

# INDUSTRIAL INTERNET OF THINGS (IIOT) AND ITS IMPACT ON THE DESIGN OF AUTOMATION SYSTEMS

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*Abstract: This application note examines the system architecture for an Industrial Internet of Things (IIoT). It focuses on the design challenges that must be solved to successfully implement IIoT-capable systems. Special attention is given to the growing need for more and smarter sensors, microPLCs, and the emerging IO-Link® standard.*

The Internet of Things, or the IoT, is a current buzzword gaining traction in a number of industries. A variation, the Industrial IoT (IIoT), is quite the rage within automation companies seeking to add a high-margin software component to their traditional businesses. Coming from a semiconductor chip company whose devices enable much of the automation equipment out there, we at Maxim Integrated have a unique perspective on how automation system architectures are evolving to support the IIoT.

This application note looks at the system architecture for the IIoT, and focuses on the design challenges that must be solved to successfully implement IIoT-capable systems. Special attention is given to the growing need for more and smarter sensors, microPLCs, and the emerging IO-Link® standard.

## The Path to Industry 4.0 Is via the IIoT

Siemens categorizes the industrial revolutions in three distinct phases. The first industrial revolution started with the introduction of mechanical production facilities helped by water and steam power. The second revolution began with the introduction of electric power. The third came with the advent of automation, which could be argued happened when the first programmable logic controllers (PLCs) appeared on factory floors. Now Siemens, along with the German government, believe that it is time for Industry 4.0, a new revolution when custom components will be produced in a fully automated fashion (Figure 1).

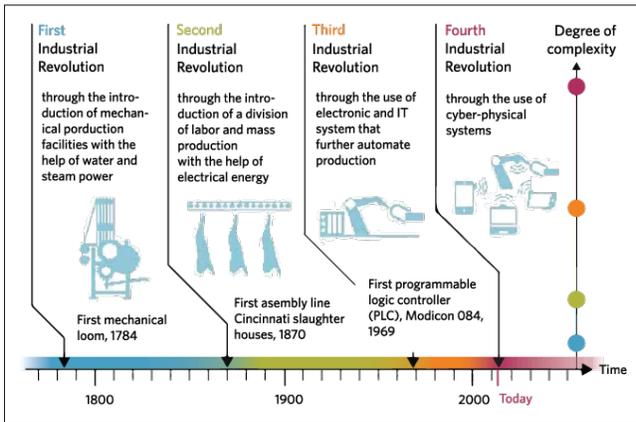


Figure 1. The path to Industry 4.0 is via the IIoT. Graphic source is: DFKI (2011).

In Industry 4.0 production from inception to delivery is based on communication among the parts to be created and the assembly line machines. Germany is pushing this IIoT movement to leverage their manufacturing and embedded software expertise within the industrial domain. In the United States General Electric (GE) is working on a similar initiative called, "The Industrial Internet."<sup>1</sup>

Manufacturing is the sector that can get the most leverage from the IoT because of the sheer amount of data captured and processed within manufacturing. And, data is the underpinning of the IIoT since it can all be analyzed and visualized to help optimize operations and costs. Within manufacturing, the intelligent sensors, distributed control, and complex, secure software are the glue for this new revolution.

## What Exactly Is the IIoT?

Industry experts and market analysts define the IIoT.

- "The Industrial Internet of Things (IIoT) is the next wave of innovation impacting the way the world connects and optimizes machines. The IIoT, through the use of sensors, advanced analytics and intelligent decision making, will profoundly transform the way field assets connect and communicate with the enterprise."<sup>2</sup>
- "Leading O&G companies are building an infrastructure where sensors, data management, advanced analytics and automation are being used to unlock production, reduce operating costs and optimize assets."<sup>3</sup>
- "The Industrial Internet, a connected network of intelligent machines working the way they are intended, will transform business as dramatically as the consumer Internet has changed our lives."<sup>4</sup>

Another way to define the IIoT is to look at industrial network in the form of layers shown in Figure 2.

