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WHITE PAPER

SENSORS WITH IO-LINK INTERFACE

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IPF ELECTRONIC

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1. INTRODUCTION

It is not a question of whether one needs to intensively address digitization in the various branches of industry, but rather of when: the digital transformation affects all sectors nearly without exception. Digitization is a mega-trend and for the area of sensors, IO-Link technology in particular is an important driving force as it provides an intelligent, decentralized interface for highly efficient, seamless digital communication on all levels of a production system in the sense of comprehensive networking.

This white paper offers an overview of the potential of IO-Link in the area of sensor technology and concludes with a presentation of the broad product range of IO-Link solutions from ipf electronic. ipf electronic is constantly expanding the selection of devices with IO-Link interface. In this context, it is therefore not possible to describe in detail all IO-Link functionalities and features of every device series or specific sensor type, as this would be beyond the scope of the white paper.
To start, first some general information about IO-Link, the system architecture and functionality.

2. IO-LINK: STANDARD FOR DECENTRALIZED INTELLIGENCE

IO-Link is now considered to be standard for a communication system that connects sensors and actuators to an automation system. IO-Link is not a bus system but a secure, manufacturer-independent, point-to-point connection for sensors and actuators. Because nothing on the sensors is changed aside from the IO-Link interface, they can be used in the usual manner. Thanks to the IO-Link interface, however, the devices are intelligent, as they can now communicate with higher-level controls (PLCs) and are also more versatile. As a result, the sensors are able to supply, among other things, a range of valuable process, diagnostic and device data for production automation and, moreover, can be configured largely during running operation.

2.1 SYSTEM ARCHITECTURE AND FUNCTIONALITY

An IO-Link system consists of an IO-Link master as interface to a higher-level control (PLC) and several IO-Link devices, e.g. sensors or actuators.

An IO-Link device has, e.g. a serial number as well as parameter data (for example, sensitivities, switching delays, etc.) that can be read or written via the IO-Link protocol. The IO-Link master features one or more ports, whereby only one IO-Link device can be connected to a given port via a point-to-point connection at a time (parallel wiring).

The IO-Link topology can also be expanded with IO-Link hubs which, to a certain extent, function as distribution boxes for devices without IO-Link interface. Conventional sensors or actuators with switching outputs can thus be connected to an IO-Link hub, whereby the distribution box itself is then virtually the IO-Link device connected to the master. Because the signals are transmitted to the master over a single, unshielded M12 connection cable, the amount of wiring work is reduced dramatically due to the fact that conventional parallel wiring of each individual device to the control unit is not necessary. This thereby eliminates a number of terminals, distribution boxes, input/output cards and cable harnesses for the user. Last, but not least, with a simple IO-Link master via USB, IO-Link – unlike bus systems – requires neither configuration nor addressing, further significantly simplifying the initial setup.

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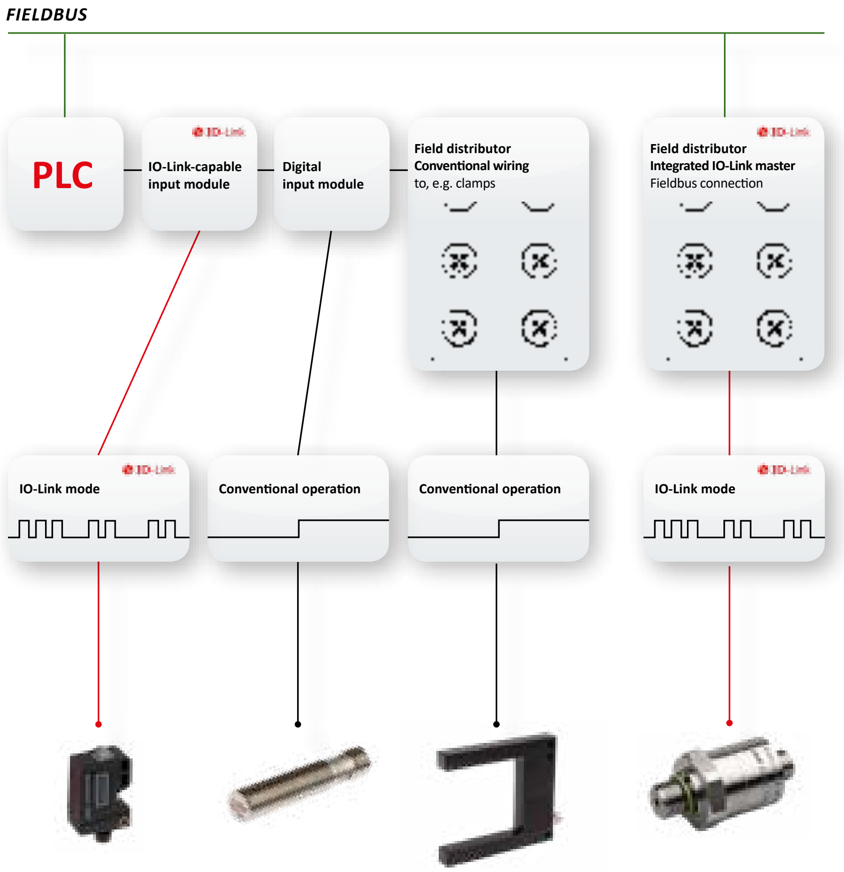
2.2 INSTALLATION AND DATA EXCHANGE

An IO-Link device is connected to the IO-Link master via an unshielded 3-wire standard line (M8 or M12 standard sensor connection) with a maximum length of up to 20 meters. No special requirements need to be met for the routing of the connection cable. Data exchange between IO-Link device and IO-Link master occurs digitally via the black core of the connection cable. This takes place automatically as soon as the connection with the master is established and this is appropriately configured. Provided the device was not connected to a master, this connection performs its basic function to a certain extent, e.g. as a switching output or teach-in input. IO-Link masters are integrated in either a PLC module or a fieldbus distribution terminal. Therefore, there are no special requirements on the wiring or for installation to implement the IO-Link in existing automation systems.

