
- Saves time and personnel costs
- Reduces environmental impact due to resource-efficient operation of systems (e.g. low levels of material and energy consumption)
- Increases flexibility
- Enhanced precision and the avoidance of errors
- Relieves human beings of mentally undemanding, monotonous, strenuous, dangerous or unhealthy work

1.2. THE INPUT-OUPUT-MODEL

The input-output model forms the basis of every automation task, this consists of an input signal (input), a controlling unit (the function) and the output signal (output).

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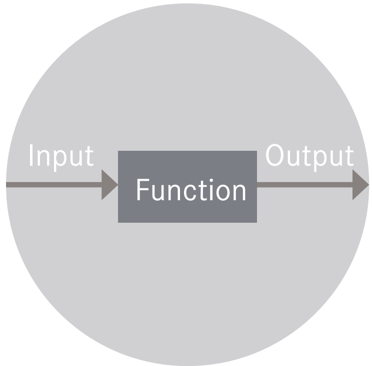


Input
The input of an automation system is generally a physical quantity that is captured by the appropriate sensors or measuring methods.

Function
A function influences the response of a technical system.

Output

In the simplest case, the output of a function or a controller is used to activate an indicator light. In general terms, we can refer to these as actuators that are activated via the output. This might be a motor or a valve.

1.3. THE INPUT-OUTPUT-MODEL: A SIMPLE CONVEYOR BELT

A simple conveyor belt has two light barriers and a drive that can be switched on and off. The light barriers are located at the beginning and end of the conveyor belt. If a workpiece is placed at the start of the conveyor belt, the light barrier is interrupted and the conveyor belt is switched on. When the workpiece reaches the end of the conveyor belt, the second light barrier is interrupted and the conveyor belt is switched.

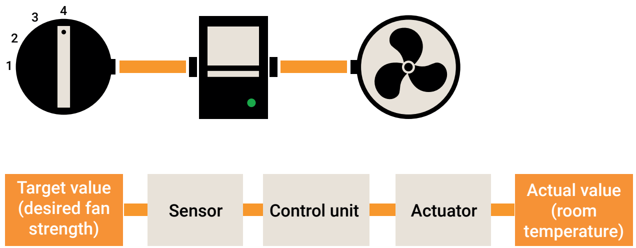
The Input-Output-model

In terms of an input-output-model, the conveyor belt comprises the following automation system: In this case the input is provided by two light barriers; the controller processes the two inputs and supplies the output in the form of the signal to switch the drive on and off.

1.4. THE DIFFERENCE BETWEEN CONTROLLER AND REGULATOR

Controller

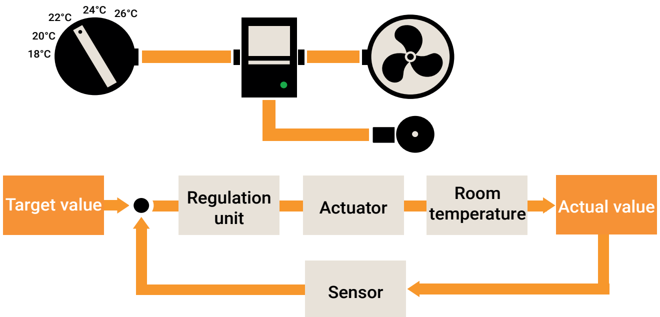
The speed of the fan is set via the selector switch, and the control unit then converts the set level into an output signal for the fan.



The speed of the fan is set via the selector switch, and the control unit then converts the set level into an output signal for the fan. In contrast to a regulation, no feedback takes place, such as e.g. an automatic adjustment of the speed of the fan due to the room temperature.

This is referred to as an **Open loop control system**:
Desired fan strength → Selector switch – Control unit – Fan → Room temperature.

Regulator
The principle of control can be explained by a fan control, which consists of a selector switch for setting the desired temperature, a temperature sensor, a control unit and a fan.



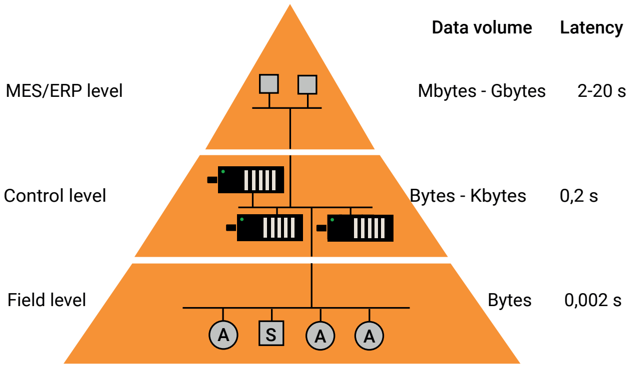
The desired temperature (setpoint) can be set with the selector switch. The room temperature (actual value) is measured by a temperature sensor. The control unit processes the information received from the selector switch and the temperature sensor by comparing the desired temperature (set point) with the room temperature and continuously calculates the necessary adjustment of the fan output signal.

Regulation is characterized by a **closed loop control system**:
Room temperature → Temperature sensor – Control device – Fan → Room temperature.

1.5. THE AUTOMATION PYRAMID

A manufacturing company can be described in the form of an automation pyramid with at least three levels, whereby all levels are interlinked in terms of information technology: the exchange of information within a level is referred to as horizontal communication, while the exchange of information between levels is known as vertical communication.

Within the pyramid, especially the latency is of importance. Latency refers to the delay time between the transmission of information to a computer and the usability of the information on the receiver computer.



Field level

As the lowest level, this level contains all sensors (input) and actuators (output) of the machines / plants of a manufacturing company. Here, only a few bytes are transmitted at the same time, for example, to control an actuator or to receive a sensor signal. At the same time, however, high demands are placed on the maximum latency: in order to be able to control the processes correctly, the control signals must be transmitted within a few milliseconds.

Control level

Within the control level are all automation computer systems (function) that control the process. The controllers are connected to the sensors / actuators of the field level and each control a part of the system. The controllers are also connected to each other and to the higher level. At this level, information is transferred in size from a few bytes to a few kilobytes. The latency is a fraction of a second.

MES/ERP Level

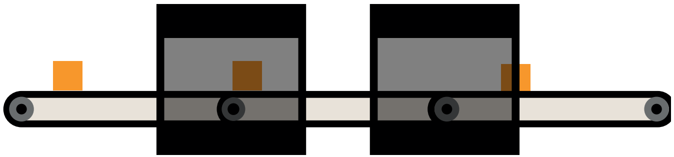
Since the Manufacturing Execution System (MES) level is directly linked to the control level, the current production data, such as the quantities produced, are read out of the control units, and based on the current availability of the machines, in order to be executed is coordinated. The Enterprise Resource Planning (ERP) level allows you to control and plan a company's resources, such as material requirements planning. At this level, information is transferred in size from a few megabytes to gigabytes. The latency is several seconds.

1.6. TYPES OF AUTOMATION SYSTEMS

In industrial automation technology, a distinction is made between production and process automation:

Production automation

- Focus: controlling processes
- Is PLC-based as standard (program logic control)
- Captures sensor data every 10 to 100 ms
- Is subdivided into serial and individual production
- Here, end products are created from numerous raw materials, materials and externally procured parts
- Numerous production and assembly processes are frequently required
- Production processes are described using work schedules (specification of production and assembly stages) and parts lists (showing which individual components a product consists of)



Process automation

- Focus: regulating processes
- Previously purely PCS-based (process control system), nowadays also PLC-based at small to medium levels of complexity in some cases
- Due to the usually very decentralized structure, these are referred to as Distributed Control Systems (DCS)
- Captures sensor data every 100 ms – several seconds
- Essentially automation of process-related operations and chemical reactions such as mixing, heating, separation or synthesis
- A distinction is drawn between continuous, discontinuous and campaign production
- Process descriptions, manufacturer specifications and formulas are used instead of parts lists and work schedules

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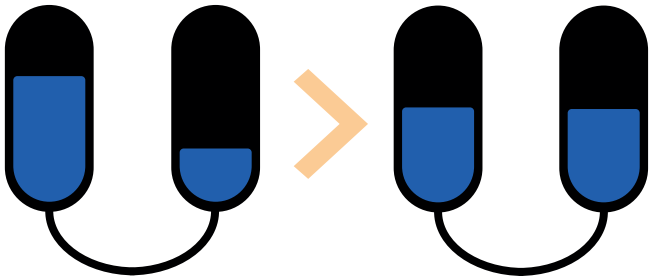


1.7. IP PROTECTION TYPES

For safety reasons, electrical components have to be protected from exterior factors such as dust, solid particles, dampness and water. IP protection classes are stipulated for the various environmental conditions in which electrical components are used. These are defined in DIN EN 60529 and generally specified in the format IP-XY. The prefix letters IP stand for Ingress Protection; while the first digit (X) indicates the degree of protection from contact and solid particles, the second digit (Y) indicates the degree of protection from dampness and water.

IP + X + Y

X ↑ Protection from contact and solid particles (first digit)

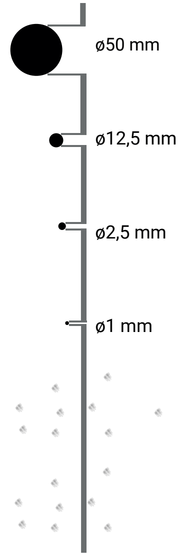
Y ↑ Protection from dampness and water (second digit)

Protection from the ingress of solid particles (X)
The protection classes for solid particle ingress is from 0 to 6. The lowest protection class 1 prevents ingress of solid particles larger than 50 mm, for example cogwheels falling in an automobile repair garage.

The best protection class is 6: this even provides protection from the ingress of dust in casings and plugs, for example in grinding machines used for production purposes.

If the simultaneous ingress of water is not relevant, the above examples might be specified as IP 1Y and IP 6Y.

1st digit	Description
0	No protection
1	Protected from solid particles (diameter of 50 mm and over)
2	Protected from solid particles (diameter of 12.5 mm and over)
3	Protected from solid particles (diameter of 2.5 mm and over)
4	Protected from solid particles (diameter of 1.0 mm and over)
5	Dust ingress is possible but cannot influence operation
6	No ingress of dust



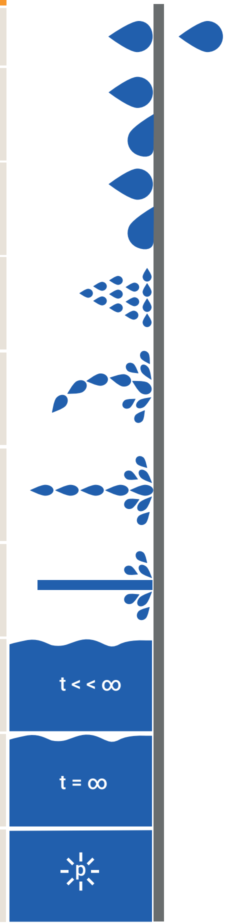
Degree of protection from liquid ingress

The protection classes for liquid ingress range from 0 to 9. The lowest protection class 1 prevents ingress of vertically falling drops of water, such as condensation water in a piece of equipment.

The best protection class is 9: this even provides protection from the jet of a high-pressure cleaner, as used in industrial cleaning processes, for example.

If the simultaneous ingress of solid particles is not relevant, the above examples might be specified as IP X1 and IP X9.

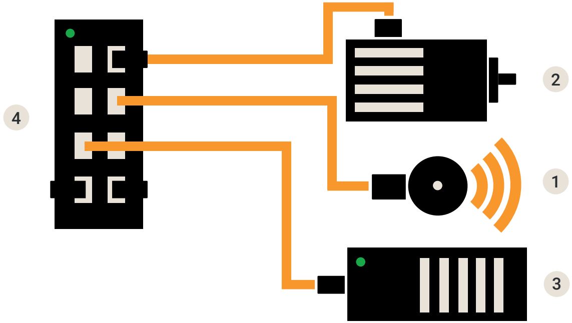
2. Kennziffer	Beschreibung
0	No protection
1	Protected from dripping water
2	Protected from dripping water if the casing is titled by up to 15°
3	Protected from spray water
4	Protected from splash water
5	Protected from light water jets
6	Protected from powerful water jets
7	Protected from water ingress when temporarily immersed
8	Protected from water ingress when continiously immersed
9	Protected from high-pressure water (incl. high water jet temperatures)



2. COMPONENTS AND STRUCTURE OF AUTOMATION SYSTEMS

2.1. OVERVIEW OF COMPONENTS

An automation system consists of sensors (1), actuators (2), a control computer (3) and a communication system (4), which interlinks the other components.



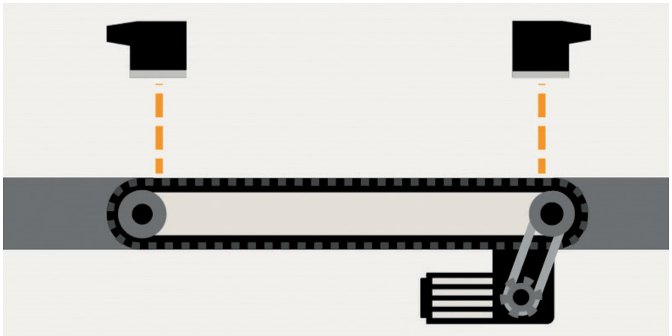
2.2. SENSORS

A sensor is a measuring device that captures analog physical quantities (mechanical, chemical, thermal, magnetic or optical) and transforms them into analog and digital electrical signals. Sensors can be distinguished by signal type (analog sensor, digital sensor), measuring principle (optical sensor, capacitive sensor, etc.), purpose (sensors in automation technology, sensors in aerospace, etc.) and quantity measured (power sensor, temperature sensor, etc.).

