

Selecting the right industrial communications standard for sensors



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Greater factory connectivity and control is ushering in what has been named the fourth industrial revolution, after the earlier revolutions of steam power, assembly lines and early automation.

This movement advances machine-to-machine communication with exponential growth in data, bandwidth and networking, creating so-called smart factories with more responsive automation at all levels.

Although large systems such as robots and coordinated assembly lines capture attention, the automation they enable would not be possible without the sensors and actuators that are busy communicating with the programmable logic controllers (PLCs) that run production lines. Sensors and actuators, functioning both locally and remotely, often greatly outnumber the complex systems they support. Optimizing overall factory communications is necessary to meet the wide variety of requirements from systems of all sizes.

Protocols adapting Ethernet to industrial usage have proven popular as fieldbuses on the factory floor. These industrial Ethernet protocols such as EtherCAT® and Profinet offer high bandwidth, long physical connections, low latency and deterministic data delivery, among other features required in automated manufacturing. In addition, the field networks based on these standards tie in easily to the larger plant data networks and the Internet. However, for sensors and actuators, industrial Ethernet is often excessively robust and powerful. These systems usually require point-to-point communications rather than a fieldbus, and their bandwidth requirements are normally low. An innovative solution lies in IO-Link, a bidirectional communication protocol based on standard cabling and physical interconnection. IO-Link not only brings data from the factory floor to the PLC efficiently, but it also supports improved setup, diagnostics and maintenance, and is complementary to the existing fieldbus cabling.

Since IO-Link and industrial Ethernet are complementary, it can benefit designers of networked factory systems to understand how the two standards work together. This white paper explains the differences between these technologies and discusses the range of solutions from Texas Instruments (TI) that can aid in industrial communication design. TI offers large portfolios of products supporting communications in general and overall industrial applications. A number of TI solutions are specific to communications in industrial automation, created with and backed by expertise gained from long-term relationships with customers. With strength in manufacturing technology and in-depth design support, TI can help industrial system developers strive to meet the needs of today's smart factories.

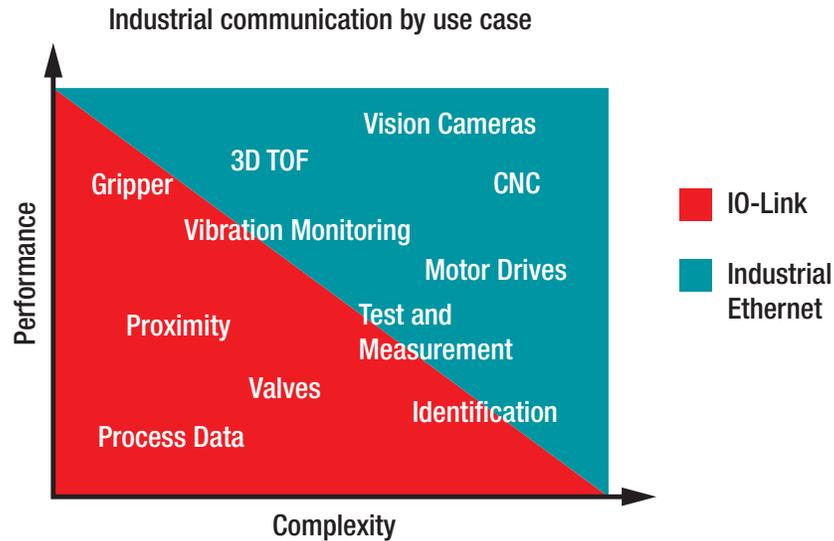


Figure 1: Industrial communication by use case.

IO-Link for low bandwidths

Sensors and actuators are the most basic units of automation, feeding information into and acting on instructions from networked systems. Traditionally, these devices connect to control units through interfaces that provide little intelligence, and thus exchange little or no configuration and diagnostic information. Installing a new device requires configuration by hand at the point of use, and without diagnostics it is impossible to perform just-in-time preventive maintenance.

IO-Link (International Electrotechnical Commission [IEC] 61131-9) is an open standards protocol that addresses the need for intelligent control of small devices such as sensors and actuators. This standard provides low-speed point-to-point serial communication between a device and a master that normally serves as a gateway to a fieldbus and PLC. The intelligent link established enables ease of communication for data exchange, configuration and diagnostics.