Three types of data are exchanged between the IO-Link master and the IO-Link device:

- Cyclic process data
- Acyclic device data (IO-Link device): e.g. parameters, diagnostic functions
- Acyclic data (events): e.g. error messages and warnings

An IO-Link device only transmits its data at the request of the IO-Link master.



IO-Link system architecture

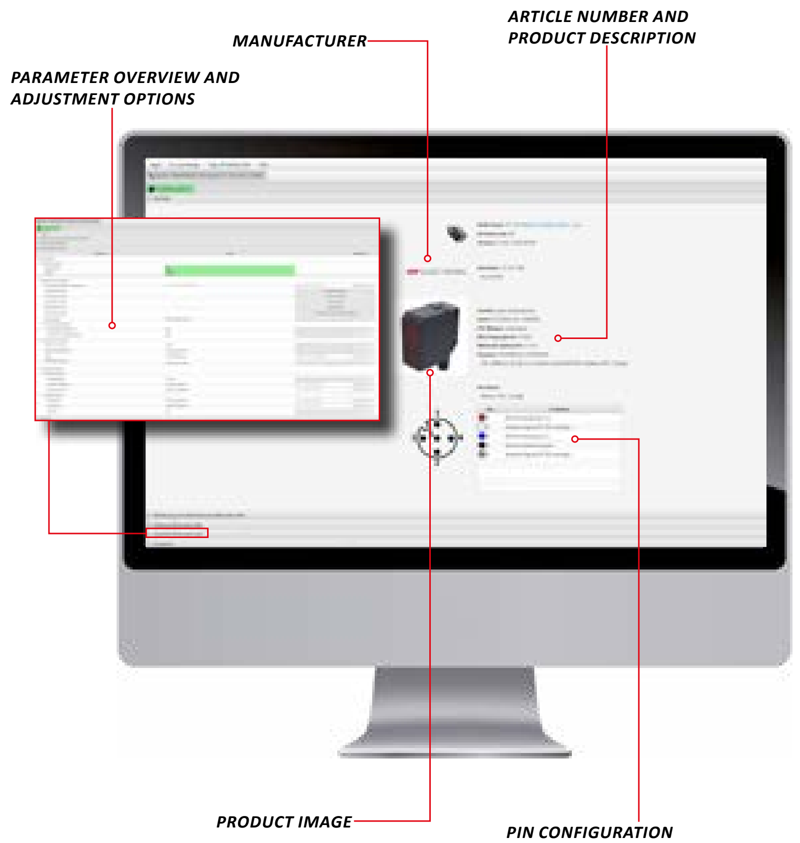
2.3 IO-LINK CONFIGURATION AND IODD

Software is required for configuring the IO-Link master and the connected manufacturer-encompassing IO-Link devices and IO-Link capable sensors. This so-called IO-Link configuration tool makes transparent representation (visualization) of the respective IO-Link system architecture possible. The next figure shows a user interface of a configuration tool and describes the functions of the individual areas.

Sensors with IO-Link interface from ipf electronic offer access to process data and variables by means of the IO-Link protocol. All sensor properties are described in the so-called IODD (IO Device Description). The structure of the IODD is identical for all IO-Link capable devices from all manufacturers. The IODD consists of image data in png format as well as one or more XML files that describe the sensor with IO-Link interface. Thus, an IODD contains information about the communication properties as well as the device parameters of a sensor, identification-, process-, and diagnostic data, a picture of the device, the manufacturer's logo and, as a rule, a PDF with all relevant information for the user of the sensor.

The IO-Link configuration files are made available by the manufacturers of the IO-Link masters. With the configuration tool, the IO-Link device can be configured for the application regardless of manufacturer. If desired, the so-called IODD file associated with the sensor is automatically downloaded from an IODD database on the Internet, thereby preventing mix-ups. The IODD file ensures that the parameter and process data are displayed correctly in the configuration tool.

CONFIGURATION TOOL OF THE IPF IO-LINK MASTER



To configure the IO-Link devices, the software of the used IO-Link master is needed as a configuration tool. This tool is able to read an IODD and, thus, represent the properties, e.g. of a described sensor.

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3. INCREASED TRANSPARENCY AND FLEXIBILITY

Sensors with IO-Link interface supply valuable information and offer a wide range of adjustment options, especially with regard to configuration. The specific properties and functions of such devices result largely from application experiences or "best practices" that were gathered in the past with various sensor types and are now incorporated in IO-Link solutions. In addition to providing process and diagnostic data, the IO-Link technology is thereby able to, among other things, combine the unique advantages or functionalities of different but structurally identical versions of a sensor model into a single solution. This greatly reduces the number of versions, because fewer sensors are required for a comparatively diverse range of tasks or requirements.

In addition to an internationally standardized and easy-to-use interface, the advantages of IO-Link sensors can thus generally be summarized as follows: greater transparency and security as well as more flexibility through:

- Process and diagnostic data as well as clear sensor identification
- Various options for device configuration

3.1 CLEAR IDENTIFICATION PLUS PROCESS AND DIAGNOSTIC DATA

As already mentioned in Chapter 2.3, the IODD itself contains a range of identity information about an IO-Link sensor. In addition, information about the installation location of a device can also be stored in the IODD file information. This can be advantageous above all in very large and complex systems with many sensors, e.g. for maintenance, as the affected devices can very quickly be located in the event of defects or failures.
By means of such identity information, the IO-Link system is also able to verify a newly connected sensor to ensure that, e.g. a replacement device is identical to the defective sensor. This is useful above all if the replacement sensor has the same construction as a defective sensor but may have different properties or parameters. More about this in Chapter 4.