How a simple sensor works

In the picture you can see a simple conveyor belt above which a sensor has been mounted in the form of a retroreflective sensor. This uses reflection to detect whether a workpiece is located at the relevant point on the conveyor belt or not.

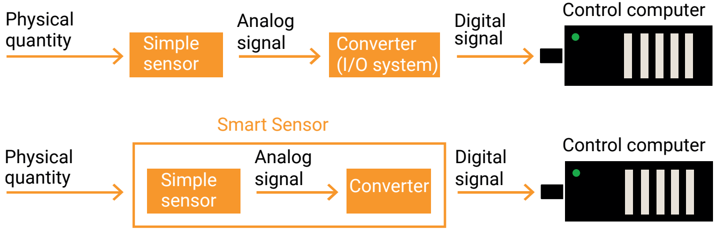
If there is no workpiece under the light barrier, the light is not reflected and the sensor delivers the value “no workpiece present” as the electrical signal. If a workpiece does pass under the light barrier, the light is reflected on the top of the workpiece and the sensor supplies “workpiece present” as the electrical signal.



Distinction between simple and smart sensors

A “simple sensor” generates an analog measurement signal from a physical quantity. This signal then has to be prepared by a converter so that it can then be further processed by a control computer.

A “smart sensor” or “intelligent sensor” has the advantage that in addition to recording the measured quantity, it can also prepare and process the latter according to predefined functions and then output this as digital information. This intelligence allows it to communicate directly with the control computer.



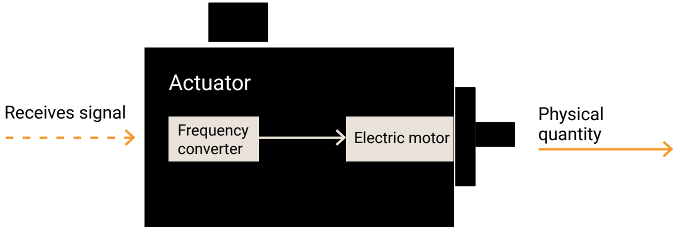
2.3. ACTUATORS

The operating principle of an actuator is the reverse of a sensor: an actuator converts electrical signals from a control computer into physical quantities. Electrical impulses are converted into pressure, sound, temperature, movement or other physical quantities by means of an actuator.

As with sensors, it is possible to distinguish between different types of actuators. Actuators are categorized as electromechanical, electromagnetic, pneumatic, hydraulic or other forms, according to the conversion process used.

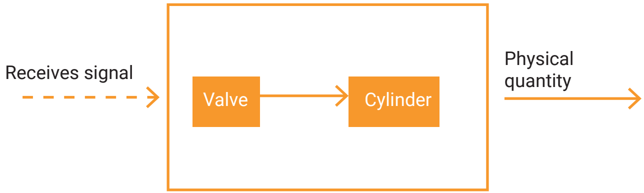
Example of electromechanical actuators

In an electric motor (electromechanical actuator), the required signals are transmitted by the control computer to a frequency converter. This signal might contain the desired rotational speed, for example. The frequency converter receives the signal and supplies the electric motor with the required current.



Example of pneumatic actuator

In a cylinder (pneumatic actuator), the required signals are transmitted by the control computer to a valve. The valve works by means of an integrated solenoid which opens or closes, depending on the given voltage. When the valve is open, compressed air flows through the cylinder, which then extends. When the valve is closed, the air in the cylinder escapes, and the cylinder retracts once again. One example of this is an automatic brake. The brake only opens if compressed air is available, otherwise the brake operation is carried out automatically.

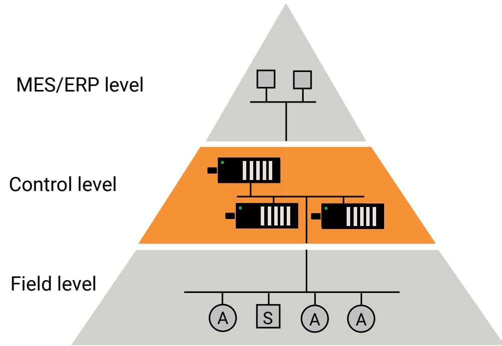


2.4. CONTROL COMPUTER

The function of the PLC (Programmable Logic Controller) is to control a process or sub-process. For this reason, it is positioned as close to the process as possible. If the sensors/actuators are positioned adjacent to the PLC, they are connected directly to the PLC. Sensors/actuators with a long distance to the controller are generally connected to the PLC via a so-called bus system. In larger systems with several sub-processes, a separate PLC is used for each sub-process, and these are networked with one another.

Looking at the automation pyramid, the control level lies between the field level and the MES/ERP level. For a control computer this results in the following tasks:

- Control of the process or sub-process using the sensors and actuators at the field level.
- Alignment with the MES/ERP level to coordinate resources. In this way, it is possible to determine which machine is currently handling which order and when it is expected to be available again, for example.

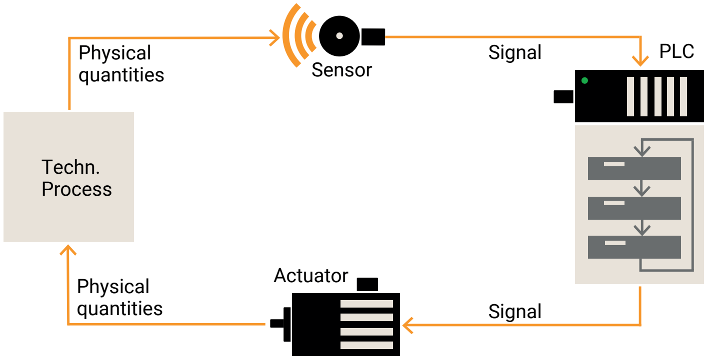


Structure of a PLC

Depending on its type, a PLC has a different number of inputs and outputs as well as a processing unit. The classic PLC is cycle-based, in other words a sequence is constantly repeated internally. The system operates according to the input-function-output model:

- The control computer receives signals from the sensors via its inputs (input).
- The signals received are processed according to a predefined logic (PLC program) by the control computer (function).
- Based on the logic, the control computer generates the appropriate signals for the actuators (output).
- Processing then starts from the beginning again (the control computer once again receives signals from the sensors).

This creates a so-called information loop.



The PLC is used in many areas of application such as:

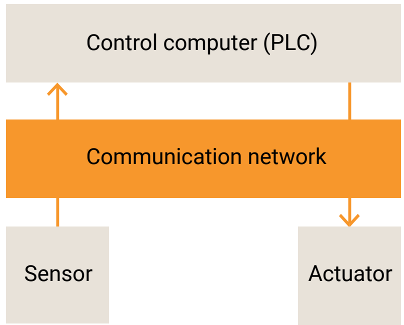
- Special machine construction (e.g. woodworking machines)
- Plant automation (use of a large numbers of PLCs, e.g. assembly line in car production)
- Mobile automation (e.g. agricultural machines, construction machines, ships)
- Energy production (e.g. wind power plants, solar power plants)
- Building automation
- Stage technology

2.5. COMMUNICATION NETWORK

Overview of the components of a communication network

In order to be able to build a complete automation system from the components sensor, actuator and control computer, a communication network is required that brings all of these components together. The essential components of an industrial communication network are:

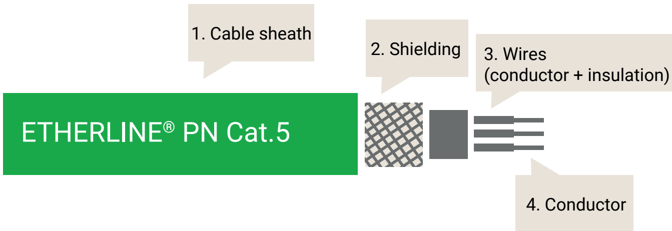
- Application-dependent cable type
- Connectors
- Network topologies
- Fundamental classification of transmission technologies into fieldbuses or Ethernet
- Network components such as switches or decentralized I/O modules



2.5.1. CABLE

Structure of a cable

A cable consists of one or more wires that are enclosed in a cable sheath (1). A wire (3) is defined as a single lead with an insulation. When a single lead is itself made up of several fine inner wires, it is referred to as a stranded conductor and the individual wires are called strands (4). Depending on requirements, an electromagnetic shielding (2) is applied to the various insulations.

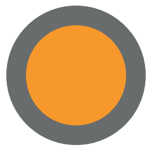
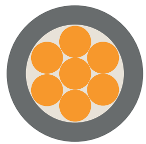
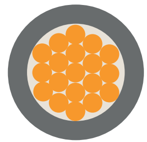


Conductor

An electrical conductor is a medium that serves to transmit electric energy (for the supply of electricity) or transmit electric impulses (for data communication purposes). Electrical conductors are generally made of copper or aluminum, since these materials exhibit a high level of electrical conductivity, low temperature dependence of conductivity, high thermal conductivity and high mechanical strength. Coatings made of tin, gold, silver and nickel often serve to protect the metal surface from corrosion. The mechanical flexibility of a cable is determined by the structure of the conductor. The following distinctions are drawn in terms of construction type:

- Solid conductors consisting of a single, solid conductor.
- Stranded conductors made up of between seven and several hundred thin inner wires (so-called strands).

The simplest construction type for an electrical conductor is the solid individual conductor. This has a constant exterior diameter and due to its large cross-section has a high level of rigidity, while the multi-strand versions offer a higher degree of flexibility.

Design	Solid conductor 	Stranded conductor, 7 wires 	Stranded conductor, 19 wires 
Installation	Fixed	Occasionally moved	Highly flexible
Example application	Tray	Patch cable	Drag chain/torsion
LAPP-abbreviation	/1	/7	/19

Wire insulation

Wire insulation serves to protect the electrical conductor so as to avoid short circuits, for fixing purposes and to provide protection from contact. The plastics used for insulation have negligible electrical conductivity, low water absorption capability, high thermal resilience and high abrasion resistance. Frequently used insulation materials are: PVC, PE, PP, PTFE, rubber and PUR.

Shielding

At high frequencies, the wires of a cable act like antennas. This means that they emit electromagnetic fields into the environment (e.g. nearby electrical cables), and also absorb electromagnetic fields from the environment. In order to reduce this influence on the environment and on data transmission, the cables are fitted with electrical protection. Typical shielding types and materials include braided shields made of copper wires (mainly coated with tin) and foil shields made of aluminum or copper. While braided shields protect the line primarily against low-frequency interference, foil screens provide protection against high-frequency interference.

Cable sheath

The cable sheath protects the inner cable structure from chemical impact (acids, alkalies, oils), mechanical stress (abrasion, torsion) and environmental impact (UV radiation). The correct choice of sheath material is therefore essential to the durability and resilience of the cable. Typical materials include plastics such as TPE, PUR and PVC.

Criteria for selecting a cable

Cables have to be selected in such a way that they are suited to the relevant operating conditions and external influences. The following criteria have to be considered when making the choice:

- What is the required purpose: Is the cable to be used for energy transmission or signal transmission?
- In which industrial sector is it to be used? (certifications, approvals)
- By means of which components is the cable to be connected? (energy or signal transmission, connection technology)
- In which temperature range is the cable to be used? Will the connection be exposed to changes in temperature during operation? (electrical conductivity, operating conductivity)
- Is the cable to be stationary or non-stationary? (flexibility of the cable)
- How is the cable to be installed? (laying method, flexibility, connection technology)
- In which environment is the cable to be used? (chemical resistance, resistance to water and dampness, combustibility, protection from UV radiation)

2.5.2. CONNECTORS

What are connectors?

Connectors are electrical components that connect two transmission components to each other electrically by means of a detachable contact area. The detachability of the electrical connection is a key factor here, since this enables installation of the machinery and plant at their place of use, flexibility of application, dismantling and assembly of production facilities when a change of location is required, repair and service of the system components and also easier handling of the system components.

Structure of connectors and material requirements

Connectors consist of two main parts: the pin insert and the socket insert. These are mounted in housings.

Contact area

The main requirements of the detachable contact area are high electrical conductivity, high corrosion resistance and high mechanical wear resistance. Copper or copper alloys are mainly used for contact elements due to their electrical conductivity. Surface coatings made of silver or gold are often used to ensure corrosion protection.

Connector housings

The main functions of the housing are to ensure the mechanical stability of the connector, protect the electrical connection, provide electric shielding and also ensure processing capability and environmental compatibility. Housings can be made of plastics or also metal alloys such as aluminum alloys or copper-nickel-zinc alloys.

CONNECTOR TECHNOLOGY TERMS

Connector face

The shape of the connecting surfaces of a connector housing is referred to as the connector face. There are connectors with round or rectangular connector faces, for example. In order to prevent mismating, connector housings with different codings can be used. The codings are applied by means of shape elements on the housings such as lugs or snap-in hooks.

Pole pattern

The arrangement and nature of the contacts in the plug is called the pole pattern. Defined pole patterns are used to ensure that only connectors of the same system can be joined to one another. This prevents connectors for power transmission being confused with those for data transmission, for example.

