# Connected sensors in industrial automation

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**In today's hyper-competitive world of global markets, efficient industrial production often hinges on the speed, accuracy and reliability of each factory's automation systems. Even manufacturers in regions with low labor costs are eager to increase the sophistication of their automation systems because they know that failing to do so could jeopardize their position in the global economy.**

The heart of industrial automation – that which keeps manufacturing lines beating – is a new generation of advanced intelligent sensors connected via low-latency and real-time networks to high-performance programmable logic controllers (PLC) and Human-Machine Interface (HMI) systems.

Of course, time is money for manufacturers. An efficient production line will run as fast as possible as long as the product manufactured achieves an acceptable level of quality. Fast and reliable sensors must monitor or measure conditions on the production line very quickly, in milliseconds or less. And then the network must communicate this information with minimum latency and no interruptions. A host of industrial communications protocols such as PROFIBUS®/PROFINET®, Ethernet/IP™, EtherCAT®, POWERLINK, SERCOS® III and others are typically called upon to achieve the deterministic communications performance required. And processing elements, such as PLCs, must respond in real time with the right course of action or the production rate will suffer and profits evaporate (see **Figure 1**).

Texas Instruments Incorporated (TI) has a long history of providing high-performance efficient and scalable technology to all aspects of industrial automation. TI's extensive portfolio across analog and embedded processors enable customers to design complete system-level solutions. Innovative and highly differentiated TI solutions highlighted in this white paper make industrial communications more affordable and more accessible while driving greater automation and productivity.

## The anatomy of industrial automation

Industrial automation systems are typically made up of four major elements that are connected with each other by speed, low-latency and real-time high-speed communications. The four elements are: sensors, human machine interface, PLCs and motor drives.

### *Sensors*

Contemporary factory automation systems increasingly rely on intelligent sensors for the information and data on which they operate. Previously, sensors would monitor and measure, but not analyze. Now, as sensors have gained more intelligence, they have been able to better evaluate what they are sensing and do so in real-time. Sensors perform a very wide variety of functions, including identifying temperature, motion, optical

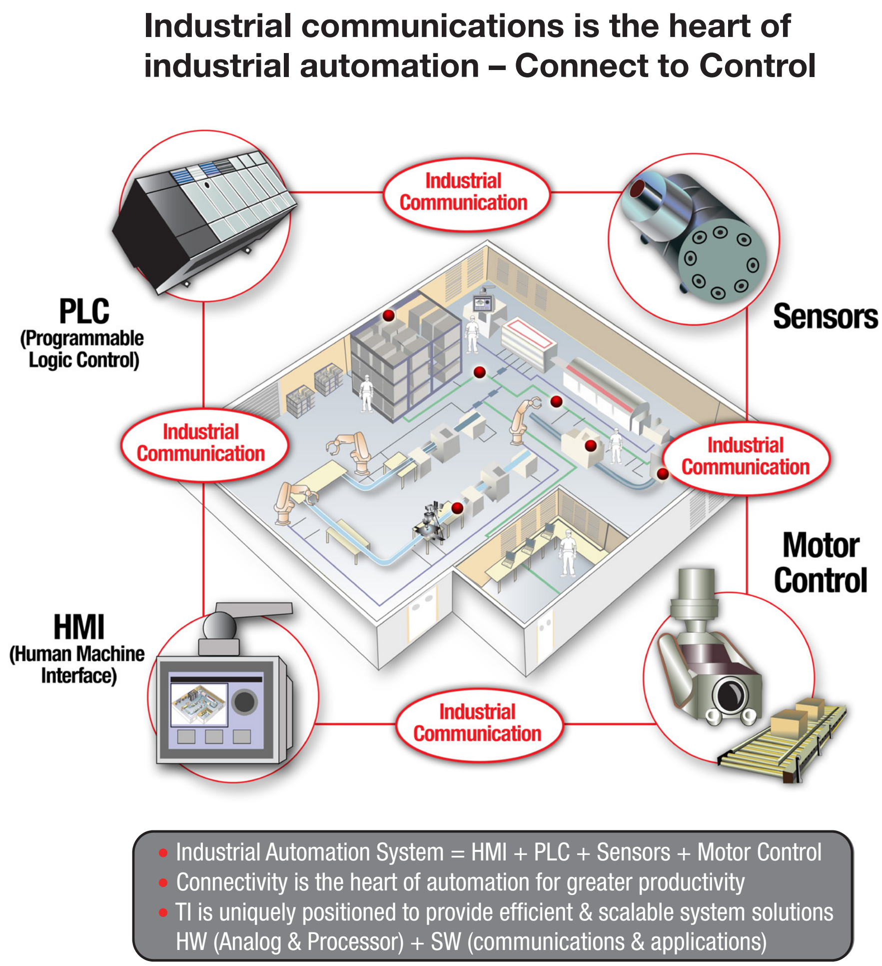



***Figure 1**. Industrial automation system with HMI + PLC + sensors + motor control.*

objects and positioning, weight, acceleration, chemical composition, gases, atmospheric or other types of pressures, liquid flow and many other aspects of the physical world.