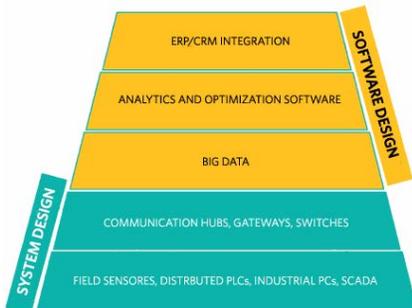


Figure 2. The automation systems stack that enables IIoT.

At the bottom of the stack are the devices (systems) on the factory or process floor. These can be field sensors, controllers, or PCs, and all of these hardware systems can include (or not) aspects of hardware security. These end devices must have useful data to communicate and are generally connected to communication hubs, gateways, and switches so that the data is put in the cloud (or an intranet) as *big data*.

Once this data is out "there," different analytics and optimization software can be developed to optimize the manufacturing assets for a myriad assortment of tasks: system uptime, scheduled maintenance, power efficiency, and more efficient resource utilization.

But that is not all. The IIoT promises that this data can be integrated within the manufacturer's ERP and CRM software. The manufacturing operation can not only be used to plan and cost out manufacturing processes more efficiently, but even to use customer information to change assembly lines and process parameters in real time.

The bottom two stacks in Figure 2 impact the design of system hardware, and the top layers affect software development and integration.

### The Critical Role of Sensors in the IIoT

The IIoT is not a mere buzzword. Factories have started using a large number of connected sensors and, by linking them to powerful computers, have begun to create the backbone of the next-generation "smart" factories. Once all of the industrial data (i.e., the "things," the "T") is finally interconnected online (i.e., the "Internet," the "I"), then complex software can be used to optimize just about anything.

A good place to find an actual IIoT is at GE's newest U.S. factory,<sup>5</sup> a \$170 million plant opened in upstate New York about a year ago. It produces advanced sodium-nickel batteries for applications that include powering cell-phone towers. The factory has more than 10,000 sensors spread across 180,000 square feet of manufacturing space; all sensors are connected to a high-speed internal Ethernet. The sensors monitor processes that determine which batches of powder are being used to form the ceramics at the heart of the batteries? How high is the temperature being used to bake them? How much energy is required to make each battery? And even what is the local air pressure? Employees with iPad computers on the plant floor can pull up all the data from Wi-Fi<sup>®</sup> nodes set up around the factory.

Airbus, headquartered in Toulouse, France, also announced that it has come quite far in applying the IIoT to create their Airbus Factory of the Future.<sup>6</sup> At a recent NI week presentation,<sup>7</sup> Airbus showcased how they have attached RFID tags to objects such as aircraft components and tools. These tags can then be read automatically from distances of up to 100 meters using special glasses (similar to a Google Glass<sup>™</sup> head-mounted display<sup>8</sup>) through which Airbus can track and visualize production processes in real time. According to Airbus, this visualization technology has been deployed on the A330 and A350 final assembly lines in Toulouse, France, and on the A400M wing-assembly operations in the U.K.

While, for now, it seems that the Airbus project is limited to digital tracking and monitoring using RFID to increase industrial operations efficiency, their concept can be extended to other types of analysis as well.

### The Promise of the IIoT

We need to be very clear about why everyone wants to make the IIoT viable. The overriding answer is systems optimization, and all the benefits that optimization usually brings. These benefits can be broken down into three primary buckets: asset, process, and business optimization...each addressed in that order. It is easier to optimize a motor than to optimize a whole drilling operation which, in turn, is easier to optimize than the many manufacturing lines of a large enterprise.

But optimizing *all* of these is the essential dream of Industrial IoT. See Figure 3.

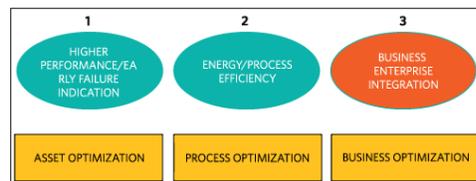


Figure 3. Benefits of the IIoT. All the factory/process data is online (cloud), so software analysis can help with asset optimization, then process optimization, and eventually business optimization.