Connection technologies in cables

Putting connectors on cables is called cable assembly. Essentially it is not necessary to assemble cables oneself: they can be purchased pre-assembled. If the self-assembly option is chosen, it first has to be decided how the cable is to be joined to the connector. The connection technology to be used for the application in question will depend on the place in which the connector or cable will be deployed, the processing location or field application, the type of conductor to be connected, tool availability and the cost of establishing the connection.

THE MOST IMPORTANT CONNECTION TECHNOLOGIES ARE AS FOLLOWS:

Soldering

This can be used for both solid wires and strands. Since soldering pure copper can be a problem, the wires and strands are often additionally coated with precious metals such as silver and gold. With this connection technology, care should be taken to ensure that the material of the soldered connection elements is appropriate to the soldering process.

Screw connection

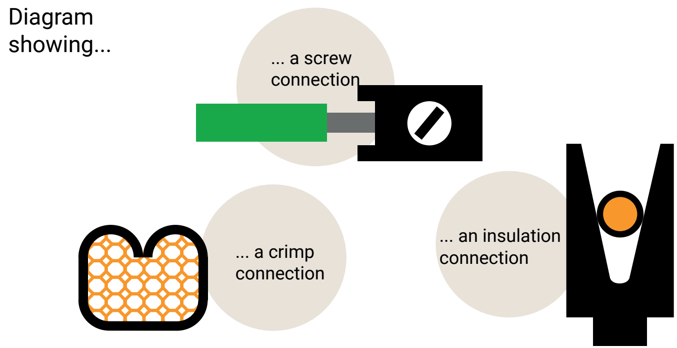
This is a detachable, non-soldered connection technology that is used to connect both wires and strands. Here it is important for the wires to be stripped and straightened prior to connection, or else fitted with a sheath, for example.

Crimping

A crimp contact is a non-soldered force-fit connection between the cable conductor and the crimp connection elements in the connector. Crimping is carried out using a special tool. The insulation has to be removed from the conductor prior to crimping.

Insulation displacement

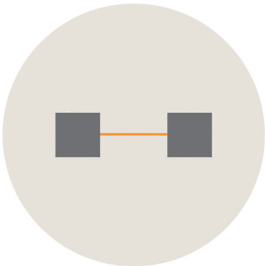
This method enables both solid wires and strands to be connected without soldering, screwing or stripping. The wire is pressed into a slit which removes the cable insulation and also ensures contact pressure with the conductor.



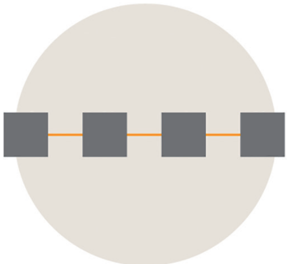
2.5.3. NETWORK TOPOLOGIES

A network topology is a graphical representation of how the devices are networked with one another. In industrial networks, the following types of topologies occur

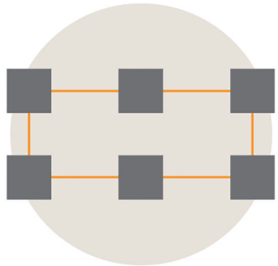
Point-to-point connection:
The simplest connection is a point-to-point connection between two devices. This might be a connection between a PLC and a PC, for example. One key disadvantage here is that if a device has to communicate with several other devices, a separate connection has to be established in each case.



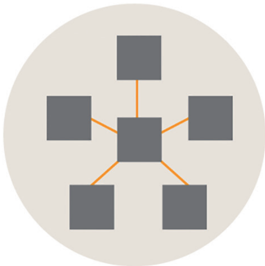
Line/bus topology:
Connecting devices in series to form a line topology is also referred to as a bus topology. The devices are all connected to one transmission medium. Classic fieldbus systems such as PROFIBUS feature this type of topology.



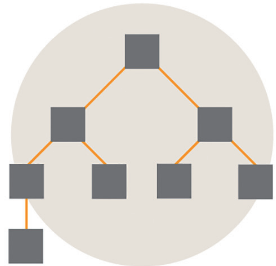
Ring topology:
When the devices are connected in a ring topology, every device can essentially communicate with every other device via two channels (clockwise , counter-clockwise). And this is the main advantage of this structure: communication between the devices is still preserved even if one section of the network is interrupted. This type of redundant ring structure can be realized with EtherCat, for example.



Star topology:
With a star topology, a distribution component is required that forms the center of the star.



Tree topology:
A tree has several distribution components, depending on its size, and can therefore be regarded as an “expanded” star. One example of this is the common type of Ethernet office network using switches as a distribution component.



2.5.4. FIELDBUS AND ETHERNET

While network topologies can theoretically take on any form, each network technology has specific properties and limitations in terms of the potential network topologies that can be used. These can generally be distinguished according to communication networks based on fieldbus or Ethernet.

Fieldbus

A fieldbus establishes the connection between sensors, actuators and control computer. Several devices can be connected to a fieldbus and send their messages via the same line. In this case, it must be specified who is allowed to exchange information and when. Virtually every PLC manufacturer has designed their own fieldbus. For this reason, there are numerous technologies that are different from each other. For example, the maximum cable length, the data rate or in the range of functions.

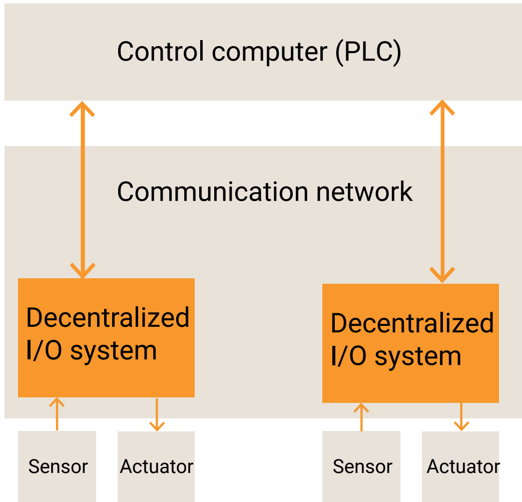
Ethernet

Ethernet is a technology originally developed for office communication, i.e. for the exchange of data in PC-based local data networks (LANs); it consists of a number of software and hardware components. Ethernet allows much higher transfer rates of up to 400 Gigabit/s. A number of PLC manufacturers have extended basic Ethernet technology in order to meet various industrial requirements. This has resulted in the existence of a number of manufacturer-specific Ethernet systems. Examples are the real-time capability or the topology.

2.5.5. DECENTRALIZED I/O SYSTEM

A decentralized I/O system consists of one or more network components connected to the PLC via fieldbuses or Ethernet, allowing direct connection of various sensors and actuators. The main advantage of a decentralized I/O system is that the sensors and actuators do not have to be wired up to the PLC but have a communication system in between: this greatly reduces the installation work involved.

Every decentralized I/O system consists of a coupler and I/O connections or I/O modules. The coupler establishes the connection to the control unit (PLC), e.g. via a fieldbus. The individual sensors and actuators are connected to the I/O modules.



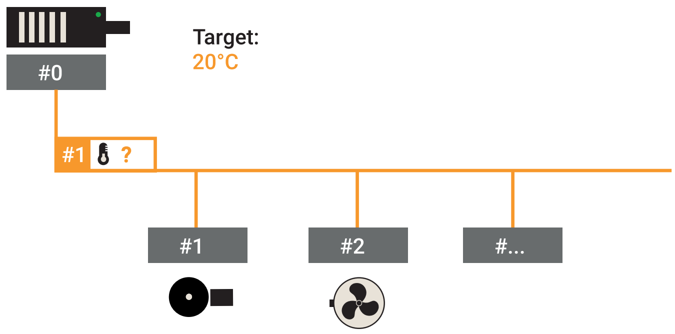
3. FIELDBUS SYSTEMS

3.1. FUNCTIONING OF A FIELDBUS

The majority of fieldbuses are based on the so-called master-slave method. Here the master takes on a role similar to that of the chairperson in a discussion, determining who is able to communicate and when.

The sensors and actuators are designated as slaves and have a unique address. The master itself is usually contained in the PLC. A temperature-controlled fan explains how it works:

The master first interrogates the sensor by requesting the sensor via message (1). The sensor then sends the current temperature value as a message (2) to the master, which is then processed in the controller. The master then sends another message (3) to the actuator containing the fan speed value. Since a fieldbus is operated cyclically like a PLC, the master then starts to query the sensor again.



3.2. ADVANTAGES AND DISADVANTAGES OF THE FIELDBUS AS COMPARED TO CONVENTIONAL WIRING

Advantages of the fieldbus

- Easy to install: less wiring and smaller, simpler switch cabinets
- Reduced error search in the event of failure
- One cable for digital/binary and analog signals
- Protection from faults with analog values
- Automated system is capable of self-diagnosis – e.g. when faults occur in the sensors/actuators
- Simpler expansion or simple addition of sensors/actuators

Disadvantages of the fieldbus

- Complexity requires qualified personnel for operation and maintenance
- More elaborate in terms of measuring technology
- Longer response times due to sequential accessing of slaves (depending on the fieldbus in question)
- Failure of the bus system causes failure of communication between all components

3.3. CLASSIFICATION OF FIELDBUSES BASED ON PROPERTIES

Fieldbuses can be subdivided into two groups based on properties such as component number or restrictions in terms of configuration options:

- Networking of complex devices at field and control level such as robot controllers
- Connection of simple actuators and sensors such as temperature sensors or limit switches

These “fieldbus types” are also often used in combination.

3.4. OVERVIEW OF THE INDIVIDUAL FIELDBUSES

The following table gives an overview of well known fieldbus systems. The following aspects are distinguished:

- Transmission medium: What type of cable (shielded/unshielded, no. of wires) has to be used? Sometimes it also possible to use fiber optic cables (FO).
- Connectors: Which type of connector can be used (depending on requirements with regard to degree of protection, EMC)? Which connection technologies can be used?
- Topology: What is the structure of the fieldbus or how are the individual components connected to one another?
- Maximum no. of components: How many components can the bus system address?
- Energy supply via the bus: Does the fieldbus allow the cable to be used for power supply and data transmission at the same time?
- System developer: Which company or which organization produced the fieldbus?
- Advantages and disadvantages: What are the strengths and weaknesses of the bus system in question?

3.5. TABLE WITH OVERVIEW OF THE INDIVIDUAL FIELDBUSES

	Profibus DP	Profibus PA	CAN (DeviceNet)
Transmission medium	Cable: 2-wire, shielded, twisted, Conductor cross-section: >0.34 mm², Characteristic impedance: 150 ohm Use of fiber optic cables (FO) possible (multi-mode, single-mode fiber-glass and plastic fiber), maximum extension 90 km	Cable: 2-wire, shielded, twisted pair Conductor cross-section: >0.8 mm² Characteristic impedance: 100 ohm Power supply optionally possible in cable	Cable: 2-wire or 4-wire (with power supply), shielded, twisted (copper strand, tin-plated) Conductor cross-section: 0.25 mm² to 0.75 mm² Characteristic impedance; 120 ohm, Overall shielding: Copper braiding, tin-plated, with drain wire
Connector	**Sub-D plug** (9-pin) for use in switch cabinet for IP 20, IP 30 Connection technology: Screw terminal, insulation displacement, cage clamp technology Active bus termination/ terminating resistor available **M 12 plug** (5-pin) for use outside the switch cabinet for IP 65/IP 67 Connection technology: Screw terminal, Improved EMC due to solid metal housing	**M 12 plug (5-pin)** for use outside the switch cabinet for IP 65/IP 67 7/8-inch connector for IP 67	**Sub-D plug** for use in switch cabinet No. of pins: 9-pin Connection types: Screw terminal, Fast Connect (insulation displacement), internal cage connector Maximum transmission rate is 12 Mbit/s Protection class: IP 20, IP 30 Improved EMC due to metallic housing **M 12 plug** for use outside the switch cabinet for IP 65/IP 67 No. of pins: 5-pin Connection types: Screw terminal Improved EMC due to solid metal housing

CC-Link	AS-Interface	IO-Link
Cable: 3 wire, shielded, twisted (5 wire, shielded, twisted incl. power supply) Structure: bare copper strand Overall shielding: tin-plated copper wires Characteristic impedance: 110 ohm Wire insulation: PE Outer sheath: PVC, PUR	Cable: 2 wire, ribbon cable, unshielded, untwisted, Cross-section: 1.5 mm^2 and 2.5 mm^2 Transmission of power and data using the same wires (yellow for data and energy, black for energy and red for 230 V energy) Outer sheath material: Rubber, PVC, halogen-free thermoplastic elastomer TPE, PUR Maximum cable length: 100 m, geometrically coded	Cable: 3-wire, unshielded Length max. 20 m High signal level of 24 V enables robust communication
Sub-D plug (9-pin) Connection technology: Terminal	No terminating resistors necessary Connection technology: Penetration technology, insulation displacement Protection class: IP 67	**M5, M8 and M 12 connector** with standardized configuration 2 classes/types of connector Type A: Pin 2 and 5 manufacturer-specific Type B: additional power supply via Pin 2 and Pin 5 Protection class: IP 65/67

