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Collecting data from industrial sensors in case of 4-th industrial revolution

P Michalski
Silesian University of Technology, Faculty of Mechanical Engineering, Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Konarskiego 18A, 44-100 Gliwice, Poland

E-mail: piotr.michalski@polsl.pl

Abstract. Smart sensor technologies are undeniably the front line in the IIoT today. IoT sensors armed with self-diagnostics and digital network proficiency are addressing a number of process and discrete industry requirements ranging from reducing maintenance to increasing overall equipment effectiveness (OEE) as well as digitally capturing the knowledge of skilled workforce. Plus, smart industrial sensors are ruggedized, are suitable for an industrial setup and are manufactured to withstand extreme temperatures, pressures, and vibrations. Consequently, these solutions are leading to a new generation of smart machines alongside representing a crucial step in the journey of IoT-enabled operational excellence. The article describes contemporary ideas associated with the use of IO-Link technology industrial sensors, and points to the direction of development of modern in cloud SCADA applications like Smart Observer, using process data exchange interface between the sensors and cloud users.

1. Introduction

If Observing trends in the industry, based on leaders of industrial sensors, we can try to define common development directions [1,5,8,10]. On the one hand, companies ensure that the products offered are diversified to ensure a unique character and to convince the customer that the selected product has been designed using the latest available technologies, efforts have been made to inspire thinking about the factory of the future (Industrial Revolution 4.0), and above all so that the end customer wants to have it. Building the "desire effect" provides the manufacturer with a partnership with the customer and motivation to develop an improved version of the device. On the other hand, there are some common features resulting from the direction of information technology development.

Access via Ethernet - this is one of the key words to convince us to choose a product. On the wave of recent initiatives of the German government (aimed at supporting the development of the German economy, directly related to the strategic Industry 4.0 initiative announced in 2013), among other things, it was possible to access process data from any level of the automation pyramid. Until now, the sensor parameters have been accessed thanks to built-in user interfaces, most often based on a simple segment display and a few buttons that control the selection or validation of several functions. The sensor after manual configuration most often cooperated with programmable logic controllers. The PLC controller, due to the processor's load minimization criterion, made only selected parameters available to SCADA systems. Today, the offered products are to provide access to all process data for maintenance engineers as well as production and logistics managers. More developed solutions ensure access to data for SCADA or SAP software agents responsible for creating current performance reports, demand for material needed for production, or determining the next planned technological downtime (associated with the need to replace tools controlled by sensors). Thanks to this approach, the controller's processor is freed from the necessity of handling this stream of information and could focuses only on the assumed machine control applications [2,3,6,7].

Sensors in the Cloud - It is hard not to be enchanted by the possibilities provided by the Ethernet interface built in modern sensors (or in concentrators that allow attaching from several to a dozen sensors), however, it is necessary to realize the consequences following the application of this solution. The process of data processing requires a cybernetic space that allows the collection and processing of large amounts of information. Users are forced to invest in IT infrastructure that provides sufficiently large storage space. They may decide to build their own Data Center or use the offer of external cloud service providers. Undoubtedly, new investments are related to expenses and considerable expenses. The question is whether is it worth investing in new technologies? This question is rather rhetorical, the essence of the matter is the right moment to invest in new technologies?

The classic life cycle of the product includes the following phases: market introduction, sales growth, market maturity (i.e. achieving full development), decrease and withdrawal of the obsolete product. In the marketing phase there is a small sale and almost zero profit. The product is not yet well known on the market, which is why sales are slowly growing. This moment is the best to invest in new technologies. The investment cost is acceptable high, but the lack of competition makes it possible to recover the incurred expenditures. The profit of the end customer, whose production lines, thanks to new sensors, become even more flexible (capable of quick conversion of production, enabling prediction of emergency states, and at the same time more energy-efficient) is growing rapidly. The most benefit is gained by those who are one of the first to introduce new solutions in the sales growth phase. A good strategy for the company will therefore be to observe trends on the industrial automation market. Each new product, which will create new opportunities, increases the benefits, should be noted in the phase of introducing it to the market. From now on, attention should be paid to those sections of our production in which the implementation of the new solution will bring the best profits and initially plan its implementation. The moment when the product sales increase occurs is the moment when it is worth implementing the modification plan into force.

