New, manufacturer-independent IO-Link interface for the intelligent process automation

by Albert Book

Industry 4.0 and innovative machine solutions in automation technology are currently a topic of wide-ranging discussions. A prerequisite for integrated networking, full transparency and end-to-end communication of the plant systems down to the lowest field device level are intelligent sensors. Irrespective of the field bus used and not tied to particular manufacturers: the IO-Link interface constitutes a new communication approach for a consistent connection of sensors and actuators to the control level via a simple and economic point-to-point connection. The following report gives an insight into the technology and application of the IO-Link interface.

Industry 4.0 is the merger of information technology (IT) and communications technology to ICT. The basis is networking of sensors, actuators and data processing to provide integrated communication down to the field device level.

The vision of Industry 4.0 integrates digitalisation, automation and networking of all applications to control the complete process for all functions, areas and segments of the manufacturing industry.

The driving force for this transformation is primarily the increasing requests coming from the customers and the necessity for manufacturing companies to adapt faster and in a more dynamic way to growing individualised customer's requests. This requires a transition from rigid centralised production control systems towards a decentralised intelligence down to the field device level.

The target of the introduction of Industry 4.0 into manufacturing processes is to reach an adaptive production and an optimisation of the individual processes in real time mode. According to the defined production and process technologies should be designed to independently select the materials and components and to make real-time adaptations and adjustments according to the motto "the product controls the plant". The advantages are increased efficiency and flexibility due to a faster response to a higher number of variants, shorter changeover cycles for complex products, production of a variety of series or individual products on the same production line, tailored products for the customers and the production of small and very small series at competitive costs.

Industry 4.0 pursues the idea to veer away from preventive maintenance and repair of plants towards predictive diagnostics and remote maintenance even beyond plant boundaries and locations. All this requires access to connected intelligent data sources such as sensors or actuators.