An unshielded three-wire cable as long as 20 meters, normally equipped with M12 connectors, establishes an IO-Link connection. Data rates range up to 230 kbps with a nonsynchronous minimum cycle time of 400 μ s, +10%. Four operating modes

support bidirectional input/output (I/O), digital input, digital output and deactivation. Security mechanisms and deterministic data delivery are not specified. A profile known as the IO Device Description (IODD) contains communication properties; device parameters; identification, process and diagnostic data; and information specifically about the device and manufacturer.

The many advantages of an IO-Link system include standardized wiring, increased data availability, remote monitoring and configuration, simple replacement of devices and advanced diagnostics. IO-Link permits factory managers to receive sensor updates and plan for upcoming maintenance or replacement. Swapping out a sensing or actuation unit that needs replacement and configuring a new one from the PLC through the IO-Link master eliminates manual setup and reduces downtime. Switching production remotely from one configuration to another without visiting the factory floor facilitates easier product customization. Factories can upgrade production lines readily to IO-Link, since it is backwards-compatible with existing standard I/O installations and cabling. Altogether, these capabilities result in reduced overall costs, more efficient processes and greater machine availability.

Field Level Communication

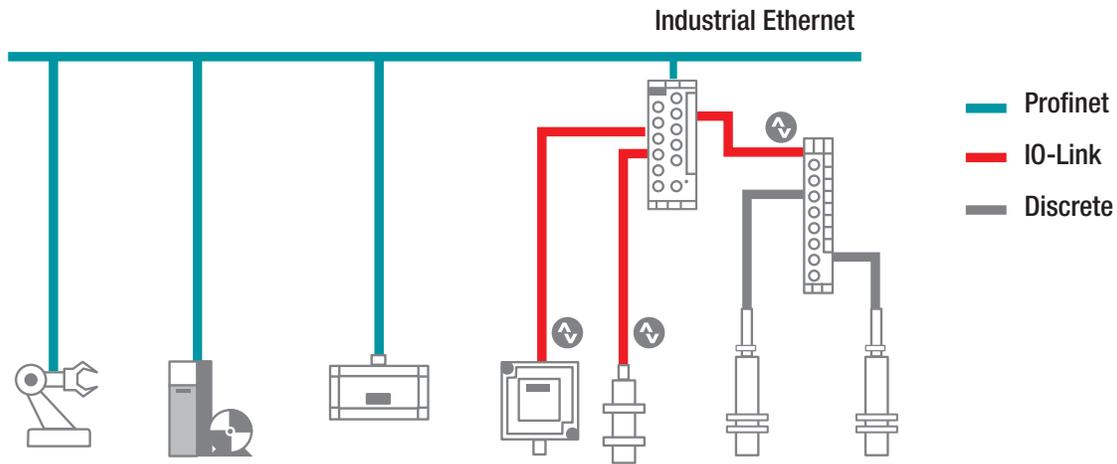


Figure 2: *Field Level Communication.*

Industrial Ethernet: the backbone of the smart factory

In recent years, industrial Ethernet has demonstrated its value in highly automated factories, becoming the standard of choice in large field networks that include complex systems, PLCs and gateways to support intercommunication with external networks. Benefits such as high speeds, common interfaces and long connection distances have made Ethernet ubiquitous for data networks. In addition, industrial Ethernet uses a modified Media Access Control (MAC) layer to provide deterministic data delivery with low latency and support for time-triggered events. Support for ring and star topologies, as well as traditional in-line connection, ensure safety and reliability in the case of a disconnected cable.

Industrial Ethernet is not a unique single specification but a large group of differing protocol implementations driven by various industrial equipment manufacturers for implementation in field-level applications. Popular protocols include EtherCAT, Profinet, Ethernet/IP, Sercos III and CC-Link IE Field, among others. The white paper [“An inside look at industrial Ethernet communication protocols”](#) compares these protocols and discusses

older, non-Ethernet serial fieldbus protocols such as Control Area Network (CAN), Modbus and Profibus.