### *Human Machine Interface (HMI)*

The human machine interface is a unit or subsystem that communicates with a person, who is controlling the machine. Given the current state-of-the-art technology, most HMIs on industrial automation systems typically incorporate a graphical display subsystem such as a touch screen because of its intuitive ease-of-use and rapid learning curve.

### *Programmable Logic Controllers (PLC)*

Generally, PLCs or programmable logic controllers are microcontroller- or processor-based systems that accept inputs from various sensors distributed throughout the factory and from the system's human operators. Based on the information provided from these two sources, the PLC will initiate actions to control the processes taking place in the production line.

### *Motor drives*

Motor drives are those machine parts that respond physically to the directions of the PLC. In an automobile assembly plant, for example, a sensor could provide input to the PLC regarding the positioning of a car body. The PLC would respond to this information with instructions to a motor control unit which, in this case, could control a robotic arm that is performing spot welding task on the vehicle.

In an industrial automation system, these four elements are brought together with a high-speed, low-latency network that ensures rapid response on the part of the PLC, resulting from sensor or operator inputs. Taken as a whole, today's industrial automation systems are real time, deterministic and highly precise systems capable of accurately controlling high-speed processes.

## Challenges ahead

The basic challenge facing industrial automation in the future will be the same as those challenges it has overcome in the past. To achieve even better results, control systems must continue to improve their real-time responsiveness, reliability, accuracy, precision and overall sophistication. Essential for meeting these challenges will be continued developments in networking and other connectivity technologies.

In the industrial automation marketplace there are currently more than 120 serial communications standards and upwards of 30 Ethernet-based protocols that can be deployed in factories today. The problem – if it is one – is not a shortage of solutions, but rather a multiplicity of them and how they have heretofore been deployed.

Each of the popular industrial communications protocols such as Profibus/Profinet, EtherCAT, Ethernet/IP and others is backed by one or more major suppliers of sensors, PLCs, HMIs and motor drives. Implementing an industrial automation system with elements from several vendors can often require deploying several of the communications protocols that are supported by the different vendors. This adds to the complexity of the overall system and can drive up costs. For instance, many of today's automation systems are typically configured with a central processing unit (CPU) to run the application and another discrete component such as an application-specific integrated circuit (ASIC) or a field programmable gate array (FPGA) that is dedicated solely to communication protocol processing. This is especially true in automation elements that are treated as a "slave" device by the communication protocol.

Most industrial automation communications protocols have adopted a hierarchical master/slave architecture. Master devices are typically PLCs or otherwise intelligent control units. Slave devices are usually the motor drives, and sensors which do not initiate actions or control processes. To achieve the fast, low-latency communications needed in the automation system's underlying network, many of these protocols have enhanced the functionality of their Media Access (MAC) layers relative to these slave devices. This places a greater local burden for protocol processing on the slave devices and results in the deployment of ASICs or FPGAs dedicated to protocol processing in the distributed slave devices. Since there are typically many more slaves in industrial automation systems than there are master devices, this drives up the cost of the overall system significantly.

## Meeting the challenges with TI

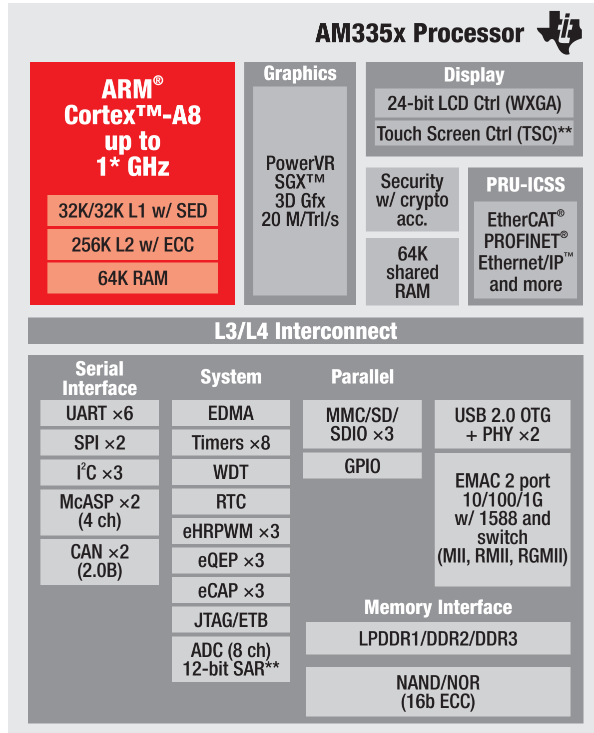
Overcoming the challenges that confront industrial automation will require advanced technology that connects and streamlines communications. TI is committed to supplying complete solutions for embedded processors, sensors, software building blocks and support tools to the makers of industrial automation systems. This technology must easily and cost effectively scale to meet the needs of the major elements in such systems – PLCs, HMIs, sensors and motor drives – and support the requirements of the hierarchical levels of slave and master devices as well. Additionally, TI focuses on providing effective support solutions that will simplify deployment of factory automation systems that are always one-of-a-kind.