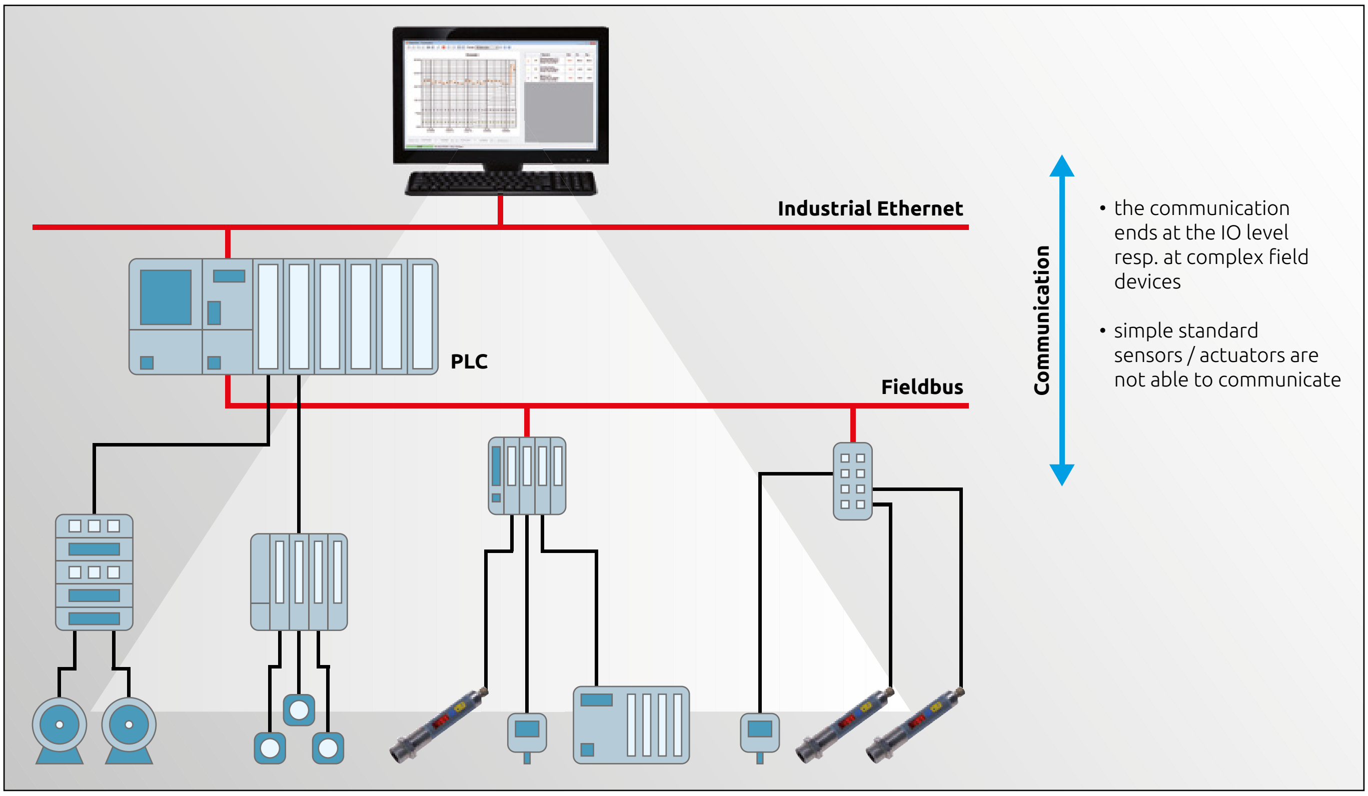

Fig. 1 *Traditional automation system with limited means of communication.*

One shortfall of industry 4.0 is the often missing standard and the inaccurate definition of the term. System-wide consistency and worldwide suitability needs a uniform framework for technologies, systems and processes on the basis of international standards combined with fundamental standardisations of structuring principles, interfaces and data formats.

Limits of classical automation technology

Traditional networks and field bus systems were developed by leading PLC manufactures supporting a system-specific technology that optimally go in line with their programming and configuration tools. The market knows several competing systems, such as Profibus/ProfiNet (Siemens), DeviceNet and ControlNet (Rockwell Automation), Modbus and CANopen (Schneider Electric), Interbus (Phoenix Contact) or CC-Link (Mitsubishi Electric). The PLC system dictates which field bus will be employed. Significant technical differences are given for the cable length, the number of data bits and the scope of functions. Functions beyond this scope, such as diagnostics, non-cyclical transmission of demand data, alarm handling and slave-to-slave communication between the individual bus participants are not supported by all field bus systems.

If we take the classical automation technology, the communication usually ends at the lowest field bus level, i.e. at the sensors and actuators (**Fig. 1**). Modules limited to mere analogue or switching input and output signals, incapable to communicate, are often used there. The sensors and actuators with a digital interface available on the market are not standardised but use company-specific hardware and software for communication. Depending on the sensor, special and mostly expensive modules have to be installed in the control system. Heterogeneous wiring with most different wire types and pin assignments entail high installation costs. Comprehensive shielding measures are necessary to provide immunity to interference both of analogue and digital signals. In practice, it is again and again visible that interferences in signal transmission can often be traced back to faulty or insufficient shielding. Likewise, the interconnection and integration of all interfaces and transmission protocols is time-consuming and prone to errors. A machine re-configuration, an exchange or just a check of the devices require manual setting of the parameters at the device itself or with the help of a separate tool, and this individually for each sensor and actuator. Again and again we experience that this is a major source of errors or possible tampering which interferes with a safe plant operation. As there is no consistent communication from the field device level to the higher levels, diagnostic data of the sensors and actuators are not available.