IO-Link sensors also lead to greater transparency on a variety of levels as they supply valuable process and diagnostic data in real-time during running operation by means of which, among other things, costly system failures can be reduced and, moreover, processes can be analyzed and optimized in a targeted manner. Such process and diagnostic data are, therefore, a decisive basis for more productive and thus more economical system operation with more efficient maintenance and service planning.

Here is an example: In the automotive industry, system audits are performed regularly. During this process, the sensor systems are also checked. Because IO-Link devices supply detailed information about, e.g. the starting processes and about the time period during which they were actually in operation (elapsed hour counter) or can display how high the temperatures are at the installation location, validatable data about the entire life cycle of these devices is now available. Using such data and other information available via IO-Link, it is thus possible to, among other things, evaluate whether a sensor may be near its operation limits and, thus, needs to be replaced, or if it is still usable, as neither process data nor diagnostic data indicate any irregularities. Spare part costs are thereby reduced because a still-intact device does not need to be replaced as a precautionary measure. At the same time, resources are conserved due to the ecologically sustainable use of the sensors and, not least of all, by ensuring a high system availability until the next audit.

3.2 MORE FREEDOM DURING CONFIGURATION

One feature of IO-Link sensors especially valued by users is the range of possibilities for the configuration, whereby adjustment options can often be used that structurally identical devices without IO-Link interface don't offer at all. As already mentioned in Chapter 3, it is thereby possible to replace multiple device versions of a sensor with different features or functions by means of a single solution. The resulting high level of versatility will now be illustrated using an example.

Ultrasonic sensors with switching output are taught in via a teach button. This generally exhausts the possibilities for device setup and, thus, adaptation to an application.

For an ultrasonic sensor with switching output and IO-Link interface, however, specific information is transferred to a higher-level control unit, e.g. the actual measured value or distance of the device to an object and even the status of the signal output. It is also immediately apparent whether the sensor is ready for operation and is within a range to the object necessary for reliable detection. Via IO-Link, the devices with switching output thereby supply the same information as an ultrasonic sensor with analog output. But this is far from exhausting the potential of such solutions.

For example, the switching output of an ultrasonic sensor can be flexibly configured via IO-Link to enable the options of push-pull (PP), NPN and PNP with a single device. In addition, it is possible to decide whether the sensor is to be used as a normally closed or normally open contact. Various operating modes can also be activated for such devices, e.g. switching point mode, window mode, 2-point mode or switchover between scanner operation and retro-reflective mode. Alternatively, the switching output can also be completely deactivated. Moreover, the switching behavior of the sensors can be influenced by a turn-on and turn-off delay.

Without IO-Link, a number of different ultrasonic sensors would have been necessary in the past for such a range of properties and parameters depending on the field of use, whereby with the adjustment options for the output logic alone, four devices can be replaced with a single sensor. Once pre-set, parameter sets can either be stored on a control unit or on a PC and are then immediately available should it be necessary to exchange a sensor. The time-consuming configuration of a new device is not necessary.

For IO-Link, the two software standards V1.0x and V1.1x currently exist. With standard V1.0x, the parameter sets of the sensors can be stored on a PLC. The identity of a defective device can then be determined via the control unit and its parameter set transferred, e.g. to a replacement sensor. For devices that function according to standard V1.1x, the identity of the sensor is determined directly via the IO-Link master which, in the event of a device exchange, automatically configures the new sensor.

IO-Link technology thereby offers a high level of flexibility and time savings both during configuration as well as with reconfiguration with respect to the use-oriented design of a sensor. For the maintenance and associated spare parts inventory alone, this means enormous cost savings and a significant reduction of the inventory that may have previously been necessary.

4. TRUE PROGRESS ON ALL LEVELS

The comments above give an idea of the potential of IO-Link sensors, which lead to true progress on nearly all levels of production automation, from installation to machine availability and system flexibility and on to maintenance.

4.1 SIMPLE INSTALLATION

As already mentioned in Chapter 2.2, the installation of sensors with IO-Link interface is extremely simple, as the unshielded three- or four-core standard cables typically used in industry are adequate for this purpose. The manufacturer-independent, uniform IO-Link interface is easy to integrate and even complex devices can be incorporated easily. EMC compatibility is execellent with IO-Link devices, since digital communication ensures a high immunity to interference. In practice, these advantages ultimately mean very easy integration of sensors with IO-Link in existing system concepts without costly work for shielding that may otherwise be necessary even when transferring analog signals. Because it is possible to set up write access and a lock for the installed sensors via IO-Link, the devices are very reliably protected against unwanted or unauthorized tampering.

4.2 MORE EFFICIENT OPERATION

After installing IO-Link devices, their accessibility – especially at difficult to reach installation locations in more complex systems – is no longer decisive as the settings can be performed via the IO-Link interface. What possibilities are available to the user in this regard was shown in Chapter 3.2 using an example.
As already mentioned above, digital data transfer is absolutely immune to interference and is open for both binary as well as analog standard devices.

In addition, the technology enables comprehensive process monitoring and error analysis of the IO-Link components via the machine control. It is thereby possible, e.g. to very precisely optimize machine processes with respect to time since the sensors supply information such as the frequency of the switching operations or the length of the actuation, from which it is possible to deduce, e.g. cycle times.

Because some IO-Link sensors also make available physical values such as the temperatures at the installation location. It is possible to a certain extent to take temperature measurements without the additional use of a temperature sensor.

An example for more efficient system operation with IO-Link is the use of inductive proximity switches. The reliable switching behavior of the switches can be monitored via the IO-Link interface, thereby always ensuring the reliable infeed of components at a scanning point. Already during installation, IO-Link allows the devices to be positioned at the scanning point in such a way that they operate in an absolutely reliable switching range, as this may vary due to, among other things, environmental conditions or specific installation situations.

Via IO-Link, it is also always immediately apparent whether an inductive sensor is operating within its operation limits or if negative changes in the mechanical infeed negatively impact the feeding of components. This means that problems within a system can be detected early on and failures can be avoided by adjusting the mechanics in a targeted manner or by readjusting the sensor.