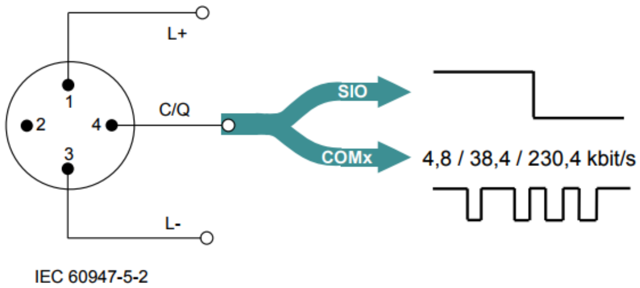
2. Experimental

The life phases of industrial sensors must always be strongly correlated with the expectations of end customers. Even the oldest solutions for mechanical limit switches are still available, and are constantly being improved. Sensors of this type have certainly reached the phase of market maturity. Classic contactless proximity sensors from induction, capacitive and magnetic groups aspire to this phase. Optical sensors continuously develop measurement methods, increasing their precision, reducing the dimensions of the housing. The sales growth phase now includes sensor solutions for all groups equipped with an IO-Link interface, thanks to which it is possible to quickly configure sensor parameters. This trend is very noticeable, and the statement "IO-Link ready" has become one of the determinants of a good product [11,12]. For example the companies such as Balluff and ifm electronic, declare that this interface will be implemented in all newly manufactured sensors. Other significant suppliers such as Turc, Pepperl + Fuchs and Siemens join this strong group. The above-mentioned manufacturers increase the range of products offered for cooperation with IO-Link devices. In addition, the software industry that supports this interface is developing strongly. Access to parameterization of sensors from mobile devices such as tablets or smartphones is a reality. All the sensors that are equipped with the Ehternet interface based on the TCP / IP or UDP / IP protocols in the wired and wireless versions are included in the marketing phase. It is expected that, soon, IoT devices (Internet of Things) will be increasingly promoted and the prices of individual products will decrease significantly. Currently available products most often from the group of optical quality control (industrial cameras detecting the presence, the arrangement according to the preset pattern, controlling matrix codes, or recognizing the correctness of printing) and devices from the group of vibro-acoustic control machines rotating (diagnosing the condition of bearing wear, axes balance, etc. .) continuously develop application and session layer software that enables the user to easily and quickly configure, review historical data or reconfigure. These software are definitely in development, but it can be said that they will play a key role in the development of 21st century sensors.

If we take the benefits of implementing modern technologies seriously and we have a limited modernization budget for the company, it is advisable to carry out current investments taking into account compliance with new technologies. If we have to replace the sensor after a failure with a new one, it is worth making such a sensor to have a conformity certificate, eg with the IO-Link interface. At the moment, several companies offer these products at the same price as the classic solutions. This approach can be crucial when the moment of further modernization takes place. In the first stage, when IO-Link devices are included in the existing application, they will work as classic - providing a typical PNP or NPN signal in the window (FNO, FNC) or hysteresis function (HNO, HNC). In the second stage, after the modernization involving the use of the IO-Link concentrator, the range of new possibilities will increase significantly. First of all, our sensor will start digital communication, which will ensure a constant reading of the process parameter, will be insensitive to interference, allow full control over the display, buttons, remote configuration and even over energy saving modes such as switching off the sensors at the moment when a given part of the process technology is not active. In addition, such concentrators are able to cooperate with SCADA or SAP systems providing process information bypassing the PLC

3. Results and discussions

The single-drop digital communication interface (SDCI) technology for small sensors and actuators (commonly known as IO-Link) defines a migration path from the existing digital input and digital output interfaces for switching 24 V devices as defined in IEC 61131-2 towards a point-to-point communication link. Thus, for example, digital I/O modules in existing fieldbus peripherals can be replaced by SDCI Master modules providing both classic DI/DO interfaces and SDCI. Analog transmission technology can be replaced by SDCI combining its robust ness, parameterization, and diagnostic features with the saving of digital/analog and analog/digital conversion efforts [11].



Pin	Signal	Definition	Standard
1	L+	24 V	IEC 61131-2
2	I/Q	Not connected, DI, or DO	IEC 61131-2
3	L-	0 V	IEC 61131-2
4	Q	"Switching signal" DI (SIO)	IEC 61131-2
	C	"Coded switching" (COM1, COM2, COM3)	IEC 61131-9

Figure 1. SDCI compatibility with IEC 61131-2 [11].

As shown in figure 1, the IO-Link concept is based on the behavior of a typical M12 industrial connector. The location of the power pins (pin 1 and 3) has been preserved. Functionality of the basic output pin (pin 4) has been extended - it is possible to use it in two ways: Q - switching signal of digital input (so called SIO – which stands for Standard I/O), and C – codes switching (by mining of digital serial communication base on COM1, COM2 or COM3 which are responsible for different speeds of transmission, respectively 4,8 / 38,4 / 230,4 kbit/s).

At the stage of machine design, it is therefore possible to maintain a standard 3-pin industrial sensor cabling system. There is no need for special cabling. In the scope of planning the selection of the appropriate industrial sensor, the purchase of a device equipped with an IO-Link interface should be considered.