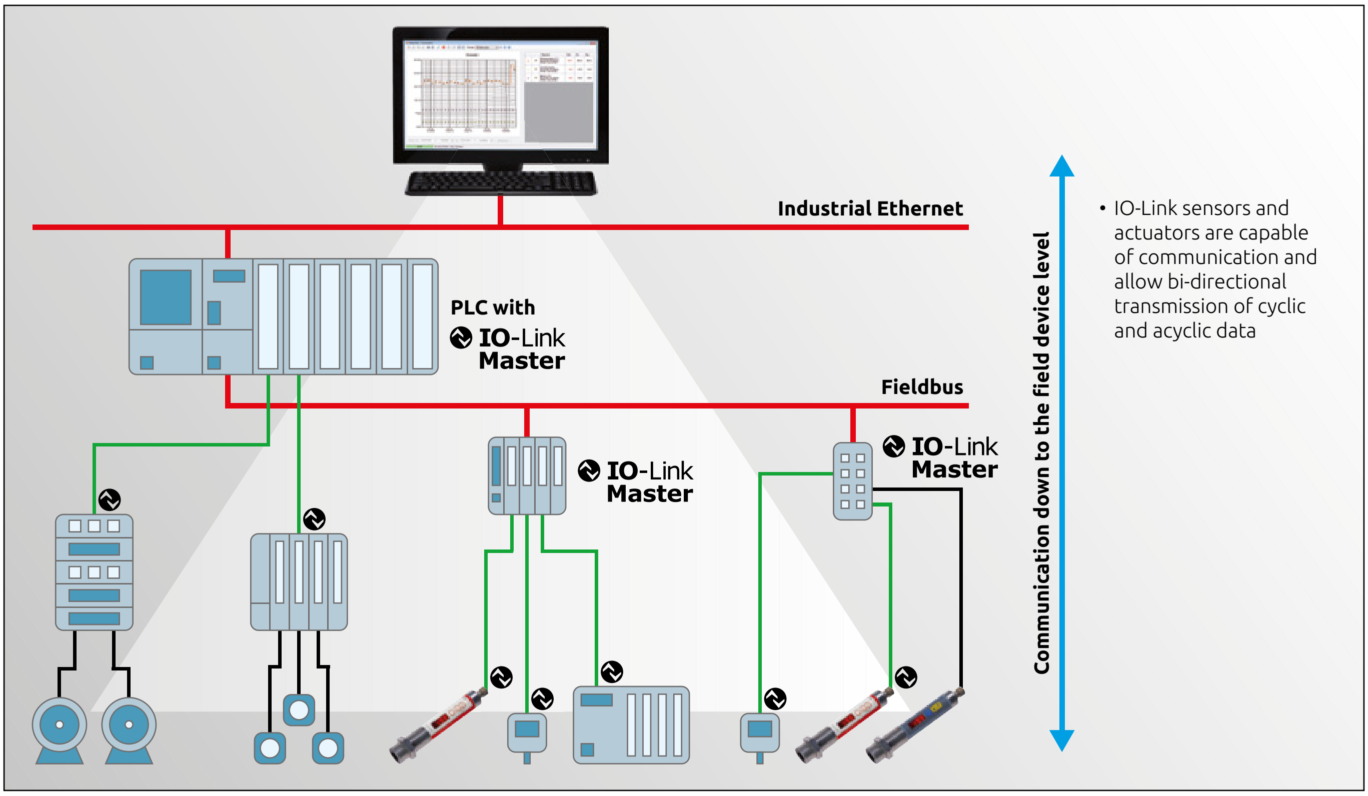

Fig. 2 *IO-Link enables comprehensive communication down to the field device level.*

However, due to their location in the plant and their exposure to difficult production conditions in industries, such as heat, cold, vibration, dirt and moisture, these modules are more often than not responsible for the origin of plant downtimes. Without diagnostic data, the troubleshooting process and subsequent elimination of errors is often difficult and time-consuming. A preventive maintenance to avoid unplanned downtime is under these circumstances most probably not an issue at all.