4.3 IMPROVE SYSTEM FLEXIBILITY

A given system is often used to manufacture different products or produce various recipes which, in turn, require a certain degree of flexibility in the individual production processes. Against this background, the corresponding adjustments to the sensors may, under certain circumstances, be associated with a considerable amount of time and longer standstill periods.

For IO-Link sensors, it is possible to instead store various parameters and, thus, settings, for a certain product or a specific recipe in such systems. In the event of a product or recipe change, the affected parameters can be transferred to the sensors without any effort. The need for an otherwise necessary readjustment directly on the device or a mechanical setting, e.g. to comply with changed switching distances, is thereby eliminated.
Not only are the set-up and conversion times reduced in a lasting way but potential error sources that may arise during the course of a system conversion are also minimized.

The result: An increase in productivity due to greater system flexibility and a reduction in non-productive times.

4.4 IMPROVE MACHINE AVAILABILITY

The ability to achieve high machine availability is heavily dependent on a successful production start. All devices with IO-Link provide their status already during system start, thereby increasing the process reliability. This applies all the more as even sensors that may not become active in the production process until a later point in time are checked for operational readiness already at the start of production.

Standstill times are also significantly reduced in the production process by IO-Link sensors, as the IO-Link master automatically configures replaced devices. This means that a time-consuming adaptation to the respective application is not necessary. Incorrect settings or the installation of the wrong sensor types is prevented by, among other things, the identity information stored for each device (see Chapter 3.1), which the IO-Link master can use to clearly verify the sensors.

4.5 OPTIMIZE MAINTENANCE

IO-Link opens a number of new potentials, especially in the area of maintenance. This begins already during the stockpiling of spare parts. Thanks to the flexible fields of application of IO-Link sensors, the number of versions decreases. It follows that the otherwise necessary inventory for largely identical devices but with different properties and functions is likewise reduced.

Through the continuous evaluation of the sensor diagnostic data, maintenance intervals can be extended since systems and machines can be automatically readjusted if necessary. Deteriorating system states can be detected before they become critical. This allows an economical, condition-oriented maintenance strategy to be realized that always responds in a timely manner, even before a sensor fails. With preventative maintenance, devices that are still fully functional are instead replaced, wasting valuable production resources. Corrective maintenance, on the other hand, does not take action until a device has usually already failed, which, as a rule, always results in system standstills and production failures.

5. IO-LINK IN PRACTICE: APPLICATION EXAMPLES

The best arguments for the use of sensors with IO-Link interface are still provided by practical applications. The following two examples illustrate some of the advantages through the use of such devices.

5.1 SUSTAINABLE REDUCTION OF DOWNTIME

Production losses due to maintenance work, be they planned or not, bring about considerable costs in everyday operation. "Commercial" inductive proximity switches were previously used in equipping devices for brass bushes, shown here, which were replaced at regular intervals as part of preventative maintenance strategy. Despite these measures in which completely intact devices were replaced, production was occasionally disrupted due to defective sensors.

Equipping device for brass bushes. The inductive sensors with IO-Link interface inform the higher-level PLC if they no longer have a sufficient functional reserve.

Because of the change to inductive sensors with IO-Link interface from ipf electronic, downtimes were significantly reduced and above all over the long-term. In concrete terms, this means that: The sensors inform the superior PLC using IO-Link as soon as they no longer have a sufficient functional reserve. The maintenance department is thereby able to plan a course of action in a timely manner before a device fails and thereby realize a condition-oriented (predictive) and, thus, more cost efficient service strategy that no longer involves the replacement of fully intact devices. Instead, only those devices that can be expected to fail in the foreseeable future are replaced.

The change to the new, IO-Link capable sensors was simple because the design of the devices remained unchanged. In addition, the already existing sensor lines could continue to be used. Only the PLC input module had to be replaced by an IO-Link capable module.

5.2 INCREASED FLEXIBILITY WITH MINIMIZED WAREHOUSING

Who doesn't know about the large storage cabinets, shelves or rooms of maintenance departments? As a spare part must be available as quickly as possible for every component that is installed and replaceable in a production system in the event of a defect or interference with a view to achieving a high degree of system availability, this cost is entirely justified but not strictly necessary.

Storage and with it related costs or rather the capital commitment can be clearly reduced by changing to devices with IO-Link interface. On a tool, for example, conventional sensors were replaced with IO-Link capable devices. The result: Separate normally closed and normally open devices no longer need to be kept on hand as spare parts. The storage costs decrease. In addition, the new sensors with IO-Link interface can be debounced by means of an integrated turn-on delay, a function that previously needed to be performed by a PLC.

The tool could be converted with minimal effort because of the long range of the connection cables of up to 20 meters and the low demands that were made of the wiring of the IO-Link capable devices.

By replacing conventional sensors with IO-Link devices, spare-parts stock could be reduced and, thus, storage costs minimized.

6. SOLUTIONS WITH ADDED INTELLIGENCE

ipf electronic already offers a number of sensors with IO-Link interface for a variety of applications, and the selection is constantly being expanded.

6.1 INDUCTIVE SENSORS

The line of inductive sensors with IO-Link interface ranges from standard solutions to devices for extreme environmental conditions and sensors with increased range, chip-resistant sensors and especially compact solutions.

6.1.1 REGARDLESS OF WHETHER STANDARD OR EXTREME USE: IO-LINK INCLUDED

Two series serve as examples for the device series of inductive sensors with IO-Link interface for flush mounting: one for standard use with active surface made of plastic and one with solutions made completely of stainless steel for use in extreme environments.

One special feature of the IO-Link capable inductive sensors for standard use is the compound-filled electronics, which provide perfect protection from vibrations. The contactless solutions in IP67 for flush mounting are designed for ambient temperatures from -25°C to +70°C. These IO-Link capable inductive sensors can, for example, be integrated for presence checks of metal parts of varying size, for the detection of object heights as well as for object detection through non-metallic container or pipe walls, or in machine parts in automation technology.