	Profibus DP	Profibus PA	CAN (DeviceNet)
Topology	Line (copper, with active bus termination), line, star and ring with FO Maximum cable length: 100 m to 1200 m depending on data rate Data transmission rate at 100 m cable length (electrical transmission) is maximum 12.0 bit/s, at 1200 m max. 9.6 kbit/s Maximum 90 km extension in the case of an optical network (depending on the fiber optic system used!) Total no. components 126	Line, star,combination of the two Max. 1900 m extension Data transmission rate for Profibus PA is 31.25 kBit/s Components per bus segment max. 32, total 126 Converter between Profibus DP / PA	Line structure with passive bus termination, trunk/drop line topology Various cable lengths are defined depending on the cable type (thin, thick, flat), there is also a distinction between trunk line and drop line Energy supply of components via the bus: optional 24 V DeviceNet specifies the following data transmission rates for the trunk line: the maximum speed is 500 Mbit/s at 100 m cable length and 125 kbit/s at 500 m cable length DeviceNet is limited to 64 components
Max. components	126	126 (32 per segment)	127
Energy supply via the bus	No	Optional 9 – 32 V Power Supply optionally possible in cable	Optional 24 V

CC-Link	AS-Interface	IO-Link
Star, line and T-branch (T-branches with up to 6 stations per branch) Cable length without repeater max. 1200 m, with repeater up to 13.2 km, Transmission speed depends on network extension: 100 m → 10 Mbit/s 1200 m → 156 kbit/s A maximum total of 65 devices (1 master and 64 slaves) can be connected Bus components are distinguished by function into master station, local stations, decentralized station, decentralized E/A station and intelligent station.	Star, line and tree No terminating resistors necessary The sum total of all cable lengths in a segment may not exceed 100 m Transmission speed 167 KBit/s With a maximum of 2 repeaters it is possible to achieve a maximum extension of 500 m. No. of slaves: max. 62 AS-i bus system requires its own power supply in addition to the master and slaves.	Poin-to-Point (star) Transmission speeds: 4.8 kBit/s, 38.4 kBit/s and 230.4 kBit/s A master has a number of ports/connections, each of which allows connection of a sensor/actuator via point-to-point connection. Star topology
64	62	Depends on no. of master ports
Optional 24 V	30 volt	24 volt

	Profibus DP	Profibus PA	CAN (DeviceNet)
Distinctive features	High transmission speed as compared to other fieldbuses Suitable for more complex components, extensive configuration options such as variable data rate	Simple to combine with Profibus DP via converter. Designed for use with simple analog sensors and actuators, fixed/low transmission speed, Limited extension	Originally designed mainly for use in vehicles and mobile automation. DeviceNet offers a much lower data transmission rate than Profibus, for example Limitation in the no. of components Limited extension Messages can be read by several components at the same time
System-developer/ organization	Siemens / PNO / PI	Siemens / PNO / PI	Rockwell Automation / ODVA
Properties	Very widespread in Europe and China, limited network extension	Very widespread in Europe and China, low transmission speed	Widespread in USA, low tranmission speeds, limited no. of components.

CC-Link	AS-Interface	IO-Link
Very high network extension with repeaters, Limitations in the no. of components Similar to Profibus DP, high transmission speed	Quick connection technology Limited extension Limited no. of slaves/components Low transmission speed, Simple installation/ configuration	Currently being expanded with IO Link Wireless to create an easily combinable wired/wireless network Limited extension Limited no. of slaves/components Low transmission speed Simple installation/ configuration Consistent device identification
Mitsubishi	Siemens, AS-Interface	IO-Link Konsortium, PNO
Widespread in Japan, Limited no. of components, high transmission speed	Very inexpensive, simple to install, limited extension, limited no. of components, low transmission speed	Simple configuration since there is no bus to configure, identity of component is detected, low transmission speed

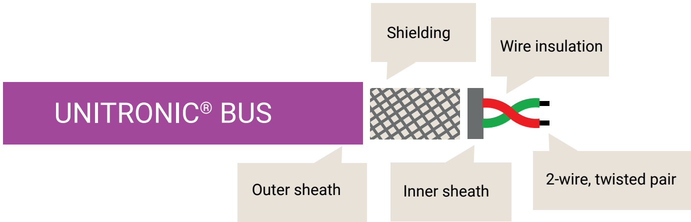
3.6. PROFIBUS

The name Profibus stands for PROcess FIeld BUS. This fieldbus is maintained and developed by the PROFIBUS User Organization (PNO) or by PROFIBUS&PROFINET International (PI). Development of the Profibus was started in 1987 and there is currently a family of several fieldbus variants. Since Siemens uses Profibus as the cen-tral bus for its controllers and these have a very large market share in Europe, this fieldbus is very widespread in Europe. Profibus is used in the manufacturing and process industry, especially in the area of traffic engineering and energy production/distribution.

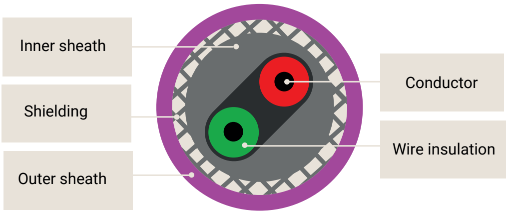
Two variants of Profibus have been developed for manufacturing and process automation: Profibus DP (Decentralized Periphery) and Profibus PA (Process Automation). The two variants differ in terms of cable, plug configuration and interface. Profibus PA can also be used in the EX area.

3.6.1. CABLE & CONNECTOR

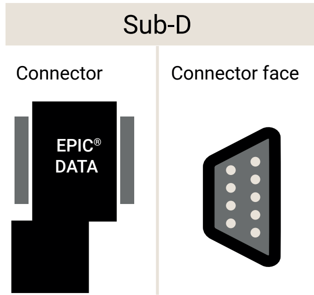
Cable

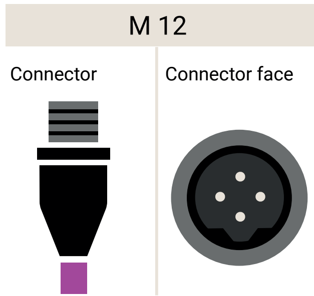


Cross section

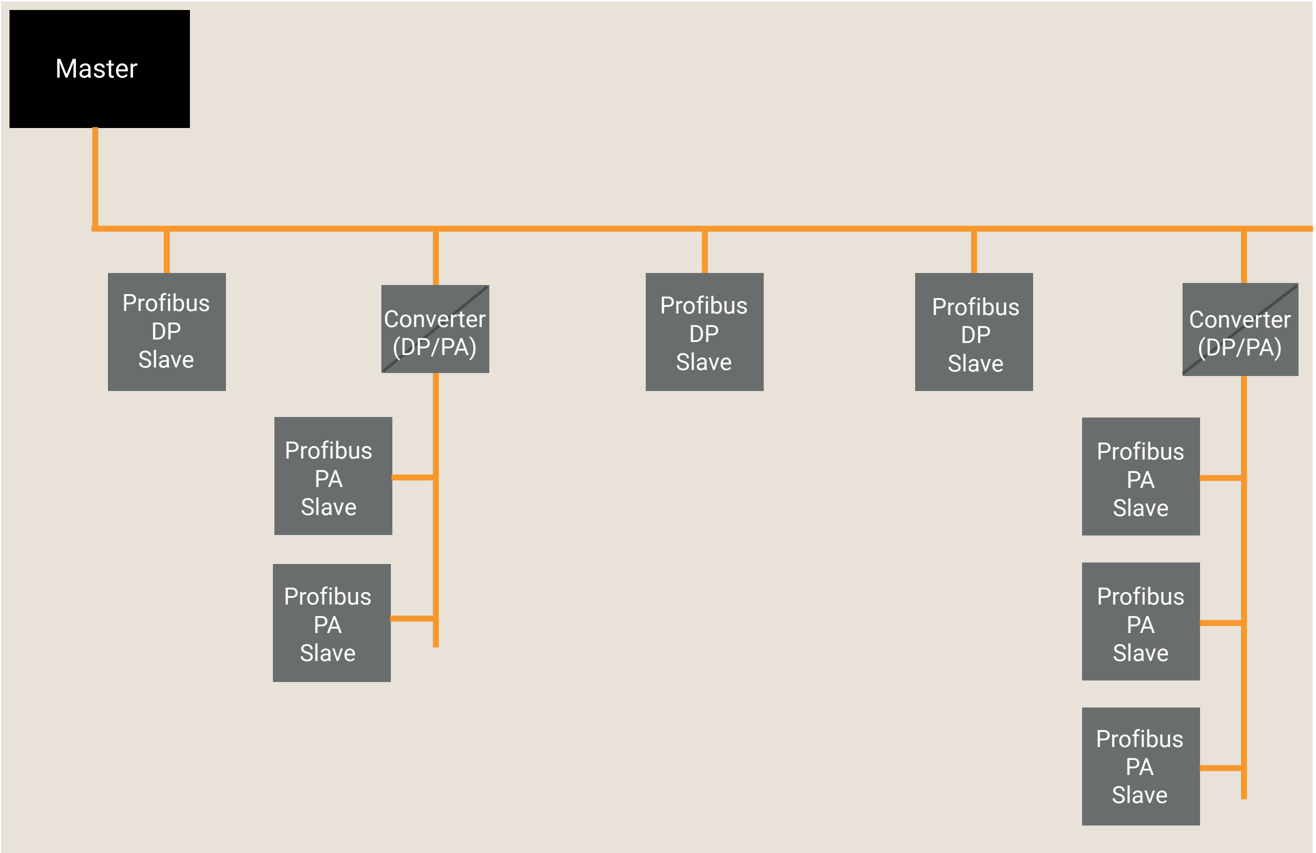


Connector





3.6.2. TOPOLOGY EXAMPLE



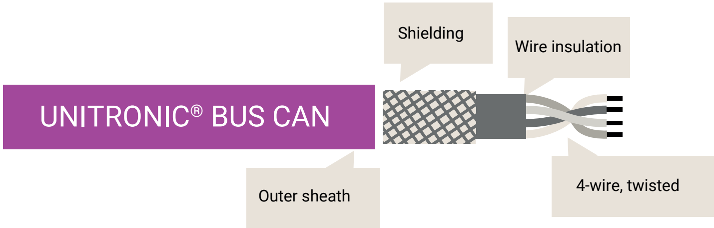
3.7. CAN-BUS

CAN stands for Controller Area Network. It was originally developed for use in the automotive area. CAN is defined in the ISO 11898 standard, which covers the network topology, the data link layer and also guidelines in terms of cables and connectors. CAN is used in manufacturing automation, for mobile machines and also in building controls systems. Various manufactures/organization have made additions to enable its use in industry.

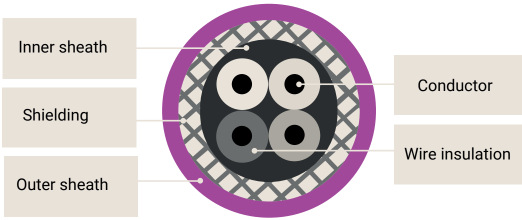
For example, Rockwell Automation DeviceNet developed DeviceNet, which applies the Common Industrial Protocol (CIP) to CAN. Since Rockwell is an American manufacturer, DeviceNet is mainly used in the USA. DeviceNet is also widespread in Asia, but not in Europe due to the existence of competing systems.