#### Asset Optimization

The first level of analysis and interaction occurs at the edge. The data is collected from a sensor, perhaps a wind turbine sensor, or a motor encoder, or the vibration signature. This data is processed locally to help operators understand how to adjust parameters for the highest efficiency, or for an early indication of a potential failure.

#### Process Optimization

The next level of analysis happens at the control room. Here sensor data from multiple end devices and even multiple assembly lines is aggregated to enable more intelligent decisions that could positively impact factory efficiency and multiple processes. For example, with more accurate sensor data, a control room can make smarter decisions about when end devices should be idle or asleep. One positive benefit is better hardware usage and, probably, a reduced power profile.

#### Business Optimization

There is a common denominator evolving from this discussion: more data and smart data usage. We are all familiar with how data can positively impact asset usage and process operations. But the IIoT envisions not just an increase in data collection and analysis at the first two stages. The IIoT also promises to integrate the process data with the enterprise data; thus, enabling really interesting, smarter management decisions that, so far, have not been made.

Consider, for example, an assembly line that can now be programmed to manufacture higher volumes of a product enjoying a market explosion, or programmed to bypass subassemblies with diminishing market value. Even a combination of operating and financial data might be used to provide more insight to the CFO office.

The IIoT is still in its infancy and has no dominant platform standard. This is the "wild-west"<sup>9</sup> phase of the IIoT and is precisely the right time to develop and drive acceptance of a platform standard. And that is exactly what we see automation companies doing.

Successful enterprise software companies such as SAP enjoy about 30% operating margins.<sup>10</sup> Automation companies make the devices that generate all the industrial data and they have the most expertise in understanding the data. They just need to develop the software capability to process, analyze, and display this data. So when talking about industrial automation and the IIoT, these automation companies are uniquely poised to dominate the emerging IIoT.

GE is the most aggressive player in this space. A few years ago, Jeff Immelt, CEO and Chairman of GE, hired Bill Ruh away from Cisco and effectively gave him \$1 billion (US\$) to rebuild his company's entire software and analytics approach.<sup>11</sup> Ruh set up shop in San Ramon, just east of Oakland, California. In the course of 24 months, this team built a new software platform, known as Predix, and late last year, GE began to deploy it. Some of the financial numbers recently published by GE about their software business are impressive.

In his letter to share owners, Immelt writes:

We believe that every industrial company will become a software company... Our customers want our assets to operate with no unplanned downtime and optimal performance. We call our data solutions "Predictivity," and so far, we have launched 24 offerings generating \$800 million of incremental revenue. We expect Predictivity revenues to exceed \$1 billion in 2014."

GE is making considerable headway in setting up their platform as the first software platform of the IIoT

#### The IIoT Drives System Requirements

The two key system trends driven by the IIoT are quite evident in the proliferation of sensors, and the growth in distributed computing.

- Pervasive sensing. The cost of sensors and their interfaces continues to decline, enabling manufacturers to track more variables and types of data.
- Distributed control. Moving process controllers (PLCs) closer to the machines that they control eliminates bottlenecks and improves manufacturing throughput and flexibility.

#### Sensors Are Everywhere

There are some public reports that estimate the growth of the sensor market. BCC Research looks at the global market for sensors in various applications, including biosensors, chemical sensors, image sensors, flow sensors, and level sensors. Another company, Emerson, is largely looking at process field sensors.

- "Sensor market was valued at \$79.5 billion in 2013 and is expected to increase to \$95.3 billion in 2015. This is estimated to reach \$154.3 billion by 2020 with a compound annual growth rate (CAGR) of 10.1% from 2015 through 2020." BCC Research, Wellesley, MA, 2014 report
- "Pervasive sensing expected to more than double the existing \$16B measurement market by helping production facilities enhance site safety, reliability, and energy efficiency in new ways." Emerson Process Management

Researchers have different estimates for the size and the growth of the sensor market. But it is clear that, as the need for analytical data grows, the need for sensors to collect this data grows as well. The broad sensor market is projected to rise at a double-digit compound annual growth rate (CAGR) and this is increasingly true for industrial sensors.