Inductive sensors with IO-Link for standard use: **IA080171** (upper left), **IA120121** (upper right), **IA180121** (bottom left) and **IA300121** (bottom right).

The inductive sensors for extreme environments with IO-Link interface feature high switching distances that can be achieved even with non-ferrous metals. Another special feature of these sensors for flush mounting is the high switching frequency of 5kHz.

They are also completely leak-proof with regard to liquids and gases on the active surface as these sensors have a housing made entirely out of stainless steel. In combination with the standard cable sockets from ipf electronic, these IO-Link capable sensors achieve degree of protection IP69K and are developed for applications in which special demands are placed on the reliability and long-life cycle of the sensors, e.g. areas of application with oil, dirt, high pressures or strong mechanical loads.

Inductive sensors with IO-Link for extreme environmental conditions: **IC080172** (upper left), **IC120122** (upper right), **IC180122** (bottom left) and **IC300122** (bottom right).

The mentioned solutions are complemented by very compact inductive sensors with IO-Link interface, also in a one-piece, stainless steel housing for flush mounting. The special features of these devices include a high resistance to shocks and vibrations according to IEC 60947-5-2/7.4 as well as a high pressure resistance of up to 60bar.

IO-Link capable inductive sensors **IC210176**, **IC080176** and **IC180106** (from left).

The IO-Link features and functionalities of the previously described sensors were already discussed in Chapter 4.2.

6.1.2 SENSORS WITH INCREASED RANGE

For increased ranges, ipf electronic also offers inductive sensors with IO-Link interface with maximum switching distances from 1.5mm to 40mm. Both devices are designed with degree of protection IP67, whereby the cuboid version in robust plastic housing also achieves IP69 when used with suitable connection cable.

Designed for increased switching distances: the **IB050176** (left) and **IN450423** with IO-Link interface.

6.1.3 CHIP-RESISTANT SENSORS

A special feature of the inductive sensors with IO-Link are solutions enclosed in a single-piece, all-metal housing (degree of protection of active surface IP68 and IP69K) making them insensitive to steel, aluminum, brass, copper and stainless-steel chippings. These sensors can therefore detect target objects made of steel, non-ferrous metals and stainless steel reliably and with ease without malfunctions caused by metal chippings. Depending on the version, the extremely durable devices have switching distances of 3 to 12mm and are pressure-proof (active surface) up to 80bar.

Chip-resistant inductive sensors detect target objects made of steel, non-ferrous metals and stainless steel reliably and with ease without malfunctions caused by metal chippings. At the left is the **IO30012F** in size M30, next the **IO18012F** in size M18 and the **IO12012F** in size M12.

6.1.4 INDUCTIVE MINIATURE SENSORS

For applications in especially constrained installation conditions, ipf electronic also has solutions with IO-Link for flush mounting in its portfolio. Devices with especially compact dimensions were designed specifically for this purpose (Ø 6.5mm, Ø 3mm and size M4). All miniature sensors have degree of protection IP67; some solutions also feature high switching frequencies of 3000Hz or 5000Hz.

Designed as a "space-saver" for especially constrained spaces, the **IB06A023**, **IB040106** and **IBR30104** with IO-Link (from left).

All of the inductive sensors described in Chapters 6.1.2 to 6.1.4 have the same IO-Link features as the full-metal devices. The solutions are, thus, easier to install as their actual switching range can be determined via IO-Link in a specific application, and the sensors can be appropriately positioned for reliably detecting components. In running operation, it is possible to monitor the reliable switching behavior via the IO-Link interface. This ensures that components are always reliably fed in at a scanning point.

Via IO-Link, it is also immediately apparent whether a device is within its operation limits or if negative changes in the component infeed are leading to an unexpected switching behavior. Using this information, the mechanics can then be corrected in a targeted manner or the sensor can be readjusted.

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6.2 FUTURE-ORIENTED FOR PNEUMATIC APPLICATION AREAS

Thanks to their IO-Link interface, the vacuum and pressure sensors from ipf electronic are future-oriented for many pneumatic application areas. The compact, extremely light-weight sensors in the robust plastic housing cover detection ranges from -1bar to 10bar, have a response time of < 2.5ms as well as a switching frequency of 200Hz, and therefore make variable and versatile use possible in all conceivable areas of handling and automation systems. Examples of potential applications are pressure monitoring, vacuum checking for vacuum lifters, compressor actuation etc.

Fast commissioning of these solutions is ensured by, among other things, simple, menu-driven programming. Alternatively, configuration can also be performed via IO-Link. Thanks to IO-Link, the parameters are very easy to adjust, even for extremely specialized applications such as “pressure window” monitoring. A lock to protect against unwanted tampering on the device can also be set via IO-Link. The devices are equipped with two independently configurable signal outputs, whose switching points can be set with precision. The respective switching point hysteresis can also be freely defined via the IO-Link interface. Because measured values are also transferred via this interface, the user can access the respective measured value as with devices with analog output.

The vacuum and pressure sensors with IO-Link are available in identical design but with different pressure ranges.

6.3 DETERMINING FLOW STATES AND BENEFITING FROM IO-LINK

Flow sensors are also among the devices with IO-Link from ipf electronic. These devices measure the airflow speed and air temperature in an integrated measurement section and thereby calculate from the flow velocity the flow rate and air consumption relative to a normal state. The air consumption is periodically stored in the device in a time interval of 15 minutes.

The function of the flow sensors with IO-Link interface is based on the calorimetric principle (thermal measurement principle), whereby the measured quantities of flow velocity (Nm/s), flow rate (Nl/min, Nm^3/h), consumption (Nl, Nm^3) and temperature (°C) can be determined. The solutions are thus suitable for the monitoring of compressed air systems. The flow sensors communicate directly with a PLC via the IO-Link interface, providing valuable process, diagnostic and device data.