3.7.1. CABLE & CONNECTOR

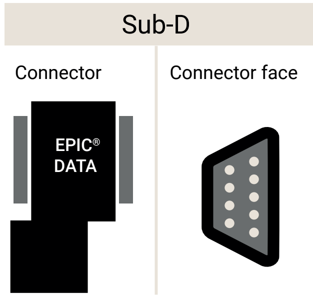
Cable



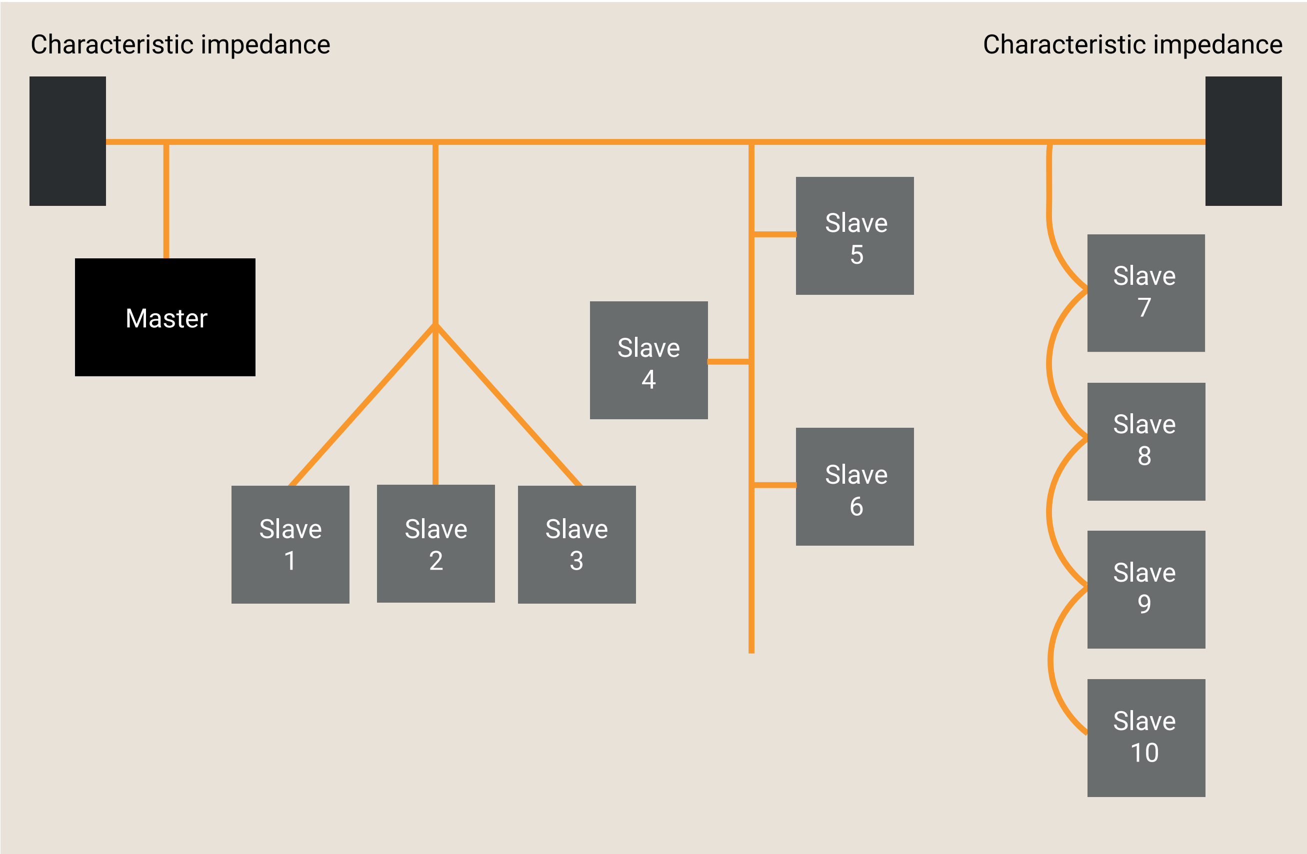
Cross section



Connector



3.7.2. TOPOLOGY EXAMPLE



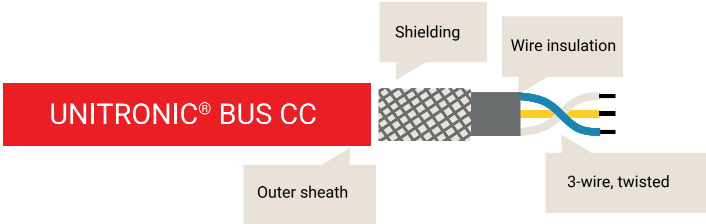
3.8. CC-LINK

CC-Link stands for Control and Communication Link. It was developed in 1996 by Mitsubishi as an internal company fieldbus so as to enable the manufacturer to network its own products in the area of plant automation. Areas of application lie in the control of individual machines, manufacturing islands, production installations and entire factories, warehouse and transportation systems as well as building automation.

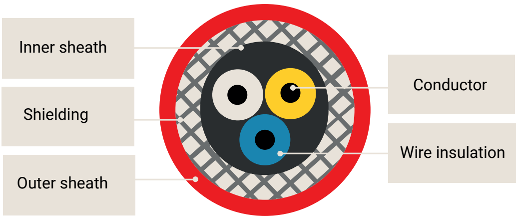
CC-Link is especially common in Asia. In addition to its country of origin, Japan, use of CC-Link is mainly growing in neighboring countries such as China and Korea.

3.8.1. CABLE & CONNECTOR

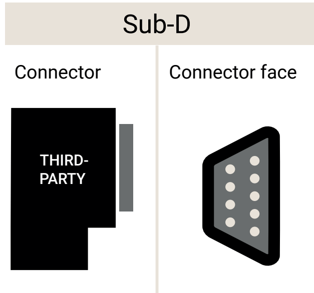
Cable



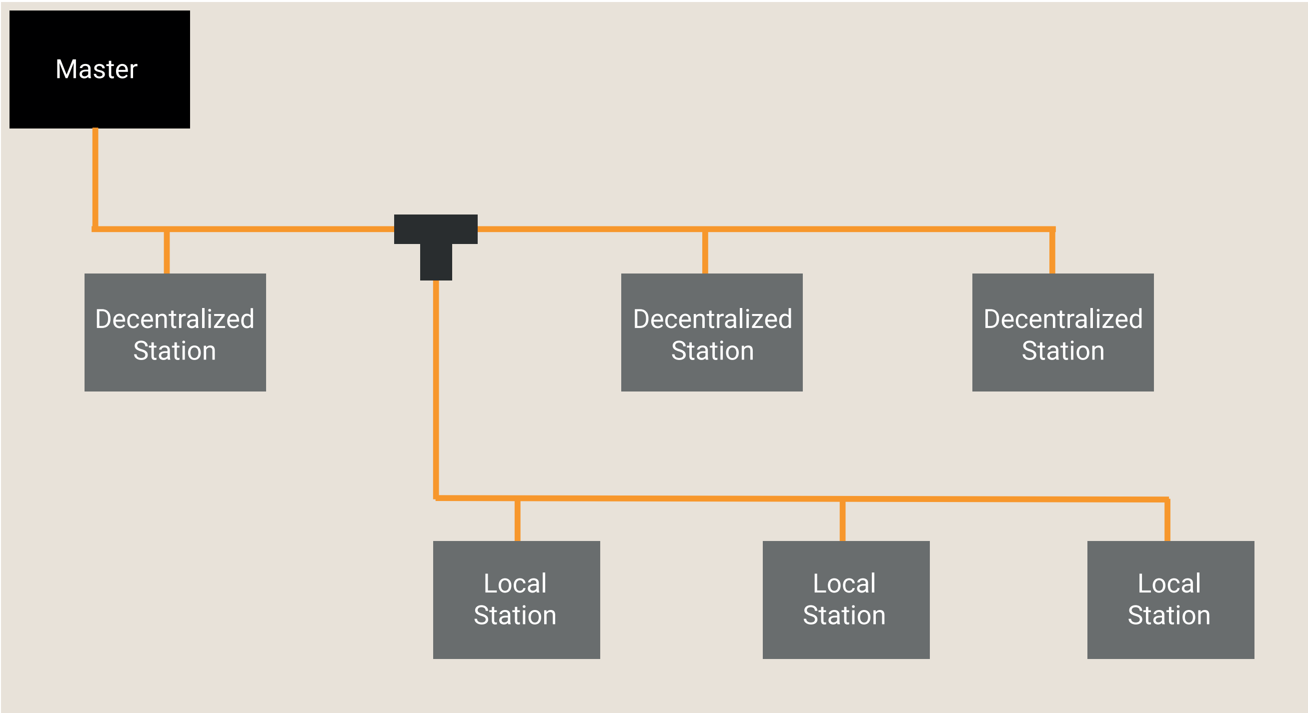
Cross section



Connector



3.8.2. TOPOLOGY EXAMPLE



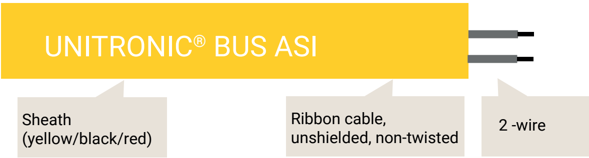
3.9. AS-INTERFACE

AS-i stands for actuator-sensor interface. It was initiated in 1990 by 11 German manufacturers including Balluff, Festo, Sick and Siemens. The aim was to develop a fieldbus that was as simple as possible to use with simple actuators and sensors requiring or supplying bit signals so as to be able to connect them to higher-level fieldbuses. AS-i is maintained by the AS-International Association.

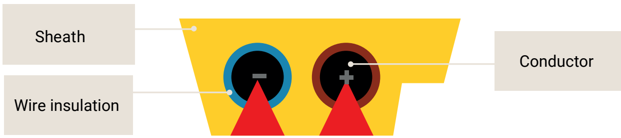
The AS-Interface is very inexpensive and ideal for purely binary I/O signals. It has a quick connection concept using piercing needles which penetrate the outer sheath and wire insulation: this means that stripping and skinning the cable is no longer necessary during installation.

3.9.1. CABLE & CONNECTOR

Cable

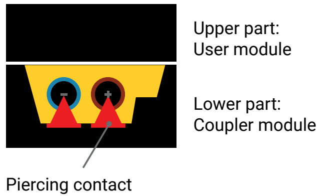


Cross section / Connection technology, piercing

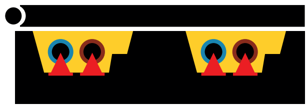


Connector

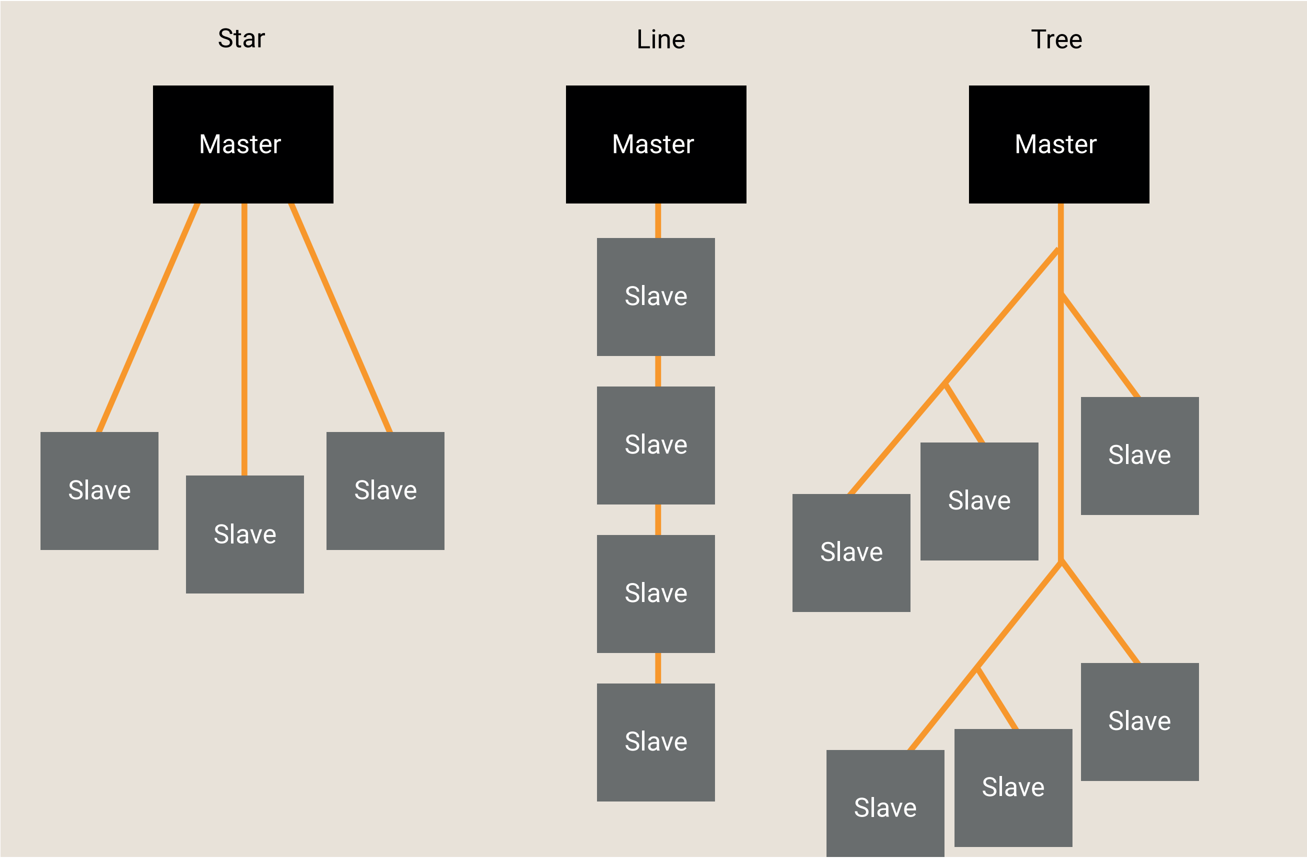
Connector face



Connector



3.9.2. TOPOLOGY EXAMPLE



3.10. IO-LINK

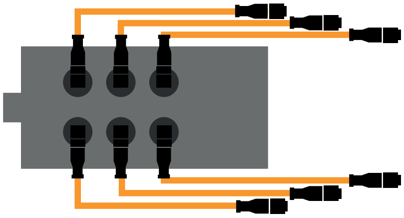
The brand name IO-Link refers to a communication system to connect sensors and actuators. Along with AS-Interface, it provides another option for the simple connection of sensors/actuators to a higher-level fieldbus. IO-Link is standardized under the designation Single-Drop Digital Communication Interface for small sensors and actuators (SDCI) and, unlike all other fieldbuses presented here, is not a bus system but a form of point-to-point communication.

IO-Link is developed by the IO-Link Consortium and is integrated in the Profibus User Organization. IO-Link is becoming increasingly widespread in Europe.