The future is called IO-Link

Such a wide variety of bus systems and the absence of standards is rather a great disadvantage for the development of automation technology, a fact that the manufacturers of automation products eventually realise. The leading manufacturers have formed a consortium with the goal to develop a general and universally standardised I/O interface technology for the communication of sensors and actuators. The result is the IO-Link concept for a uniform, field bus independent and non-proprietary connection of switching devices and sensors to the control level by means of a cost-effective point-to-point connection. These communication specifications are defined in the IEC 61131-9 standard. IO-Link devices create transparency and consistent communication from the field device level up to the highest automation level (**Fig. 2**).

As it is an open interface, the IO-Link can be integrated in all common field bus and automation systems. Ultimately, instead of the so far parallel usage of analogue, switching and digital signals, the IO-Link is designed to provide exclusively digital transmission. The IO-Link offers a centralised error diagnostic and localisation down to the actuator/sensor level. Offering a dynamic parameter setting of the sensors directly from the plant control system allows the adaptation of the field devices to the specific production requirements during running production. Field devices with the IO-Link interface are therefore the basis for the implementation of Industry 4.0.

Advantages of the IO-Link interface

For certain, the IO-Link interface is rightly regarded as the USB interface of automation technology. Both are inexpensive serial point-to-point connections for signal transmission and are suitable for plug-and-play operation. A key feature is very simple wiring with standardised cables with screw connectors. In addition to huge time savings during wiring, since terminal blocks are not needed, the solution with plugs prevents incorrect connections. The elimination of separate multipole cables for analogue signal transmission, switching contact and external parameter setting saves time for wiring and also space in the control cabinet, as there is no more need to connect each device separately to the central periphery. The non-proprietary standardisation reduces the range of interfaces of sensors and IO modules and cuts down the variety of connecting cables.

Sensors with an IO-Link interface provide a reliable diagnostic method. Diagnostic messages, especially preventive status messages, can be forwarded together with their description and are displayed at the HMI (Human Machine Interface). This allows for fast responses in case of sensor failures, polluted optical sensors, inadmissible operating temperatures, wire breakages or short-circuits and thus avoids longer downtimes.

If it is still necessary to replace a sensor, setting the correct parameters or finding the right sensor so far is always a large source of error. The parameters of IO-Link devices are stored in the IO-Link Master. The IO-Link identifies the devices by their unique serial numbers, vendor and device IDs which eliminates a mix-up of devices. When a device is replaced, the parameters are automatically transmitted to the sensor. Operating errors or even tampering with data is therefore impossible. Furthermore, parameter changes will be documented and can be traced back at a later date if needed.

The IO-Link data transmission is based on a 24 VDC signal which makes is particularly insensitive to electromagnetic interference. The signal transmission is purely digital and secured by checksums which excludes faulty and incorrect transmissions caused by signal conversions; faults that may happen with analogue signals. Shielded cables and special earthing connections are normally not necessary.

Components of the IO-Link system

An IO-Link system consists of IO-Link masters as a gateway between the higher-level communication systems, such as Profinet, Ethernet/IP and the IO-Link devices. The IO-Link devices are now the communicating field devices, such as sensors, switching units, valves or signal lamps.

The data transmission via IO-Link always happens between an IO-Link master and the IO-Link device (slave). IO-Link masters are either field bus interface modules or PLC interface modules. Optionally, switching devices can either be traditionally operated with switching input or output or, working in IO-Link mode, the switching status is digitally transmitted. Parallel operation is not possible as both signals are transmitted via the same pin 4. An IO-Link system allows combining and running in parallel components with and without IO-Link in any way you require. Standard devices that are not supporting an IO-Link can either be connected via special IO ports or compatible IO-Link ports of the master. Binary or analogue sensors can thus be linked via the master to the field bus level. The IO-Link interface module ensures downward compatibility of the IO-Link ports through two different operating modes, the IO-Link mode and the standard IO mode (SIO). IO-Link sensors can be operated as a binary device. An IO-Link switching sensor can therefore also be integrated in a conventional automation system. Upon initialisation, the IO-Link Master automatically establishes a communication. Mixed operations of standard sensors and IO-Link sensors are supported by the IO-Link Standard.