The flow sensors programmable via IO-Link in IP54 (sensing element in stainless steel 1.4305) are designed for media temperatures from 0°C to + 60°C and can be operated in environments with temperatures from -10°C to +60°C. The pressure resistance of the sensors is maximum 16bar.

All possible adjustment options on the device can also be performed comfortably via IO-Link. This includes the setting of the units for the measured quantities as well as selecting whether the device is to be used for temperature or flow measurement. In addition, the following options are available for the outputs: Time functions, normally open/normally closed, NPN/PNP, range/limit value monitoring, dosing function and pulse output. Moreover, IO-Link can be used to define whether output 2 should also supply an analog signal or serve as a reset input. The following data can also be called up via the IO-Link interface: Min/max flow, min/max temperature, 24h average flow value and 24h average temperature value.

IO-Link also offers a number of additional functions for flow sensors that were not previously available for devices without IO-Link interface. For example, the user levels in the menu structure can be locked or enabled and error messages for excessively high (>60°C) and excessively low (<0°C) media temperatures as well as supply voltages (>30V or <18V) can be output. In addition, the IO-Link interface supplies the measured values for temperature and flow rate.

The flow sensors are suitable for all applications in which the velocity or presence of air flows or the air temperature needs to be determined. The devices communicate directly with a PLC via the IO-Link interface, supply valuable process, diagnostic and device data as well as a number of additional functions that were not available with the devices without IO-Link.

6.4 FLEXIBILITY BOOST WITH ULTRASONIC SENSORS

The performance spectrum of the ultrasonic sensors with IO-Link was already discussed in Chapter 3.2 with regard to flexible device configuration. In this area, the sensors show an especially high level of flexibility, making them even more versatile. We will therefore again summarize the most important features and functions at this point.

The ultrasonic sensors are offered with switching output and analog output, whereby the devices with switching output can easily be toggled between scanner operation and retro-reflective mode via IO-Link. As a result, these sensors can be adjusted not only to an object that is to be detected but also to a background (e.g. a machine part). Irregular, structured, round or inclined object surfaces can, in particular, deflect the signal echo of an ultrasonic sensor in such a way that it does not function reliably. Retro-reflective mode solves this problem as all deviations from the object background (object in the detection area) are reliably detected and result in switching.

With the IO-Link interface, every sensor delivers a range of valuable information in spite of the compact design and also offers intelligent additional functions such as temperature compensation that can be activated and also enables individual settings (e.g. output function of the switching output, turn-on/turn-off delays, switching hysteresis). Also available are diagnostic data, such as the number of starting processes, the number of operating hours or the minimum and maximum object distance.

The same applies for the even more versatile ultrasonic sensors with analog output, which make three measurement signals available for selection via IO-Link (4-20mA, 0-20mA or 0-10V). In addition to the analog output, the solutions integrate a multifunctional teach input that can be configured via IO-Link as, among other things, a switching output. Thus, all functions and adjustment options are available that are also offered by sensors with switching output.

If multiple devices are used next to one another in a small space, two further options for suppressing mutual interference can be selected via the teach input: synchronization mode and multiplex mode. Here, the inputs of the affected devices are electrically connected to one another so that they can communicate with each other. In synchronization mode, all sensors generate an acoustic pulse at the same time or in synch and then switch to receive. In multiplex mode, on the other hand, only a single sensor generates an acoustic pulse and then switches to receive to evaluate the echo before the next sensor is activated.

Ultrasonic sensors with IO-Link interface open entirely new potentials of this device technology for a very broad range of applications. Shown in the middle is an ultrasonic sensor with beam columnator with which, e.g. filling levels can be monitored through even the smallest openings.

6.5 WIDE RANGE OF SOLUTIONS IN THE AREA OF OPTICAL SENSORS

In the area of optical sensors, ipf electronic has also expanded its portfolio of solutions with IO-Link interface. The spectrum here spans from forked light barriers, angular light barriers, through-beam sensors, retro-reflective sensors, scanning retro-reflective sensors, to energetic sensors and sensors with background suppression and sensors that measure distance.

6.5.1 FORKED/ANGULAR LIGHT BARRIERS AND THROUGH-BEAM SENSORS

The series of forked and angular light barriers with IO-Link interface comprises devices of various size and light source such as red light and lasers.

One example of this is, among others, the **OG500572** forked light barrier, which is exemplary of devices that have been tried and tested for decades and have gained new features and functions thanks to IO-Link technology. This forked light barrier replaces its predecessor but has the same dimensions and can be used in the usual manner via the standard settings. Thanks to the IO-Link interface, the solution does, however, have new features which would have required multiple devices in the past. For example, it is possible to select from various operational modes, such as higher response speed, finer resolution or lower sensitivity to soiling. Moreover, time functions can be assigned to the switching outputs, the switching behavior varied (normally open/normally closed, NPN/PNP) and the control elements on the device locked.

Especially interesting are the additional functions available via IO-Link such as the current measured value of the receiver element. In a concrete application, it is thereby made apparent how much light reaches the receiver or what the object properties are (translucency) so as to enable an effective switching point setting. In addition, the internal device temperature (current, min/max) can be used to determine the respective environmental conditions at the operation site of the forked light barrier. And the data of a switching operation counter can also be transferred via IO-Link.

ipf electronic also offers numerous solutions with IO-Link with through-beam sensors as well, such as the two devices shown in the figure (**OE050175**, **OS050075**) in very compact M5 design with a housing made of V2A stainless steel. There are absolutely no adjustment options present on the devices themselves.

If several of these through-beam sensors are operated next to one another, IO-Link can, however, be used to set modulation frequencies for each light barrier to prevent them from interfering with one another. Moreover, the switching threshold and the operational mode can be set for the system to standard, high resolution or high speed. Time delays or a normally open/normally closed switchover for the signal output are also available via IO-Link. Additional information and data, such as the current and maximum internal temperature, a detection counter reading or a stability alarm, can likewise be transferred via IO-Link and thereby complement the various options that this technology offers for the devices.