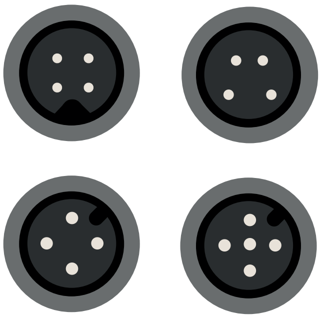
3.10.1. CABLE & CONNECTOR

Cable

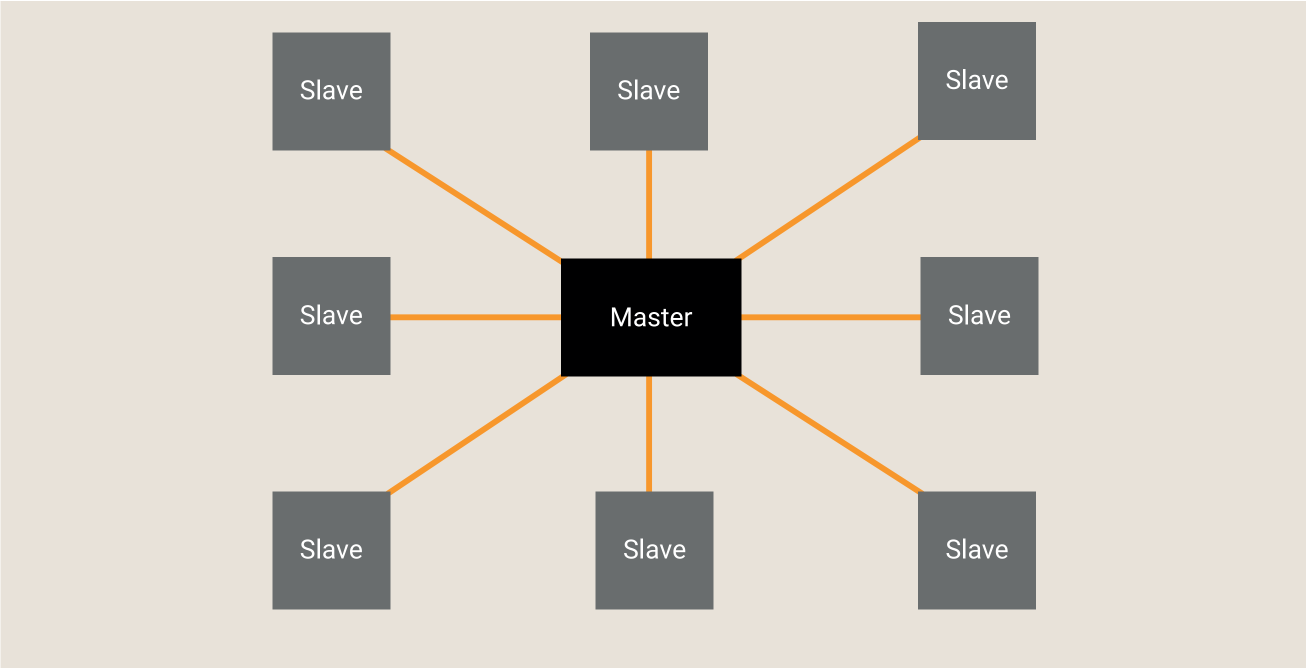
Connector



Connector face



3.10.2. TOPOLOGY EXAMPLE



4. ETHERNET IN INDUSTRIAL USE

4.1.1. FUNCTION OF ETHERNET

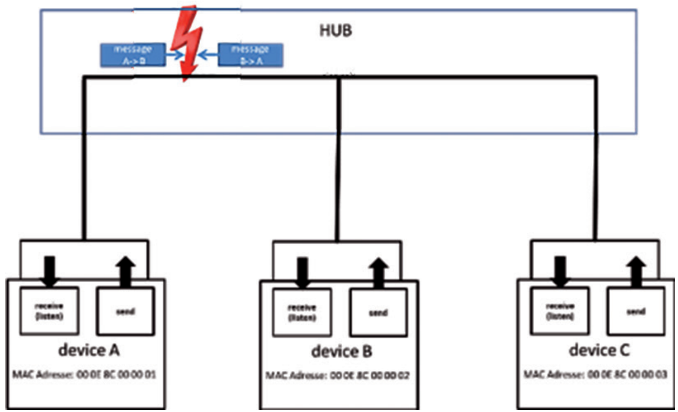
Comparison of Ethernet and fieldbuses

The following properties are unique to Ethernet versus fieldbuses:

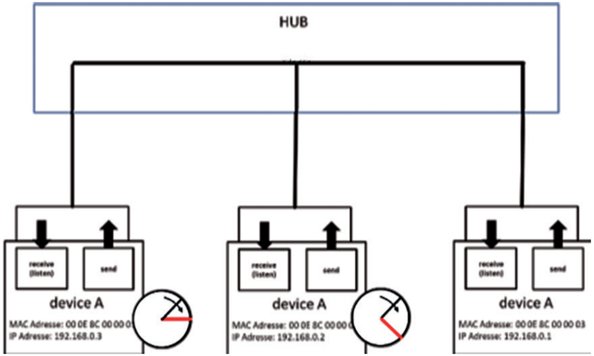
- Point-to-point connections only, so no terminal resistance necessary
- Very large address space for components (approx. 281 billion individual MAC addresses)
- Very large distances possible in networks since each component (such as switches and routers) refreshes the signal
- High transmission speeds allow fast transmission of large data volumes (e.g. 10 Gbit/s as compared to 12 Mbit/s)

Operating principle

Unlike the master-slave method used in fielbuses, all Ethernet components are equal. This is why collisions can occur in the network when messages are exchanged. A “listening mechanism” in each device detects whether another device is sending a message and waits accordingly. If two devices happen to transmit simultaneously, however, the transmitting components detect the collision and stop the transmission process. After a random waiting period spent “listening” to see if the line is free, each component tries to send its message again. According to the IEEE standard, Ethernet communication is random and therefore not deterministic. This has an impact on its use in industry.



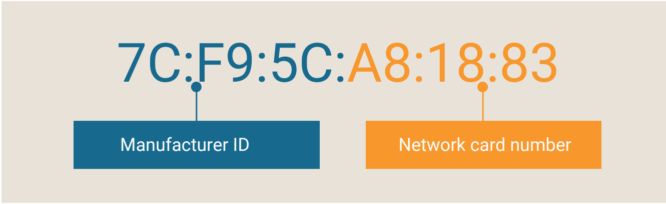
Collision of messages with standard Ethernet



Different, random waiting time avoids further collision

What is a MAC address

Every network card or network connection of a device has a unique MAC address which cannot be altered by the user. MAC stands for Media Access Control. A MAC address consists of a manufacturer ID and a number for the network card itself. If the MAC address is “7C F9 5C A8 18 83”, for example, “7C F9 5C” is the code for the Lapp U.I. and “A8 18 83” is the code for the specific device. The MAC addresses of the transmitter and recipient are included in every Ethernet message so that the recipient can recognize whether the message is meant for it as well as who sent it or whom it should reply to.

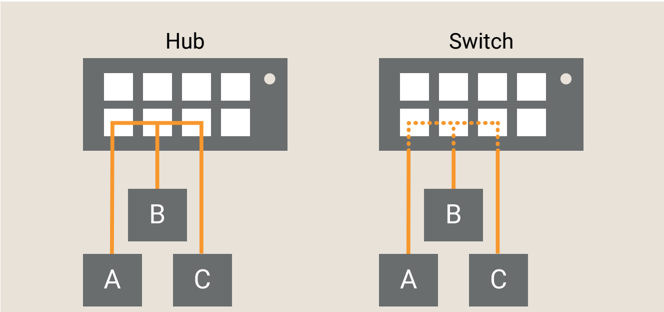


Network components

In local Ethernet networks, hubs and switches are used to connect the components to one another (our products of the Ethernet Access line). Each of these network components has a different number of so-called ports to which the components are connected. The figure below on the left shows a network with a hub. The latter does not have its own “intelligence” and distributes all the messages received at one port to all the other ports.

By contrast, a switch remembers the MAC address of the component connected to it and can recognize from the Ethernet message which port the recipient is connected to. It then sends the message exclusively to the recipient’s port. So if there are a large number of other components connected to a switch, numerous connections can be activated at the same time. This means that in contrast to a hub, collisions can be avoided.

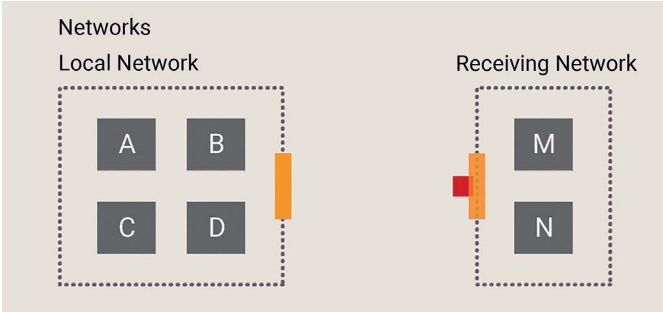
Managed switches possess additional intelligence that allows settings to be made. For example, individual ports can be deactivated or only certain ports can be interconnected (so-called VLANs).



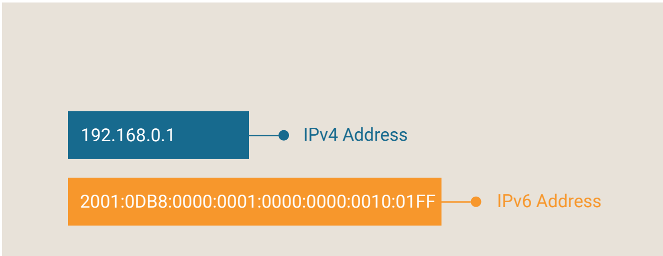
The Internet Protocol (IP) and the router as an associated component

The MAC address is sufficient for communication in a local network. A MAC address provides an unambiguous description of the component, but not the network in which it is located. This function is performed by the IP address, which enables attribution of the component to the local network. If the recipient of the message is not part of the local network, the sender sends the message out of the local network using the IP address. Exit from the local network is enabled by a device called a router.

A router receives the messages that are to leave the local network and reads the recipient's address so as to forward the message to the recipient's network.



There are currently two standardized versions of the Internet Protocol: IPv4 and its successor IPv6. Each version of the protocol has its own format for the address (see also figure).



An IPv4 address appears as four decimal numbers (0-255) with a period between the numbers and can contain a maximum of 232 addresses (4.3 billion). An IPv6 address is subdivided into eight blocks separated by a colon, each containing a number between 0 and 65535. This appears in hexadecimal format (0-15 equals 0-9,A-F) and can contain a maximum of 2128 addresses (340 sextillion = 3.4 x 1038). The reason behind the creation of a successor for the address format was the rapid increase in demand for addresses. The last IPv4 addresses in the world were assigned in 2012. 50 billion devices are expected to be connected directly to the internet by 2020.

4.1.2. COPPER AS A TRANSMISSION MEDIUM

The dominant Ethernet transmission medium is copper. It has two key benefits as compared to fiber optics: it is much simpler to pro-cess and it is capable of supplying power to the connected devices at the same time. The ISO/IEC 11801-1 standard specifies compo-nent requirements (cables and connectors), grouping these togeth-er as a category (the so-called Cat. rating). These currently range from Cat. 5 to Cat. 8.2. For example: The 40GBASE-T Standard can only be met by cables and connectors of category CAT 8.1 (see ta-ble).

One key difference between the various categories is the frequency that can be used for data transmission and the transmission speed that this enables.

				Kategorie				
Standard	Data Rate	Wire Pairs	Distance	5	6	6_A	7	8,1
100BASE-TX	100 Mbit/s	2	100 m	X	X	X	X	X
100BASE-T	1,000 Mbit/s	4	100 m	X	X	X	X	X
10GBASE-T	10Gbit/s	4	55 m		X	X	X	X
10GBASE-T	10Gbit/s	4	100 m			X	X	X
40GBASE-T	40Gbit/s	4	30 m					X

Each component of a patch cable (i.e. a cable with connectors) is rated according to categories. The overall category of a patch cable is the lowest category of the three components (principle: “the weakest one wins”).

The copper cable

Ethernet cables are operated at higher frequencies than fieldbuses (up to 2 GHz) and require higher-quality shielding as well more installation expertise (e.g. lay length). In order to prevent the wires from influencing each other, plastic cross separators are used in highly flexible applications, for example.

These ensure permanent spacing between the wires. In contrast to the considerable variance in the case of fieldbuses, the characteristic impedance of a copper-based Ethernet cable is always 100 Ohm and typically +/- 15% tolerance.

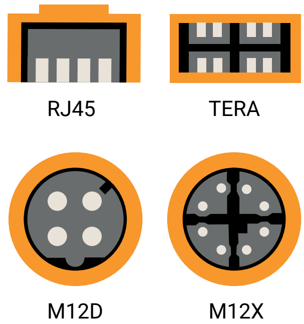
ETHERLINE® Cat.7 FLEX

The connector

In terms of connectors, the RJ45 connector has become established as the standard. Due to its design, however, this is not suitable for Categories 7, 7A and 8.2 (the contacts are positioned very close to each other, which can cause mutual interference). The limit values for Category 8.1 were deliberately defined so that the RJ45 is able to meet them.

Other connectors – so-called chamber plugs – cluster the individual wire pairs so as minimize interference, enabling them to meet the more rigorous limit values of Categories 7, 7A and even 8.2. Typical representatives of these are TERA and GG45 connectors, though the latter have not yet achieved a very high level of market penetration due to their high cost and the lack of compatible end devices.

All connectors mentioned above have the protection code IP20. In order to be able to use Ethernet in this context, the M12 connector familiar from the fieldbus module has been adapted. Typically, D and X coding are used for four and eight wires.