With an IO-Link the line for the switching signal is simultaneously used for serial communication. Technically, it is a half-duplex interface where sending and receiving of data is carried out in succession. M12 plugs are used by default. The maximum cable length to the IO-Link master is 20 metres.

When first planning the specification of the IO-Link the focus was set on switching sensors and actuators. Meanwhile, we found out that the IO-Link interface also makes sense for measuring devices. More and more sensor manufacturers already offer devices for various physical measured variables. The IO-Link specification states that only pins 1, 3 and 4 are defined in the pin assignment Port Class A. Pins 2 and 5 that are used for additional voltage supply when more power is needed can alternatively be used with measuring devices to provide an analogue 0/4-20 mA output or a second switching output (**Fig. 3**).

Parallel operation of the analogue and switching outputs and the digital interface offer interesting options for external parameter setting, evaluation of error messages and diagnostic signal functions when the users do not want to give up the analogue output completely. If, at a later date, they decide to fully convert the control system to digital measurement value transmission, it is only necessary to change the configuration of the control software. Measuring devices such as, for example, infrared thermometers for non-contact temperature measurements must be able to handle very small signals in the picoampere range. This requires a high degree of internal measures to provide interference immunity and external measures such as a shielded cable. Although the IO-Link Consortium advertises that a shielded cable is not necessary for the connection of IO-Link devices, as there is no interference for digital signals, certain restrictions are nevertheless inevi-

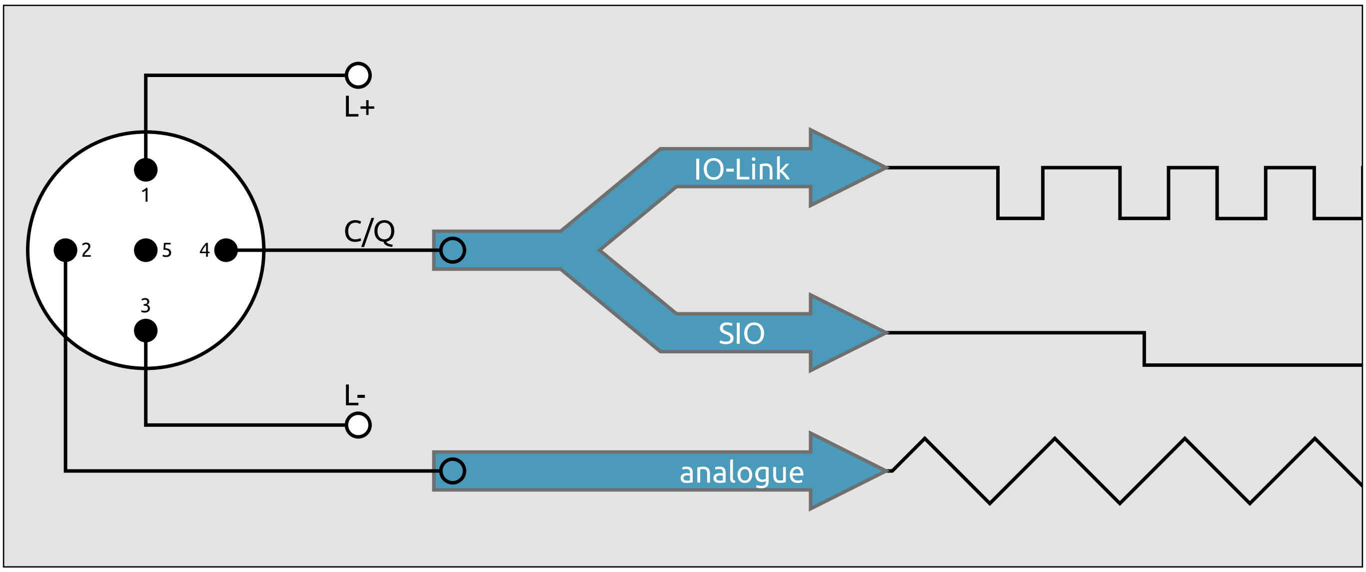

Fig. 3 *Connection of a modern sensor with IO-Link interface and analogue output.*

table with the introduction of an IO-Link interface for measuring devices. The market already reacted and offers ready-made shielded cables.