The success of TI's approach has been demonstrated by the proven track record of the Sitara™ ARM®-based processors in industrial automation applications. The Sitara ARM Cortex™-A8 systems-on-a-chip (SoC) family incorporates multiple processing cores, real-time communications accelerators for multi-protocol processing, real-time and high-level operating systems, graphics processing and a vast array of other resources to meet the challenges of industrial automation for years to come.

As an example, the AM335x ARM Cortex-A8 SoCs exemplify TI's industrial automation strategy. With processing speeds from 300 to 1 GHz, AM335x SoCs can scale to meet the processing requirements of intelligent sensors to PLCs, as well as the other automation elements in between. Additionally, the low power consumption fits the AM335x processor into the tightest power budgets.

The AM355x processor is a versatile SoC capable of effectively performing practically any role in an industrial automation network. Its optional support for 2D and 3D graphics, for example, makes it particularly well suited for HMI units. In addition, with support for high-level operating systems (HLOS), such as Linux™, Windows® Embedded CE and Android™, the AM335x SoC is easy for operators to interact with in HMI and other applications. A long list of real-time operating systems (RTOS), including TI's SYS/BIOS™ and many other third-party RTOSs, give developers effective solutions for sensors and motor drives where a memory-intense HLOS is not needed and low-latency real-time performance is needed.

For connected drives and sensors, the AMIC110 SoC, designed for Industrial Communications applications, has integrated multi-protocol communications capabilities, eliminating the need for discrete ASICs or FPGAs dedicated to protocol processing. This in itself can reduce the bill of materials (BOM) costs for a slave device by as much as 40 percent. And integrating support for popular protocols like Profibus and EtherCAT into the AMIC110 SoC simplifies considerably the task of connecting a motor drive or sensor to an Industrial Ethernet network. Also, connecting the AMIC110 SoC based sensor to a factory automation system can be as simple as programming a typical PHY or UART interface, something that most industrial programmers are already very familiar with. Deployment times are shortened and costs are reduced because a steep learning curve is avoided.




** 1 GHz only available on 15×15 package. 13×13 is planned for 600 MHz.*
*** Use of TSC will limit available ADC channels.*
*SED: Single error detection/parity.*

