Intelligent, IO-Link connected sensors underpin the Industrial Internet of Things

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Factory automation environments are currently experiencing a massive surge in the number of sensors deployed. These sensors measure everything from temperature to proximity and weight to pressure, as well as a host of other variables. The key trend is smart sensors. Traditional industrial sensors simply communicate an analog voltage/current, or a digital on/off signal. Smart sensors communicate critical parameters enhancing the agility of modern factories and enabling rapid process decisions. Furthermore, these smart sensors add critical pieces to the Big Data resource that will eventually allow for better plant optimization and/or predict the maintenance and/or failure of critical systems.

While there are various communication protocols for sensors, the fastest growth is now occurring with the new and open standard called IO-Link. This simple interface, based on the popular 3-wire sensor cable, allows users to build relatively inexpensive sensor systems with a minimal set of components. The simplicity of this sensor protocol has resulted in a double digit compounded annual growth rate (CAGR) of IO-Link sensors deployed within the control and automation market. IO-Link can be used wherever analog or digital sensors were previously used—and it provides significantly more information and affords higher levels of configurability of each sensor.

This article looks at emerging IO-Link sensor protocol in detail, and show real-life designs of various IO-Link based sensor systems. It also details how these sensor systems can be utilized to provide relevant information within a factory automation environment

Introduction to industrial IoT

While much of the industry buzz has been around Internet of Things (IoT), many large companies have been quietly implementing and deploying an industrial version of IoT. This is primarily to gain operational efficiency, but also to better serve their customers and to grow their revenue by offering more services around their product.
Maybe one day all the toasters and washing machines will connect to the Internet to give us IoT, but the value of doing this is unclear. What is not unclear is the value of monitoring the health of your servo drive in the factory—by analyzing the sensor data sent to a local controller. The value of the investment in that sensor, communication channel, and data analytics software are evident in the scheduled downtime of the servo drive and in the early warnings of impending failure. This leads to an optimized assembly line operation.

But wringing out operational efficiency is the starting point for the benefits accrued by the Industrial IoT (IIoT). Capturing and understanding the data across a manufacturing assembly line is a core expertise that can be used to generate more value-added services and even entirely new sources of growth for an enterprise.

A recent research report from PwC writes, “In the future, successful companies will use the Industrial Internet of Things to capture new growth through three approaches: boost revenues by increasing production and creating new hybrid business models, exploit intelligent technologies to fuel innovation, and transform their workforce.”

To enable the IIoT, first we must extract the valuable data from the different end-points within the manufacturing flow. This data is in effect the lifeblood of the industrial Internet, as all the higher end processes rely and operate on this data to deliver the promised benefits of the next generation digital factory.

Sensors are integral in both process and factory automation systems, and there is indeed a proliferation in the number and the intelligence of the sensors deployed on the factory floor.

**Trends in industrial sensors**

The two key trends we see are that sensors are getting increasingly smaller and the information that they collect/transmit is increasingly more complex. These two system level trends are directly influenced by the need to collect and analyze an ever-increasing volume of data from the factory—this is the key for the deployment of IIoT.

**Figure 1** shows a tiny IO-Link proximity sensor with an IR receiver, matching IR LED driver, IO-Link transceiver, and energy-efficient step-down converter all on an 8.2mm x 31.5mm printed circuit (PC) board. The high level of semiconductor integration allows us to build an entire sensor subsystem in such a small form factor.
Proximity sensors detect the proximity of certain objects, and so we can get away by transmitting a simple digital signal (ON/OFF) that signifies proximity. However, in many cases, modern sensors have to detect and transmit more information—for example, the color detected or the distance from a certain object. This is when we have to use a simple, robust yet effective communication protocol such as IO-Link.

Since the 1980s, industrial field buses have allowed smarter devices, quicker installations, reduced wiring, and easier maintenance. However, the lack of a single, universally accepted field bus has also created confusion, training challenges, high costs, and compatibility issues among equipment. IO-Link is the first open, field bus diagnostic, low-cost, point-to-point serial communication protocol used for communicating with sensors and actuators.

**IO-LINK: An introduction**

IO-Link has been adopted as an international standard worldwide (IEC 61131-9) for the communication with sensors and also actuators. This powerful point-to-point communication is based on the long-established 3-wire sensor and actuator connection without additional requirements regarding the cable material.
IO-Link is not a fieldbus nor is it based on any fieldbus—this is a point-to-point communication protocol between a slave and the master system. The best way to think about IO-Link is that it is kind of like a USB for sensors—simple to use and implement, and capable of providing intelligent data from smart sensors. IO-Link is still used in a small portion of the sensors worldwide. Research from IHS projects that a majority of industrial sensing networks still rely on fieldbus technology, as conveyed in Figure 2.