Many sensors and actuators nowadays are already equipped with microcontrollers offering a UART interface that can be extended by addition of a few hardware components and protocol software to support SDCI communication. This second operational mode uses "coded switching" of the 24 V I/O signaling line. Once activated, the SDCI mode supports parameterization, cyclic data exchange, diagnosis reporting, identification & maintenance information, and external parameter storage for device backup and fast reload of replacement devices. Sensors and actuators with SDCI capability are referred to as “devices” in this standard. To improve start-up performance these devices usually provide non-volatile storage for parameters [10,11,12].

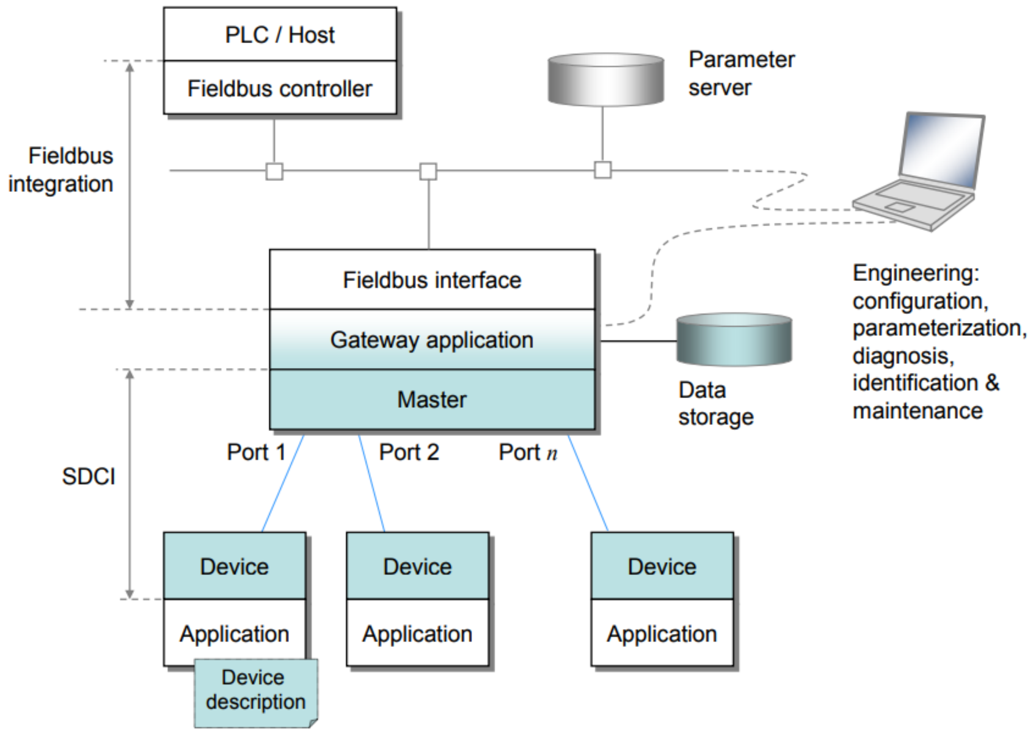


Figure 2. Positioning within the automation hierarchy [11].

Figure 2 shows that SDCI devices has to be connected to the concentrator, which is a master of the IO-Link interface. A Master accommodates 1 to n ports and their associated data link layers. During start-up it changes the ports to the user-selected port modes, which can be INACTIVE, DI, DO, FIXEDMODE, or SCANMODE. If communication is requested, the Master uses a special wake-up current pulse to initiate communication with the device. The Master then auto- adjusts the transmission rate to COM1, COM2, or COM3 and checks the "personality" of the connected device, i.e. its VendorID, DeviceID, and communication properties. It is typical that master is at the same time the gateway to the fieldbus interface such as: Profibus, Profinet, Ethercat, Powerlink, etc. Gateway application included inside the master electronic allow to support additional connections to data storage system. This simple topology shows that machine designer needs to project the space for master of the IO-Link system which is already collector of the signals and cable path for power supply and fieldbus interface. From this point of view it is easy to use one collector for different signal, which is different from the equally popular interface it is AS-interface [5]. Also on the stage of preparation of the project of electrical part it is much more easer to create drawings (there less of them and the structure is much more transparent). On this stage is also more extra benefits for automation engineers, because IO-Link system supports bidirectional transmissions of cyclic and acyclic data. That fact is very robust because the process parameters of each sensor could be changed from the level of PLC or HDMI device. Figure 3 shows the basic relationship between nature of data and transmission types. All of the benefits are well visible.