Power over Ethernet (PoE)

If a component is supplied with power in addition to data transmission, this is referred to as PoE (Power over Ethernet). PoE can essentially be realized in two different ways: the power is transmitted on unused wire pairs or else on wire pairs in addition to those already being used for data transmission. The table shows the development of PoE. This shows that as the specification has advanced, the potential output transmitted has increased considerably (15.4 watts → 25.5 watts → 51 watts). 4PPoE means that all wire pairs are used to supply power.

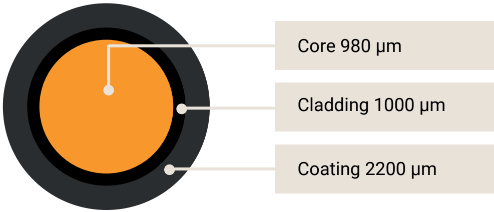
In order to keep power loss to a minimum, the cross-sections of the wires have to be as large as possible. In addition, the connector contacts must have a special design for the purpose of electric arc protection, which can occur when the cable is unplugged when live. Otherwise there is a risk of the electric arc damaging the contacts to such an extent that data transmission is no longer fault-free.

Power over Ethernet	Standard	Release	Output	Amperage per wire pair
PoE	IEEE 802.3af	2003	15,4 W	350 mA
PoE+	IEEE 802.3at	2009	25,5 W	600 mA
4PPoE (bzw. „PPoE++“)$_A$	IEEE 802.3bt	2018	Probably 51 W (possibly 71 W)	Probably 600 mA (possibly 960 mA)

4.1.3. FIBER OPTICS AS A TRANSMISSION MEDIUM

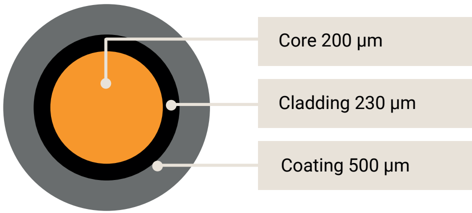
Polymer Optical Fiber (POF)

POF stands for Polymer Optical Fiber. The fiber is relatively simple to process. It has high attenuation, however, and therefore a low data rate and range.



Polymer Cladded Fiber (PCF)

PCF stands for Polymer Cladded Fiber, also known as HCS ("hard-clad silica optical fiber"). Processing is less straightforward than in the case of POF but still possible by hand. PCF has medium attenuation and therefore a better data rate and range than POF.



Glas Optical Fiber (GOF)

GOF stands for Glass Optical Fiber. The term "glass fiber" generally refers to this type of fiber. GOF cannot be processed by hand – a special splicing robot is required. GOF has very low attenuation and therefore a high data rate and range.

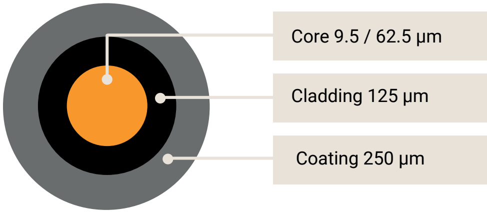
Single-mode fiber optics:

Here the light of one wavelength is transmitted. Due to the low attenuation, this type of fiber optics is suitable for long distances. The fiber core has a diameter of 9µm in this case, while the diameter of the jacket is 125µm (notation: 9/125).

Multi-mode fiber optics:

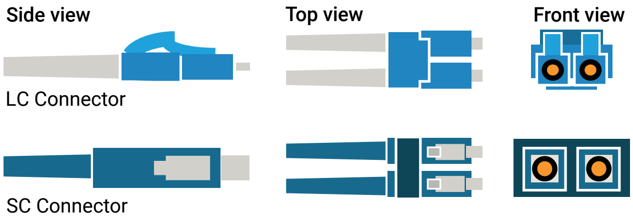
Here the light is transmitted on different wavelengths. Due to the higher attenuation, this type of fiber optics is more suitable for shorter distances and local networks. The fiber core in this case has a diameter of 50µm (or 62,5µm respectively) and the jacket has a diameter of 125µm (notation: 50/125 or 62,5/125 respectively).

As is the case with copper cables, there are also defined categories for fiber optics (defined in ISO/IEC 11801-1). Here the properties of GOF are subdivided into the classes OM1 to OM5 for multi-mode, while OS1 and OS2 apply to single-mode. As with copper-based cables, a higher number means more rigorous requirements, which in turn indicates that higher data rates and distances are possible.

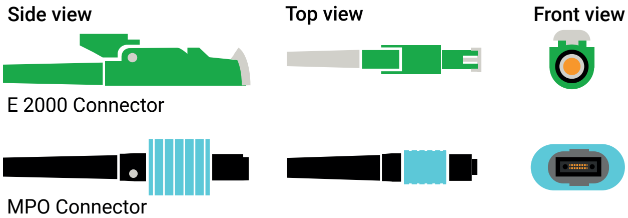


Connectors

Fiber optic lines use one conductor per transmission direction (simplex). For this reason, two lines are combined to form a pair so as to be able to transmit and receive data (one line for each direction results in duplex). As such, the connectors normally have a facility for combining two individual connectors to form a pair. The most common connector is the LC connector (Lampert connector). Due to its small size, this has replaced the SC connector (Subscriber connector).



The E2000 connector has a release tab and also a protective cap which automatically opens when the connector is plugged in. It can be used for both single-mode and multi-mode. The MPO connector (multiple-fiber push-on) clusters up to 32 fibers and is mainly used as a substitute for duplex patch cables as well as for applications where fiber optics lines are grouped together.



4.1.4. AIR AS A TRANSMISSION MEDIUM

Data does not have to be transmitted via cables (such as copper cables or fiber optic cables): it can also be transmitted through the air, for example by means of Bluetooth, LTE and WLAN.

Limitations to transmission via the air

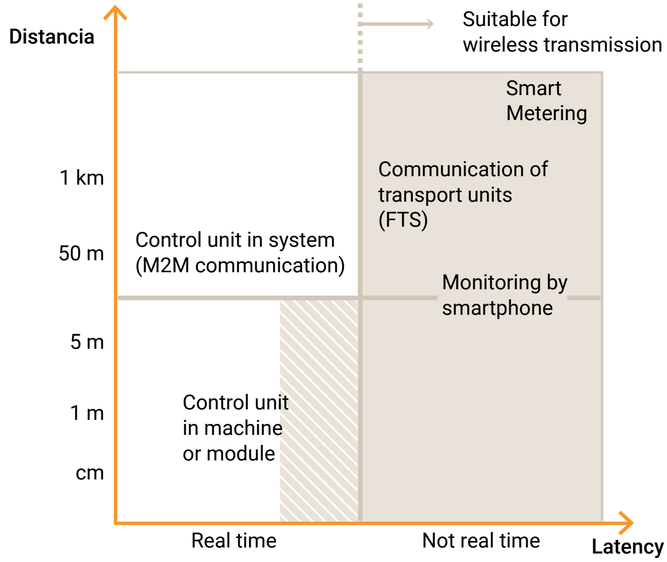
Air is generally accepted as a shared medium. This means that in a similar way to the hub mentioned at the beginning of this module, simultaneous collision-free wireless transmission by several parties is not possible. An increase in the number of users is bound to lead to a reduction in the transmission capacity available to each user. In order to avoid influencing other types of wireless transmission (such as military or police radio), specific radio frequencies have been defined for civilian use. The frequency ranges of 2.4 GHz and 5 GHz are used for wireless LAN worldwide. Restrictions are applied to these frequency ranges in the various groups of countries (USA, Japan and Europe). Transmission is via so-called channels. The more recent standards allow several channels to be bundled so as to achieve higher data rates.

Differences between cable-based and wireless-based communication

Wireless-based communication offers benefits where flexibility and mobility are important, for instance in mobile applications (Figure: “Monitoring by Smartphone” or “FTS”) or when sensors are used in large-area installations as is common in the chemical industry (Figure: “Smart Metering”).

Even in the future, however, wireless data transmission will not entirely replace cables. Whenever long distances, reliable data transmission, energy efficiency and real-time capability are required, wireless technologies cannot compare with cable-based technologies (Figure: “Control unit in machine or module” or “M2M communication”). Cables are also generally less prone to deliberate interference – and this won’t be any different with new wireless standards such as 5G.

In short: wireless data transmission does not pose a threat to cable-based systems but complements the latter where special requirements apply.



Ethernet Wireless Standards

The IEEE Working Group 802 that is responsible for the Ethernet standard also approved the wireless LAN standard (IEEE 802.11) at almost the same time as the 100BASE-T standard (part of IEEE 802.3).

A number of new wireless LAN standards have since come into being as a result of technological advancements. The table shows a selection of the most important standards.

Standard	Frequenzy channel	Channel Bundling	Maximal Range	Maximal Transmission Speed
802.11a	5 Ghz	1 channel (20 Mhz)	120 m (outdoors)	54 Mbit/s
802.11g	2.4 Ghz	1 channel (20 Mhz)	140 m (outdoors)	54 Mbit/s
802.11n	2.4 Ghz/5 Ghz	2 channels (40 Mhz)	250 m (outdoors)	600 Mbit/s
802.11ac	5 Ghz	8 channels (160 Mhz)	35 m (in a building)	3,466 Mbit/s
802.11ad	60 Ghz	„108 channels“ (2160 Mhz)	3,3 m (in a building)	6,757 Mbit/s

4.2. INTRODUCTION TO INDUSTRIAL ETHERNET

Distinction between Industrial Ethernet and standard / office Ethernet

In contrast to use in the office environment, the following requirements apply to Industrial Ethernet:

- **Environment requirement:**
  The network components (cable, plug, switches) must have a higher protection class so as to be resilient to dust, splash water, lubricants and acid. Increased electromagnetic interference resistance and an extended temperature range are also key aspects. Vibrations caused by machines have to be taken into account, too. This requires the use of suitable cables (e.g. sheath resilience) and robust plugs.

- **Network requirements:**
  While star topology has mainly become established in the office environment, line topology (daisy-chaining of devices) tends to be used in industry. In order to ensure a high level of fail safety, the network components have to be very reliable and precautions also have to be taken in the network itself (ring closures, redundancy concepts). Since the network has to be deterministic and as fail-safe as possible, "controlled" communication is required in the network. Most Industrial Ethernet systems were developed based on FAST Ethernet (100 Mbit/s) with full duplex connectivity. Full duplex is the capability of a component to receive and send messages at the same time.

Categories of Industrial Ethernet technologies

The various Industrial Ethernet systems can be subdivided into categories based on their technology type. The criterion here is the way in which they achieve real-time capability and determinism in Ethernet communication:

1. **Standard IP communication**
   In this case, IP-based communication takes place as in regular office communication. Components are addressed using their IP address. This makes communication beyond network limits very simple, as well as integration in company networks. The drawback is that it is not possible to achieve the classic real-time properties familiar from the fieldbus area. Here, average latencies of 100ms are possible. Typical representatives are EtherNet/IP and Modbus-TCP.

2. **Standard Ethernet communication**
   In this category, communication takes place directly using standard Ethernet messages. Components are addressed by means of their MAC address. Simplified communication (no IP information), means that the time response is improved, with average latency at around 10 ms. Since no changes have to be made to the network hardware, IP communication and pure Ethernet communication can take place at the same time. Typical representatives include Profinet RT or Powerlink.

3. **Proprietary Ethernet communication**
   This category does use parts of the Ethernet standard but with the addition of manufacturer-specific software and hardware extensions so as to achieve a deterministic response. For example, an Ethernet message contains special information that can be processed by a proprietary hardware/network component (e.g. a slave component). The speed which can be achieved in this way is less than 1ms and the response is deterministic. Representatives include CC-Link IE, EtherCAT and Profinet IRT.