***Figure 2**. Block diagram of Sitara ARM AM335x processors.*

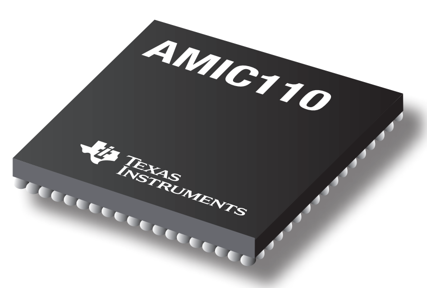



***Figure 3**. AMIC110 chip.*

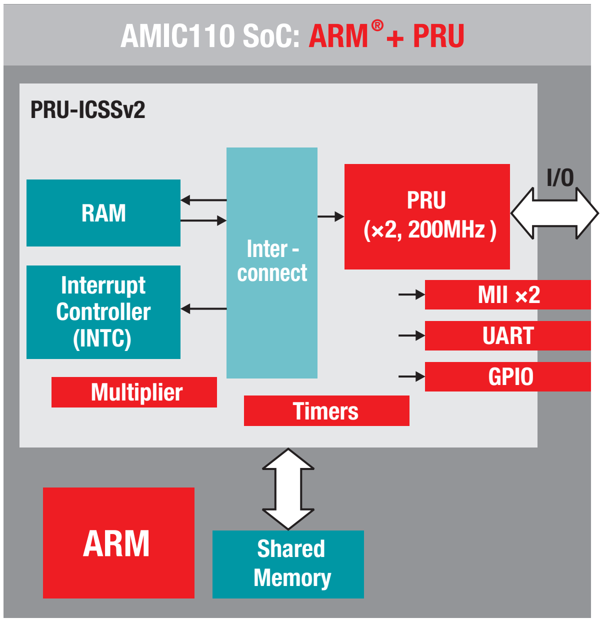



***Figure 4**. PRU-ICSS block diagram.*

Central to the success of the AMIC110 SoC embedded processor in industrial control systems is its Programmable Real-time Unit based Industrial Communication Subsystem (PRU-ICSS), which enables multi-protocol processing on-chip and ensures the requisite low-latency communications for both master and slave devices. The PRU-ICSS is made up of two 32-bit RISC processing cores running at 200 MHz. It is capable of single-cycle execution and its direct I/O interface samples at 5 nanoseconds, ensuring the fast throughput rates needed for real-time communications. The PRU-ICSS is also equipped with a complete memory subsystem made up of core-specific and shared memory, as well as a 32-bit interrupt controller. These capabilities as well as its logic, control and arithmetic make the PRU-ICSS ideal for supporting real-time slave communications interfaces for all of the popular industrial automation protocols including Profibus/ Profinet, EtherCAT, Sercos III, PowerLink, and Ethernet/IP. Because of its programmability, the PRU-ICSS can also implement custom intellectual property (IP) or a custom backplane bus.

The reliability and longevity of components are other critical criteria for industrial automation systems. Most often, these types of systems are deployed in harsh environments that can be quite challenging. And because of the time and the cost involved with deploying them, the expected useful life cycle for factory automation systems is usually quite lengthy. The AMIC110 SoC has demonstrated it is a very reliable device. It operates over an extended temperature range and can be in the power-on state for more than 100,000 hours without interruption. TI also supports longer life cycles for its Sitara family of SoCs that are targeted at Industrial applications space.

## A head start on the marketplace

TI's factory automation solutions are supported by extensive software and hardware development tools that allow automation suppliers to quickly implement their system designs with the most advanced capabilities in the market. For example, the AMIC110 SoC is supported by a simple but powerful development tool, AMIC110 Industrial Communications Engine (ICE), which provides a cost effective development environment for Industrial applications. The AMIC110 ICE is a small form factor development platform targeted at industrial communications and industrial Ethernet, such as EtherCAT, PROFINET, Ethernet/IP, Powerlink, SERCOS 111, etc. This ICE platform showcases the AMIC110 SoC in a booster pack form factor and the AMIC110 ICE can be used in conjunction with C2000 Launch pads for developing solutions for Connected Motor Drives, as well stand alone for applications such as Industrial Sensors and IOs in Factory Automation.

**The key features of AMIC110 ICE EVM are:**

- AMIC110 SoC featuring Sitara™ ARM® Cortex®-A8 and PRU-ICSS
- 512 MByte of DDR3 & 8 MByte of SPI flash
- 2x 10/100 industrial ethernet connectors with external magnetics
- 20-Pin JTAG header to support all types of external emulator
- RoHS & REACH compliant design
- EMC-compliant, industrial temp dual port EtherCAT slave with SPI interface
- 5-V input supply, single chip power management IC TPS650250 to power entire board & dual DP83822 PHYs
- 3.3V SPI interface to any host processor such as C2000 (for example via launch pads)

The unified ProcessorSDK RTOS software development environment, the PRU-ICSS application protocols (including Industrial Ethernet) and sample applications that come with AMIC110 ICE give developers a sizeable head start on their own industrial automation application.

## A competitive future

In order to meet global demand for manufactured products and processed materials, industrial automation systems will continue to improve in speed, accuracy, reliability and precision. Increasingly, manufacturers will turn to automation to improve their efficiencies, reduce costs, become more competitive and gain market share. Moreover, manufacturing companies of all sizes will strive to tightly couple their production systems with their other enterprise business systems, including supply-chain and demand-monitoring systems. As a result, the communication protocol environment will become even more heterogeneous, accentuating the importance of multi-protocol support for factory automation systems as well as the other business systems in the enterprise. The goal for manufacturers of all sizes will be to become nimble, agile and exceedingly efficient producers of products and processed materials. Leading-edge technology like TI's AM335x processors and AMIC110 SoCs complemented by an extensive analog portfolio, supported by a wide array of tools including the ICE platform, will ensure that industrial automation vendors have the capabilities they need to meet the requirements of the marketplace.

***Figure 5**. AMIC110 Industrial Communications Engine (ICE).*

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