IO-Link communication data types

IO-Link communication supports the transmission of cyclic and acyclic data. Process data and status information concerning the validity of process data are transmitted cyclically. The exchange of device data, i.e. identification data, parameters and diagnostic information, is acyclic on request of the IO-Link master. In addition, a device transmits events, such as error reports (short-circuits, interruptions) or warnings (pollution, overheating) to the master.

Integration of IO-Link devices in the control system

To facilitate and to standardise access of the user programs to the control system, the IO-Link uses defined device profiles. These profiles contain codified data structures, data content and the basic functionality, guaranteeing an identical program access from the control system. The device profile “smart sensor profile” is defined for the IO-Link.

One component of an IO-Link device is the IODD (IO Device Description). The structure of the IODD is identical for all devices of all manufacturers. This ensures that all IO-Link devices can be handled in the same way, independent of the manufacturer. The IODD contains all information and descriptions for identification, for the device parameters with their value ranges, error messages, process and diagnostic data and communication characteristics (**Fig. 4**). The texts can be stored in several languages. The ports of the connected devices are allocated in the IO-Link master (**Fig. 5**). Usually, the IO-Link master is connected to the control system as a field bus slave.

A functional bloc in the machine control system automatically sets the parameters and carries out a diagnostic. For parameter setting, the functional block first requests the IO-Link to check the identification parameters of the connected devices. Then a data base comparison checks whether these sensors are authorised for the machines used. If positive, the functional