4.3. OVERVIEW OF INDUSTRIAL ETHERNET SOLUTIONS

	Ethernet/IP	CC-Link IE	EtherCAT
Connector	The connectors to be used are RJ45 connectors (either in the regular version (IP20) or an encapsulated version (IP67) as well as M12 D-coded connectors (IP67). In the case of fiber optics, ST, SC and LC connectors are used.	shielded RJ45 connectors.	In terms of connectors, RJ45, M8 D-coded and M12 D-coded connectors are recommended, though others are possible.
Transmission-medium	fiber optic and copper-based Ethernet Ethernet Standard with at least 100 Mbit/s recommended	1 Gbit/s, copper-based	Ethernet Standard with at least 100 Mbit/s

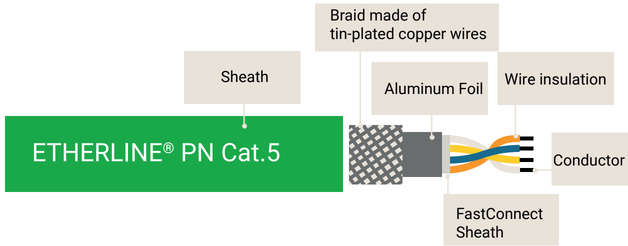
ProfiNET IO
specifies various connectors for data transmission. distinguishing feature is the protection class, i.e. the distinction between “inside” and “outside”. RJ45 (copper, IP20) and LC connectors (optical, IP20) as well as M12 D-coded and X-coded connectors (copper, IP67).
based on the Ethernet standard and uses either two or four wire pairs. Precise requirements in terms of the cables to be used, braided shield and pair foil shield, specific external diameters and two relatively large wire cross-sections (typically AWG22 with two pairs and AWG23 with four pairs). Three application types: 1. Permanently installed, no movement, green outer sheath 2. Flexible (typical patch cable), occasional movement/vibration, green outer sheath 3. This includes special applications such as cables for highly flexible use (FD or torsion) as well as cables for permanent installation with a black outer jacket

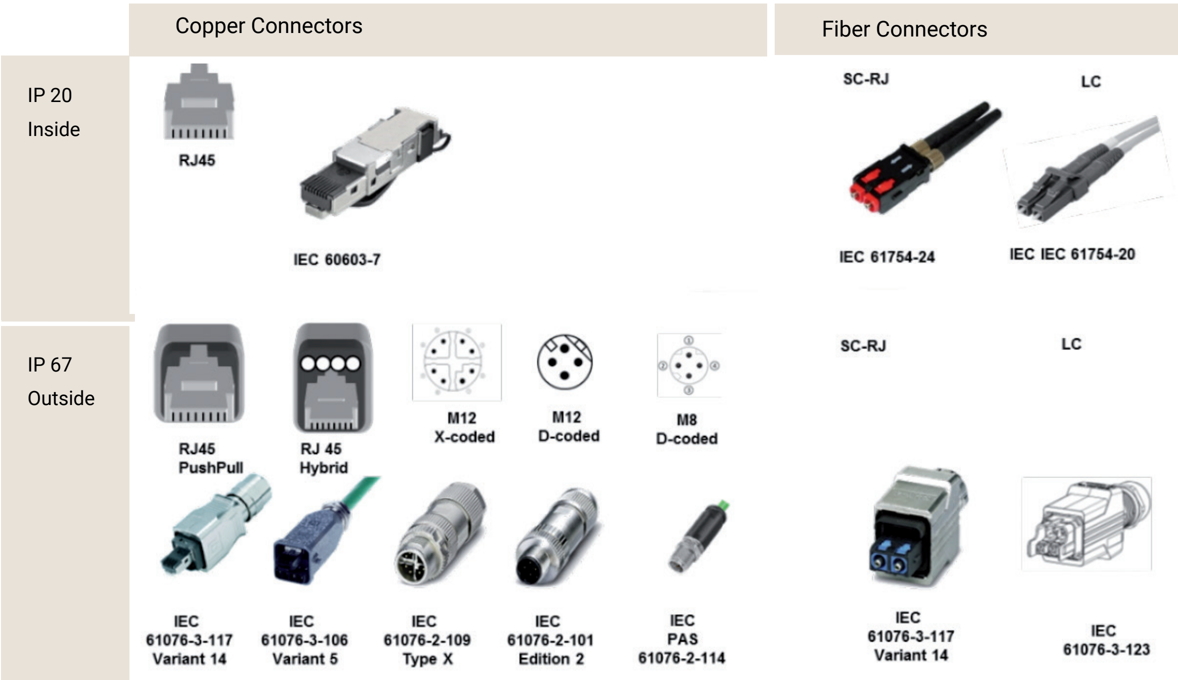
	Ethernet/IP	CC-Link IE	EtherCAT
Topology	star and tree topologies are possible.	Line, ring and star topologies as well as a combination of line (bus) and star.	Star, tree, ring and line (drop line) topologies are possible, as well as combinations of these.
Distinctive features	uses the Common Industrial Protocol (CIP).	Standard Ethernet network components (switches), devices with proprietary hardware. Communication is based on the master/slave principle.using the token-passing method). Only the component holding the token at any given time may send information.	master/slave principle. master is a software solution only based on standard Ethernet hardware, proprietary hardware is used in the slave. use of full duplex capability of Ethernet in that the master sends an Ethernet message which is then read, altered or extended and then forwarded by the components. The last component sends the Ethernet message back to the master. Use of the EtherCAT infrastructure for standard Ethernet.
Systemdeveloper/ organization	Rockwell / ODVA	Mitsubishi Electric, CLPA	Beckhoff, ETG
Category	1	3	3

ProfiNET IO
Star (switch) and line (field devices with integrated 2-port switch) can be combined to tree topologies. Uses the MAC address combined with an assigned IP address and a symbolic name. Redundancy mechanisms which can be used in conjunction with a ring structure.
Available in a Real Time (RT) version and a deterministic Isochronous Real Time (IRT) version. RT version uses standard Ethernet with the prioritization options. Communication is between two components. IRT enables a deterministic procedure allow communication between the PLC and components which is synchronized precisely to the nearest 1µs. This method allows the combination of hard real-time or deterministic communication and standard IP communication. special switches required.
Siemens, PNO
2 und 3

4.3.1. PROFINET IO

Cable &Connector





4.4. TSN

TSN stands for Time Sensitive Networks and has the goal of connecting all layers of the pyramid from the field level to the ERP / MES level with a uniform communication technology. Various real-time extensions within the Ethernet standard allow TSN to largely replace existing proprietary Industrial Ethernet solutions. The following mechanisms are used:

- Each participant in a TSN-based communication network has its own clock, with all clocks needing to be synchronized with each other
- Priorities can be defined to influence different bandwidth and timing requirements
- The way in which 2 participants can communicate with each other can be determined

The term OPC UA over TSN has brought together manufacturers of proprietary industrial Ethernet solutions such as Siemens, Rockwell Automation, Mitsubishi Electric or Schneider Electric to develop products based on the TSN standard.

Source: WEKA FACHMEDIEN

5. Glossary

Actuator
Motoric and energetic component e.g. motor or heater with a variable as input.

Analog signal
Has any signal level within a voltage range

ARPANET
Advanced Research Projects Agency Network. Developed for the US Air Force at the end of the 1960s. The precursor of what is now the internet.

AS-I
Actuator-Sensor Interface

Automation pyramid
Logical structuring of a manufacturing company in terms of networking and information flow

Bus termination
Bus terminations are required at the ends of the line in the case of some fieldbuses. These can be either passive or active bus terminations

CAN
Controller Area Network

CC-Link
Control and Communication Link

Characteristic impedance
The characteristic impedance, synonymous with wave impedance, is a property of a cable which is important in terms of the transport of information and is dependent on the latter's speed.

CIP
Common Industrial Protocol

CNC
Computerized Numerical Control

Communication network
Connects automation components among each other for the purpose of exchanging information

Control computer
Computer which controls a process

Control level
Level of a production facility at which all control computers are to be found

Controller
Controller consists of an open control chain without feedback

DCS
Distributed Control System

Decentralized I/O station
This station only exchanges individual bit data with the master. Suitable for connecting simple switches/a light barrier etc.

Decentralized station
This station can exchange various data with the master station. Suitable as a bus component for measurement recording or interlinking of actuators (valves).

Deterministic
A communication system is deterministic if the duration and timing sequence of information transmission can be precisely predicted.

Digital signal
Has the two signal levels 0 and 1

DIN 61508
International standard for the development of electrical, electronic and programmable electronic systems which perform a safety function.

DIN 66025
Standard for CNC control programs

DIN EN 61512
Standard for batch-oriented process control

Electrical signal
An electrical signal must be variable in terms of amperage, voltage or resistance in order for it to be able to transport information. In automation, a digital electrical signal is used where, for example, 0 V means “off” and 24 V means “on”. If the electrical signal indicates an “on”/”off” sequence over time, it can be used to convey any machine-readable protocol.
An analog electrical signal, which in automation can have any value between 0 V and 24 V, contains sufficient information to set the speed of a motor, for example.

ERP
Enterprise Resource Planning

Fiber optics
Fiber optics (FO) allows the transmission of light of differing wavelengths; the cables are made of glass fiber or synthetic fiber. A distinction is drawn between mono/single-mode and multi-mode FO. Single-mode FO only transmits light of one wavelength, while multi-mode FO is able to transmit light of different wavelengths. FO enables much higher bandwidths than copper and is also less sensitive to EMC interference.

Field level
Level of a production facility at which all sensors and actuators are to be found.

Fieldbus
A fieldbus is defined as a bus system that connects sensors and actuators to a controller/PLC for the purpose of information exchange.

Function
A processing specification which creates output values from input values.

GOF
GOF stands for Glass Optical Fiber. The term “glass fiber” generally refers to this type of fiber. GOF cannot be processed by hand – a special splicing robot is required. GOF has very low attenuation and therefore a high data rate and range.

IEC 61131
Standard for the basic principles of programmable logic controllers; IEC 61131-3 describes programming models.

IEC 61158
Standard containing the technological description of 18 different fieldbuses.

Input-output-model
Describes the connection between input, function (information processing) and the output created from this.

Input signal
Input of a control system

Intelligent station
This station exchanges data with the master station. To a certain extent it can process values (e.g. convert analog measurement values into digital values) and forward them to its own local interfaces (e.g. serial connection).

IP

The abbreviation of Internet Protocol. The address defined in this protocol is frequently used to address devices. The most common forms are Version 4 (example: 192.168.0.1) and more recently Version 6 (example: 2001:0DB8:0000:0001:0000:0000:0010:01FF).

IP protection class

Ingress Protection Classifies the level of protection from ingress of solid particles and water

Latency period

Period of delay between the transmission of a piece of information and the point at which it becomes available for use by the receiver.

LC

Abbreviation for Lampert Connector. The dimensions of the connector are specified similar to the RJ45 to allow the smallest possible design.

Link control

Logical linking of input signals (e.g. and/or link)

Listening mechanism

Since Ethernet involves all components of a network communicating on an equal footing with one another without a coordinating, overriding component, mechanisms are require which prevent the exchange of messages from being interrupted unnecessarily. A component‘s listening mechanism prevents it from sending a message when another component is already doing so, which would otherwise cause interference.

Local station

This station can send messages to the master and other components. One such local station can be a PLC.

MAC

The abbreviation of Media Access Control

Master station

The master station manages and controls the entire CC-Link network.

MES

Manufacturing Execution System

Multi-mode fiber optics
Here the light is transmitted on different wavelengths, so higher speeds can be achieved as compared to single-mode. Due to the higher attenuation, this type of fiber optics is more suitable for shorter distances and local networks. The fiber core in this case has a diameter of 50µm and the jacket has a diameter of 125µm (notation: 50/125)

NC
Numerical Control

Network topology
A network topology is a graphical representation of how the devices are networked with one another.

Off-delay
Function with an adjustable duration that delays the deactivation of a signal

Output signal
Output of a control system

PAA
Process image of the PLC outputs

PAC
Programmable Automation Controller

PAE
Process image of the PLC inputs

PCF
PCF stands for Polymer Cladded Fiber, also known as HCS ("hard-clad silica optical fiber"). Processing is less straightforward than in the case of POF but still possible by hand. PCF has medium attenuation and therefore a better data rate and range than POF.

PCS
Process Control System

PE
Polyethylene

Physical quantity
An example of a physical quantity is temperature in Celsius.

PLC
Programmable Logic Controller

POF
POF stands for Polymer Optical Fiber. The fiber is relatively simple to process. It has high attenuation, however, and therefore a low data rate and range.

PP
Polypropylene

Process automation
Automation of process-related operations and chemical reactions

Production automation
Automation of production of unit goods where production requires numerous manufacturing and assembly processes.

Profibus DP
PROcess Field BUS Decentralized Periphery

Profibus PA
PROcess Field BUS Process Automation

Profinet RT und Profinet IR
PROFINET RT (Real Time) and PROFINET IRT (Isochronous Real Time) are two different technical versions of PROFINET IO which meet differing requirements in terms of the communication between components. While PROFINET RT is prioritized for standard Ethernet messages but does not define exact time slots for transmission, PROFINET IRT enables synchronized data transmission based on fixed cycle times, thereby meeting hard real-time requirements.

PTFE
Polytetrafluorethylene, trade name: Teflon

PUR
Polyurethane

PVC
Polyvinyl chloride

Real-time capability
Real-time capability is an application-specific requirement as to how long the transmission of information can take. If the maximum transmission time cannot be adhered to, the system does not have real-time capability.

Redundancy
In this context, redundancy means that more than one of each component is available, so if a fault or disruption occurs, the function of the defective component can still be performed.

Regulator
Regulator consists of a closed regulation cycle with direct feedback.

Repeater
Signal or line amplifier which enables the maximum extension of a network to be enlarged.

SC
Abbreviation for Subscriber Connector

SDCI
Single-Drop Digital Communication Interface for small sensors and actuators.

Sensor
Measuring device capable of transformation physical quantities into electric signals

Sequence control
A control system that works through a sequence of steps.

Shared Medium
A shared medium is when components access a common transmission medium and have to share the transmission capacity.

Single-mode fiber optics
Here the light of one wavelength is transmitted. Due to the low attenuation, this type of fiber optics is suitable for long distances. The fiber core has a diameter of 9µm in this case, while the diameter of the jacket is 125µm (notation: 9/125)

SPE
Single Pair Ethernet

Token Passing Method
Token passing is used in communication networks in order to define coordinated communication between components. A token is passed on from one component to the next. Only the component holding the token may send messages to other components. The order in which the token is passed on from one component to the next has to be defined in advance.

Topology
Communication networks are made of devices or components which are connected to each other via lines. The topology of this communication network describes how the devices and lines are arranged in relation to each other.

Trunk/drop line
Trunk/drop line topology is a mixture of trunk line and drop line topology. By way of comparison: imagine a main road (trunk line) with lots of dead-end streets branching off to the right and left (drop lines), each of which has a few houses along it.

Twisted Pair
A twisted pair generally refers to two copper wires twisted together to form a pair. A twisted pair has electromagnetic advantages over two individual wires.

UV radiation
Ultraviolet radiation

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