![Figure 2: Share of communication protocols within industrial sensors](image)

The connection between an IO-Link Master and slave is via a maximum 20ft long 3-pin cable (M12 connector for most IO-Link devices).
The IO-Link master establishes the connection between the IO-Link devices and the automation system. As a component of an I/O system, the IO-Link master is installed either in the control cabinet or as a remote I/O communicating via regular fieldbus networks to the controller.

Three transmission rates (baud rates) are specified IO-Link Specification V1.1:

- COM 1 = 4.8 kbaud
- COM 2 = 38.4 kbaud
- COM 3 = 230.4 kbaud

An IO-Link slave device supports only one of the defined data transmission rates. The IO-Link master supports all data transmission rates and adapts itself automatically to the data transmission rate supported by the slave. IO-Link finally standardizes interoperability within different types of industrial sensors used all over the world. An IO-Link enabled sensor can communicate directly to an IO-Link Master module in the PLC or to a gateway that can communicate to the PLC via a fieldbus.

The key advantage of this protocol is the ease of use for deployment and maintenance.

It is estimated by the IO-Link Association that by the end of 2015, there were about 112 IO-Link member companies and over 3,000,000 sensors deployed world-wide that use IO-Link. While this is still a fraction of all the automation sensors used, the IO-Link sensor CAGR is over 40%.
Example IO-LINK based sensors

**Figure 4** shows an IO-Link based temperature sensor reference design based on Maxim’s IO-Link transceiver and an integrated (resistance temperature detector) RTD-to-digital converter IC. A rugged, on-board female M12 connector allows off-the-shelf RTDs to be connected to the board using a standard M12 extension cable. The temperature sensor performs accurate temperature conversions to 15-bit resolution with multiple fault detection features. A display shows coarse temperatures rounded to the nearest °C, while the IO-Link communication tracks and provides fine temperature values.

![Figure 4: Maxim’s IO-Link based temperature sensor reference design](image)

**I/O expansion with IO-LINK**

PLCs use digital inputs more than any other I/O types and it is becoming common to see multiple 16-channel or 32-channel IO modules on even a compact PLC. Running wires in parallel back to the PLC for industrial digital inputs is not only expensive but also creates a wiring rat’s nest that is difficult to maintain.

One way to simplify this is by using an IO-Link aggregation module such as the K20 module developed by Siemens. As shown in **Figure 5**, The IO-Link K20 module allows up to eight binary
sensors to be collected outside the cabinet and connected to an IO-Link port over a three-wire connection. This means significantly less wiring overhead and more space in the control cabinet.

Figure 5: IO-Link K20 module from Siemens
Maxim has also developed a 16-channel Digital Input (DI) to IO-Link module that fits on a small 53.75×72mm (PCB).

The reference design shown in Figure 6 consists of an industry standard Maxim IO-Link device transceiver (MAX14821), an efficient high-voltage step-down converter (MAX17552), a Renesas® ultra-low-power 16-bit microcontroller (RL78) utilizing TMG TE’s IO-Link device stack, and two Maxim digital input serializers.

Of course, all sensors are not connected directly to the factory’s programmable logic controller (PLC). This is increasingly true when you have hundreds or thousands of sensors distributed plant-wide and at external locations. To accommodate communication with this disparate array of sensors, they are aggregated via gateways.

Shown here in Figure 7 is Comtrol’s IO-Link Master gateway that combines the benefits of the IO-Link standard with the EtherNet/IP® and Modbus TCP protocols. This IO-Link Master effectively shields the PLC programmers from the IO-Link complexities by handling those complexities itself. The result is simplified EtherNet/IP and Modbus TCP interfaces, and decreased system development
time and installation efforts.

Figure 7: The IO-Link to industrial Ethernet/fieldbus interface can be made with a gateway device like the Comtrol IO-Link Master shown here. Graphic courtesy of Comtrol 6.

Conclusion

As IIoT becomes a requirement to optimize resources and assets, sensors will have to get smarter and communicate more effectively with the control system or even with the optimization software. IO-Link has the potential to become the dominant standard for factory automation systems since it is low-cost, robust, and most importantly, an open standard that is being increasingly deployed across industries.

References
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Also see:

- Industrial Internet of Things and its impact on the design of automation systems
- Building the IoT: standards and hardware needs
- IO-Link transceiver halves power dissipation