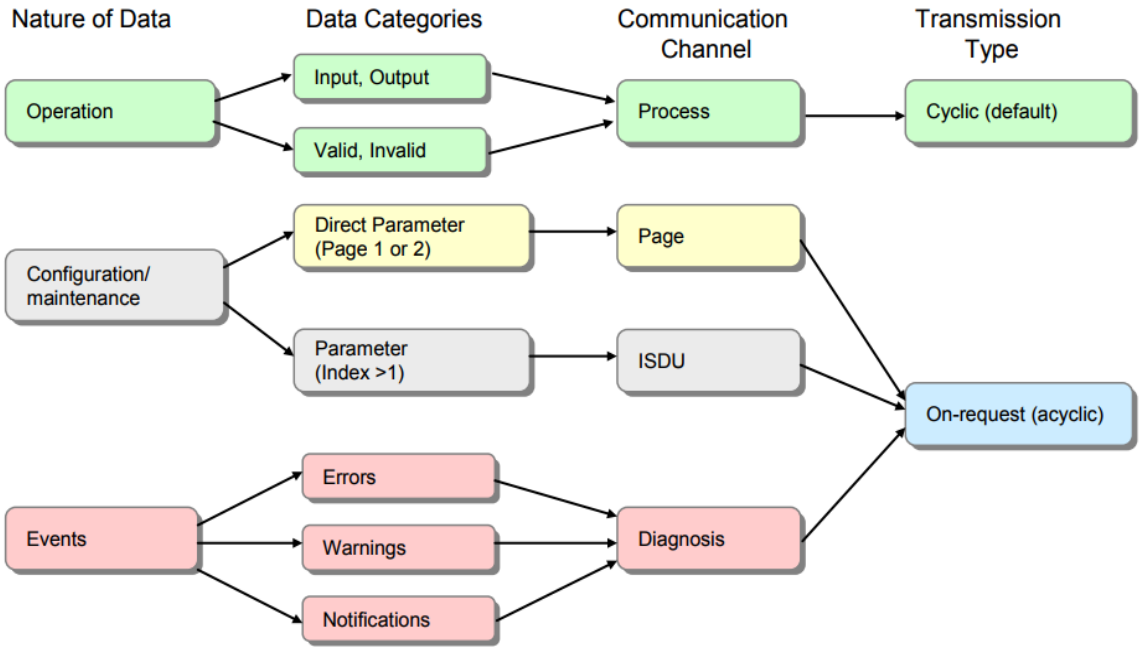


Figure 3. Relationship between nature of data and transmission types [11].

Data of various categories are transmitted through separate communication channels within the data link layer, as:

- Operational data such as device inputs and outputs is transmitted through a process channel using cyclic transfer. Operational data may also be associated with qualifiers such as valid/invalid.
- Configuration and maintenance parameters are transmitted using acyclic transfers. A page channel is provided for direct access to parameter pages 1 and 2, and an ISDU channel is used for accessing additional parameters and commands.
- Device events are transmitted using acyclic transfers through a diagnostic channel. Device events are reported using 3 severity levels, error, warning, and notification.

The first octet of a Master message controls the data transfer direction read/write) and the type of communication channel. A device may receive process data (out) to control a discrete or continuous automation process or send process data (in) representing its current state or measurement values. The device usually provides parameters enabling the user to configure its functions to satisfy particular needs. To support this case a large parameter space is defined with access via an Index (0 to 65535; with a predefined organization) and a Subindex (0 to 255). The first two index entries 0 and 1 are reserved for the Direct Parameter page 1 and 2 with a maximum of 16 octets each. Parameter page 1 is mainly dedicated to master commands such as device startup and fallback, retrieval of device specific operational and identification information. Parameter page 2 allows for a maximum of 16 octets of Device specific parameters. The other indices (2 to 65535) each allow access to one record having a maximum size of 232 octets. Subindex 0 specifies transmission of the complete record addressed by the Index, other subindices specify transfer of selected data items within the record. Within a record, individual data items may start on any bit offset, and their length may range from 1 bit to 232 octets, but the total number of data items in the record cannot exceed 255. The organization of data items within a record is specified in the IO Device Description (IODD). All of those gives a very simple and powerful communication system. Using this standard the user of the end machine is support by process data as well as information about implemented devices and their special parameters or event information which are generated automatically by the device (i.e. errors, warnings or notifications). Additionally the gateway application implemented in the master unit is able to push the process data to the external systems responsible for data processing i.e. for the needs of predictive diagnosis or looking for trends.

4. Conclusion

This approach simplifies the maximum number of components in the way of industrial automation from sensor to PLC. Instead of: multi-core cables, intermediate boxes, connectors, terminals, hundreds of cable descriptions, automation systems integrator chooses increasingly clear industrial network bus. Therefore, let us not refrain from modern solutions, we will not run away from them. In line with the principle that you will not earn the one who does nothing, let us plan the modernization of our technological line in advance in terms of benefits stemming from it.

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