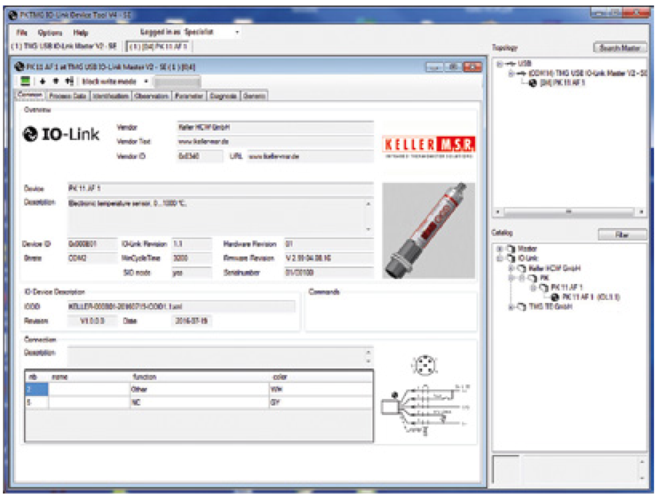

Fig. 4 *Characteristics of the connected IO device.*

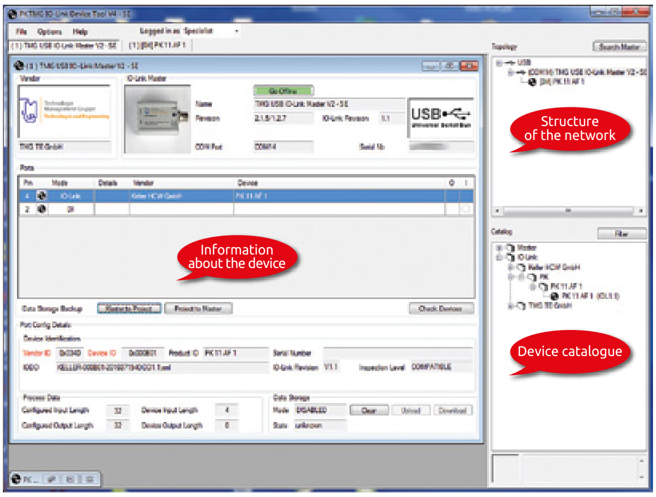

Fig. 5 *Connection of an IO sensor to the master.*

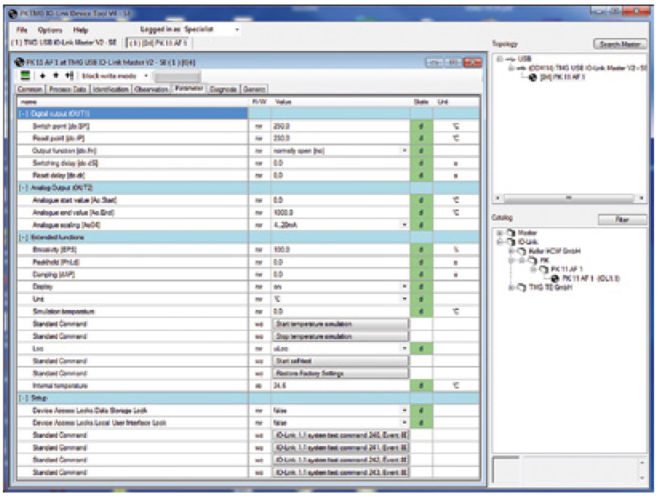

Fig. 7 *Parameter setting and commands.*

block will find the configuration parameters pertaining to the sensors in the data base. Via IO-Link these parameters are then automatically attributed to the respective sensors. The following parameters can, for example, be set for the infrared thermometer (**Fig. 6**): emissivity, switching points and function of the switching contact, current range of the analogue output and peak picker. Also available are command functions: temperature simulation, self-test and reset to factory settings (**Fig. 7**). Hardware or software errors, maintenance calls or an operation of the device outside of the given specifications can, for example, be evaluated with the diagnostic function. The integration in the control system makes all sensors also accessible to remote maintenance.

A user-specific parameter setting of an IO-Link device can be made externally as follows: with a personal computer with USB IO-Link-master, with a software tool in the PLC control system or program-controlled by functional blocks in the plant control system.

Fig. 6 *Infrared thermometer with IO-Link interface, analogue output and switching contact.*

IO-Link tools for servicing

A veteran commissioning engineer will certainly argue that it was and is much easier to check an analogue sensor with an ammeter. Parameter setting could be made with a button or switch on the device. If, however, we would have to do without all other advantages of digital communication, then the question is whether this is still a decisive buying criterion to optimise production costs in times of international competition.

IO-Link USB masters are offered for service purposes (**Fig. 8**). The IO-Link device can be addressed via the USB interface of a PC. Special IO-Link adapters can be looped into the supply line to access and record data either non-reactively by cable or via Bluetooth. Also available are adapters to clone the device parameters.

It is not yet predictable how fast the conversion to a purely digital signal communication will take place. It certainly depends on the level of automation of the machinery, the industry branch and the application ranges. As modern sensors with IO-Link interface and analogue output are often offered without extra costs, it is recommendable to proactively use these devices for replacements, extensions of the plant or even for a new plant. A conversion at a later date will then be easy without extra costs for sensor modifications or wiring.

Meanwhile, the market offers more than 3000 IO-Link products. IO-Link masters are now available for 16 field bus systems and eight manufacturers of control systems already offer central masters.

Fig. 8 *IO-Link Master zum Anschluss eines IO-Link Device über die USB-Schnittstelle an einen PC.*

In addition, there are numerous sensor manufacturers for a large variety of measured variables, for object recognition or position feedback as well as actuators such as signal lamps, valves, power contactors or frequency converters. A number of firms also offer the technology for instrument design and for technical support. The requirement for certification and the use of accredited test tools makes sure that all products on the market fulfil the IO-Link standard.

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