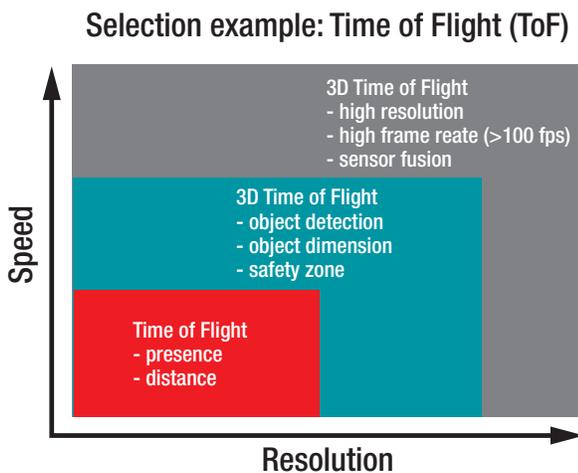
Two of the most widely used protocols, Profinet and EtherCAT, illustrate how the types of industrial Ethernet differ with each other and with IO-Link. Both are specified at 100 Mbps transmission speeds and over distances up to 100 m. Profinet requires power to be supplied independently of the data cable power, while EtherCAT offers a version (EtherCAT_P) that includes power and data in the same cable. Profinet supports full duplex traffic and is capable of sending packets to each node on the network. The protocol also offers three classes that allow the user to match the level of performance required to the network. By contrast, EtherCAT sends a shared frame in one direction on the network that all slaves place their data in—a scheme that supports extremely fast forwarding times.

Both Profinet and EtherCAT have faster cycle times than IO-Link with much less tolerance. Both base timing on network synchronization rather than from the start of communication, as with IO-Link. Additional protocols provide functional safety for connections. Industrial Ethernet protocols in general offer a number of services in order to simplify integration within an automation environment.

Although most sensors do not need the robust set of features offered by an industrial Ethernet connection, an important exception is visual sensing. The massive data created by a video camera is itself a sufficient reason for a higher data-rate connection than what IO-Link can offer. Visual and sometimes other types of sensing may provide essential inputs for real-time process control, thus requiring the deterministic delivery of industrial Ethernet.

For example, time-of-flight applications track and anticipate the three-dimensional movement of an object. A typical response would be a robot arm that moves to intercept the object. IO-Link may provide sufficient speed and resolution for limited sensing of presence in these applications, but industrial Ethernet offers sufficient bandwidth and low-enough latency to determine some characteristics of the object and its surrounding space. Even higher levels of identification may be possible using camera feeds via Gigabit Ethernet, but the industrial Ethernet protocols discussed here have not yet been specified at these speeds.

Figure 3: Selection example: time of flight.



TI technology for smart factory communications

Many possibilities exist among the competing industrial Ethernet protocols to serve cameras, motors, robots, PLCs and other complex systems; and even simple sensors and actuators need to operate effectively within a larger industrial Ethernet environment. With so many options for communication among automated equipment, industrial system designers need solutions that are flexible but easy to use. TI technology addresses these requirements with integrated solutions for industrial communications based on a range of standards, including IO-Link and the most popular industrial Ethernet protocols.

TI's TIOL111x transceiver family provides complete IO-Link functionality plus electrostatic discharge (ESD), electrical fast transient (EFT) and surge protection for sensors and actuators in automated systems. An evaluation module (EVM) allows you to review the devices in operation, and reference designs help speed development of transmitters, proximity switches, solenoid drivers, ultrasound and other applications.

Application designers that require greater bandwidth and deterministic timing must decide how many industrial Ethernet protocols to support in order to make their systems compatible with multiple fieldbus environments. Traditionally, adding protocols requires creating additional interfaces or interchangeable modules that plug into the motherboard. Either decision involves additional hardware design, a larger bill of materials, and a longer cycle of testing and certification.

Instead of adding hardware, the TI Sitara™ family of ARM® processors offers an integrated programmable real-time unit and industrial communication subsystem (PRU-ICSS) that supports multiprotocol industrial Ethernet.

The PRU loads industrial protocol firmware at device runtime, with options for EtherCAT, Profinet, Sercos III, Ethernet/IP and Ethernet PowerLink. The PRU-ICSS handles real-time critical tasks that you would otherwise build into an application-specific integrated circuit (ASIC) or field-programmable gate array (FPGA), thus offering an upgradable software-based solution if you need to add new features or protocols. Based on the scalable ARM core (Cortex®-A8, A9 or A15, depending on the processor), Sitara processors enable a single-chip solution for factory automation using multiple industrial Ethernet protocols.

TI offers a wide line of interfaces for industrial Ethernet and other standards such as CAN, both as stand-alone solutions and as technology modules available in other integrated solutions. Many TI network products feature reinforced isolation for the protection of circuitry and humans, and other devices provide reinforced isolation to add to designs. In-depth development support includes software, tools, EVMs and reference designs for a variety of applications in automated industrial equipment.