Among the through-beam sensors with IO-Link, there are also some especially compact solutions. Via IO-Link, the modulation frequencies, among other things, can be set separately for each light barrier.

6.5.2 RETRO-REFLECTIVE SENSORS FOR TRANSPARENT OBJECTS

Unlike through-beam sensors, retro-reflective sensors with IO-Link integrate transmitter and receiver in one device. One solution with very special features is the **OR270478**, which can detect even transparent objects independent of their shape and material thickness.

The system consists of an optical sensor and reflector and operates with extremely short-wave, polarized UV light with a wavelength of just 275nm. Due to its physical characteristics, the sensor's short-wave UV light is unable to penetrate transparent materials, which would otherwise be very difficult to detect. This means that objects like these are no longer seen as transparent by the retro-reflective sensor, instead they are detected as non-transparent objects.

Retro-reflective sensors with IO-Link. At the left is the **OR270478**

As already mentioned above, the IO-Link interface offers a number of application-specific adjustment options here as well and, moreover, supplies valuable data. It is thereby possible to, e.g. set the response sensitivity of the devices and select the operational mode (standard, high resolution, high speed) as well as the teach procedure. For the two switching outputs, different time functions can be activated in addition to the adjustable switching behavior (normally open/normally closed). Thanks to IO-Link, these devices also pass on the current temperature as well as maximum internal temperature and transfer a stability signal that provides information about how reliably the system in use detects objects.

6.5.3 AUTO-REFLECTIVE SENSORS WITHOUT REFLECTOR

Like retro-reflective sensors, auto-reflective sensors with IO-Link interface also integrate transmitter and receiver in one device but do not require a reflector. Sufficing instead is a surface such as a machine part that then serves as a reflector. If an object passes through the detection range of the red light beam, it is interrupted and the switching output of the sensor changes its status.

The **ON330571** and **ON430570** with IO-Link interface function like retro-reflective sensors but require no reflector for operation.

With respect to IO-Link, auto-reflective sensors are similar to retro-reflective sensors. For example, the response sensitivity can be set and the teach procedure selected (teach only reference surface/teach object and reference surface). For the switching output, on the other hand, time functions can be activated. With these devices as well, IO-Link enables the transfer of a quality signal to immediately detect how reliably the system detects objects. The so-called quality threshold can also be adapted here.

6.5.4 ENERGETIC DIFFUSE REFLECTION SENSORS WITH INTENSITY DIFFERENTIATION

Energetic diffuse reflection sensors from ipf electronic with integrated IO-Link interface operate according to the principle of intensity differentiation. If the amount of light reflected by the object reaches or exceeds the preset threshold, the device switches on. If only a small amount of light is reflected by the object to be detected (intensity), the sensor does not emit a switching signal. The design of the system means that diffuse reflection sensors reliably detect all objects that reflect sufficient light, i.e., objects that reflect enough light for the switching threshold to be exceeded. Thus, only objects with sufficient reflectivity can be reliably detected.

The **OT059170** with IO-Link reliably detects all objects that reflect sufficient light, i.e. objects that reflect enough light for the switching threshold to be exceeded.

The main IO-Link functionalities of these devices are nearly identical to the previously listed properties: Selection of the operational mode (normal, high resolution, high speed), time functions that can be activated for the switching output as well as the setting of the switching behavior (normally open/normally closed), the transfer of a detection counter reading as well as the current and maximum internal device temperature. How reliably a diffuse reflection sensor detects an object is immediately made apparent here as well by means of a stability signal made available via IO-Link.

6.5.5 OPTICAL DIFFUSE REFLECTION SENSORS WITH BACKGROUND SUPPRESSION

IO-Link capable optical diffuse reflection sensors with background suppression from ipf electronic detect objects and materials in their sensing range independent of the surface color. Because the effective sensing range is not dependent on the object that is to be detected with these devices but rather on the previously set sensing distance, interfering backgrounds can be reliably suppressed.

Added value through IO-Link: the optical diffuse reflection sensors with background suppression **OT450521**, **PT330570** and **OTQ80576** (from left).

In the following, the main IO-Link functions of the individual device series are briefly presented. For the diffuse reflection sensors of the **PT33** and **OT45** series, the switching point and the switching hysteresis can be set with millimeter precision or different teach procedures activated. A quality signal can be transferred via IO-Link and its response threshold set. If desired, an alarm signal for indicating device errors is also available via the interface. Both the switching behavior (normally open/normally closed) as well as time functions can be activated. In addition, the control elements on the devices can be locked or the time until they are locked can be defined via IO-Link.

For the sensors of the **OTQ8** series, IO-Link transfers not only the measuring distance but also the switching signal, a quality signal and an alarm signal. A switching operation counter is available via IO-Link for which a switching function (limit value or area monitoring) can also be activated. After, e.g. a specified number of switching signals, one receives an additional switching signal here.

The switching output for the object distance can also be used for limit value or area monitoring. Furthermore, switching points can be entered directly or corresponding teach procedures activated for stationary and moving objects. The switching function (normally open/normally closed) can also be used to activate various time functions. For the sensors of the **OTQ8** series, IO-Link enables the selection of various operational modes (standard, high resolution, high speed) and the output of the internal device temperature for diagnostics. In addition, the transmitter LED can be switched off for maintenance purposes and a sort of "positioning function" used via the integrated signal LEDs to more easily identify the position of a sensor in unclear areas or in more complex systems by means of permanent flashing of the LEDs. As with all IO-Link sensors, the control elements of the **OTQ8** devices can be locked via the interface.

6.5.6 INTELLIGENT MEASUREMENT OF PATH, DISTANCE AND POSITION

Distance-measuring sensors with IO-Link determine the path, the distance and the position of objects with various surface properties.