Technology for the future of smart factories

The growth of smart factories depends on versatile networking that matches the requirements of individual equipment units with the overall communication needs of the factory. Industrial Ethernet protocols provide high bandwidth and fast, guaranteed timing for fieldbus connections to PLCs, cameras, robots and other complex automated systems. IO-Link offers a straightforward alternative for point-to-point connection between a fieldbus master and a sensor or actuator, aiding in configuration and maintenance. TI offers a broad portfolio of solutions and flexible technology that help designers make use of these complementary standards as they create innovations in automation for the fourth industrial revolution.

IO Link Master with Sitara AM437x Processor

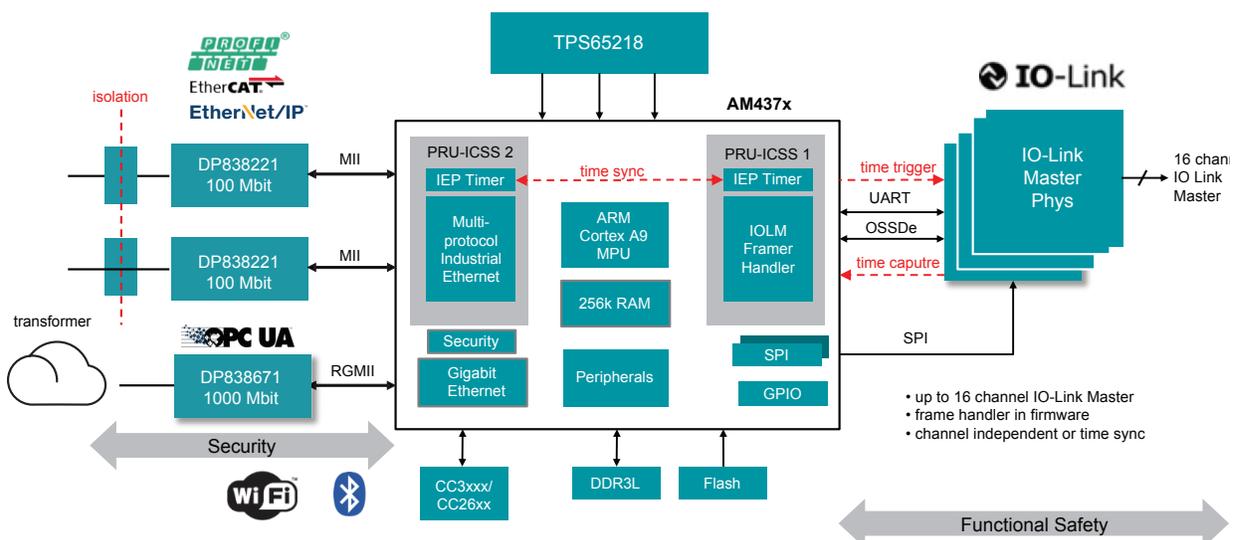


Figure 4: A Sitara™-based system that communicates directly with IO-Link Masters.

Feature	IO Link	Profinet	EtherCAT	Comment
Physical layer	<=230 kbit, half duplex, 20 meter, power in same cable	100 Mbit, full duplex, 100 meter, separate power	100 Mbit, shared packet, 100 meter, power in same cable defined	Only Profinet supports concurrent receive and transmit of packets
Topology	Point to point	Line, ring, star	Line, ring, star	Ethernet allows for large scale networks
Min. cycle time	400 μ s + 10%	250 μ s (31.25 μ s with DFP)	31.25 μ s	IO-Link allows additional tolerance of +10%
Time synchronization	Based on communication start	PTCP < \pm 1 μ s, IRT test <250 ns	Distributed clocks \pm 100 ns	IO-Link has no application time
Security	Not available	Limitations of no Profinet traffic	Not available	All need additional security protocol for IT connection
Functional Safety	Only sign of live on redundant channel	Profisafe	Functional Safety over EtherCAT	Ethernet transmission is seen as black channel
Profiles and Services	Smart sensor, fieldbus integration, firmware update, OPC UA	Profidrive, CiR, system redundancy, diagnostics	SoE, CoE, EoE, FoE, AoE, EAP	All support integration into automation network, no drive profile on IO-Link

Table 1: IO-Link versus industrial Ethernet for manufacturing field communications.

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