As a laser sensor (laser protection class 1), the **PT230020** with switching output and analog output features a very large measuring range from 0.1 to 5m and, like the **OT430025**, which operates with a point-shaped light beam, can easily be adjusted by means of teach-in. In addition to degree of protection IP67, the **PT230020** is also available in a higher degree of protection IP69k for especially demanding applications.

The extremely compact **OT430025** enables distance measurement in a measuring range from 50 to 400mm, features not only an analog output but also a switching output that can be configured as, e.g. an alarm output and is also characterized by a high resolution from 0.1 to 1mm.

High range as with the **PT230020** (left) or a compact solution with high resolution like the **OT430025**, everything with added intelligence thanks to the IO-Link interface.

While the sensors of the **PT23** series have only one switching output on the device itself, two switching outputs are available via IO-Link for the solutions. After installation, the exact measuring distance to the object and the signal quality can be determined via the IO-Link interface. In addition, the measurement characteristic curve and analog characteristic curve can be inverted and the offset as well as the measuring range defined. The limit values can be preset with millimeter accuracy. If necessary, an averaging function can be activated to calm the measurement signal.

Via IO-Link the analog output offers either 4-20mA or 0-10V as measurement signals. The two switching outputs, in turn, can be configured fully independent of one another, whereby the switching behavior (normally open/normally closed) and the switching function (limit value/area monitoring) can also be set here. The switching points are set with millimeter accuracy via the IO-Link interface; the need-specific activation of various teach procedures for stationary and moving objects is likewise performed via the IO-Link interface. Various time functions for the switching outputs can be activated via IO-Link with these devices as well. Data such as operating hours and switching operations are also available for diagnostics. As with the **OTQ8** optical diffuse reflection sensors with background suppression, the transmitter LED can be deactivated for maintenance activities with the **PT23** and the internal signal LEDs used for sensor location.

Thanks to IO-Link, the devices of the **OT43** series can be used to transfer the exact measuring distance, the signal quality and an alarm signal. The switching output/IO-Link data is configured ex works as an alarm output and can be changed by means of IO-Link. With respect to the measurement and analog characteristic curves, the measuring range and averaging, the same functions are available as with the **PT23** thanks to the IO-Link interface. The "virtual" switching output of the **OT43** series made available by IO-Link can be used for monitoring (objects in the measuring range, inadequate signal quality) or for area monitoring.

Range limits can be specified or taught with millimeter accuracy for the monitoring of a switching range. For monitoring or diagnostics, parameters such as measuring range limits, switching range limits and quality parameters are also output.

All sensors can generally be reset to the factory settings and the current device status queried via IO-Link.

7. SUMMARY AND CONCLUSION

Associated with the entry into or transition to the digital future of production with IO-Link is a manageable amount of effort, thereby making it relatively easy to realize. On the sensor side, only the existing devices are to be replaced by solutions with IO-Link and wired to the IO-Link master. The new sensors can then be used as usual.

The IO-Link capable devices are, however, now able to exchange process and service data with a systems control unit. In addition, they offer a multitude of functions that are not available in devices without IO-Link interface. Thanks to the diversity and flexibility of the IO-Link technology, there are often opportunities to replace multiple versions of a sensor solution with a single IO-Link capable device that combines all advantages of the predecessor versions as well as additional practically-oriented features.

In the area of sensor technology, IO-Link solutions open an entire range of options for device-specific settings and configurations. The main points are summarized in the following. As the statements in this white paper illustrate, on a global device level the selection of the operational mode of a sensor (e.g. standard mode, high resolution or high speed) is among the most important aspects. For sensors with analog output, it is generally possible to flexibly select various measurement signals via IO-Link, e.g. 0-20mA, 4-20mA or 0-10V. Because of the IO-Link interface, such devices can also perform additional functions which are otherwise only available in sensors with switching output, thereby significantly increasing the flexibility and, thus, the potential areas of use.

For devices with switching output, IO-Link enables the selection of, e.g. both the switching behavior (normally open/normally closed) as well as the switching function (limit value/area monitoring). In the case of limit value monitoring, the switching points can, in this context, be set very precisely in the millimeter range. It is also possible to activate on an as-needed basis various teach procedures, such as for stationary or moving objects, as well as various time functions. If present, multiple switching outputs can be configured independent of one another.

IO-Link sensors significantly simplify not only the installation but also ensure reliable operation through optimum device positioning during installation right from the start as they are able to transfer the exact measuring distance as well as the signal quality.

During use, on the other hand, the IO-Link devices generate data such as operating hours and number of switching operations and can transfer an alarm signal. They thereby supply, among other things, valuable information and insight that enable a timely response before a sensor fails. IO-Link sensors thus form the basis for much more economical, condition-oriented (predictive) maintenance strategies flanked by cost-efficient, minimized warehousing due to a significantly reduced need for device solutions.

The positive effects of the IO-Link technology on the various levels of a production system are very wide-ranging. In addition to the already mentioned simpler installation and optimized maintenance, these include more efficient operation (due to, among other things, the central remote access of all sensors via IO-Link) as well as a noticeably increased system and machine availability that is also accompanied by greater flexibility in production.

Given the arguments and concrete solutions presented in this white paper, it cannot be a surprise if IO-Link technology gains in acceptance on the sensor and actuator level, whereby the demand has further strengthened on account of the increasing digitization as a megatrend. According to the Profibus User Organization, with 5 million devices in 2020, more IO-Link solutions were ordered than ever before. The communication standard has thereby reached a growth rate of 31 percent.

As a supplier of IO-Link sensors, ipf electronic is convinced that this growth will continue or will remain on a high level and is therefore systematically expanding its extensive selection. Thanks to the decades of experience in a wide range of industries and application areas, ipf electronic is both a competent and reliable partner, especially in regard to the future requirements on IO-Link solutions.

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