The phrase "pervasive sensing," coined by Emerson and used above, implies that sensors are installed everywhere. It also means that the sensors enable, or will soon enable factories, refineries, chemical plants, and other industrial facilities to gather more data about the processes being monitored. The aggregation of this data gives customers greater visibility to operate with greater safety, reliability, and profitability.

A byproduct of this astounding sensor growth is the expectation that the sensors must communicate more than just an ON/OFF signal. Industrial management needs real-time operational data... and this leads to one of the first system-level design trends that we can discuss.

#### The Emerging IO-Link Standard

Industry is witnessing an explosive growth of the digital IO-Link standard for factory automation sensors. The IO-Link protocol is the first open, low-cost, point-to-point serial communication standard based on standardized I/O technology worldwide (IEC 61131-9). It applies to communication between PLCs and sensors and/or actuators positioned anywhere. This powerful point-to-point protocol is based on the long-established 3-wire connection. The best way to think about IO-Link communication is like a USB for sensors—simple to use and implement, and capable of providing intelligent data from smart sensors.

The IO-Link protocol is showing explosive growth along with the rise of smart sensors. A Quest TechnoMarketing Survey of almost 200 machine manufacturing companies finds that by 2016, 47% of machine manufacturers—almost 1 in 2—will want to use IO-Link! This would triple the number of IO-Link users in the next three years.

Of course, all sensors are not connected directly to the factory's PLC. This is increasingly true when there are hundreds of thousands of sensors distributed plant-wide and at external locations. To accommodate communication with this disparate array of sensors, they are aggregated through gateways.

Shown here in **Figure 4** is Control'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 4. The IO-Link to industrial Ethernet/fieldbus interface can be made with a gateway device like the Control IO-Link Master shown here. Graphic courtesy of www.control.com.

Sensors are also getting smaller. **Figure 5** shows what we believe is the world's smallest IO-Link ambient light sensor. It can read the color value and send that information via the IO-Link connection. The entire system here is about the size of a paper clip.



Figure 5. Industry's smallest IO-Link light sensor has six integrated sensors: ambient light (clear), red, green, blue, infrared, and temperature. This light sensor uses a Maxim IO-Link device transceiver with integrated 3.3V/5V linear regulators, configurable outputs (push-pull, pnp or npn), reverse-polarity/short-circuit protection, extensive fault monitoring. This all comes in a tiny 2.5mm x 2.5mm WLP package. It also features 64KB on-chip programmable flash memory, 4KB on-chip data flash, and operates down to 1.8V.

To understand how small and integrated the underlying technology is, consider that the light sensor has six integrated sensors, each with its own on-chip dedicated PGA and 14-bit ADC inside a miniature optical 2mm x 2mm OTDFN package. An ultra-low-power Renesas® microcontroller with current consumption down to 66µA/MHz provides system control.

All the components on this IO-Link light sensor system were carefully selected to ensure that they meet the harsh conditions in an industrial environment.

#### Distributed Control with Wireless Sensors

There are key design challenges with the widespread deployment of wireless sensors within the IIoT. Some of these challenges include standards confusion, equipment interoperability, industrial safety, available bandwidth, and cyber security.

One thing is quite clear today: wireless sensors constitute a very small portion of the industrial market. The technology is still largely concentrated with North American vendors who make sensors for oil, coal, and natural gas processing. Adoption of wireless sensors across broader automated industries can still take off, once some of the distributed control challenges are resolved.

It is clear, moreover, that there is no consensus about the radio standards. In fact, this could become another fieldbus/industrial Ethernet standards war where no single standard ever emerges as the clear winner. A study done by Control Engineering<sup>16</sup> highlights the different radio standards that are prevalent today

#### Distributed Control with MicroPLCs

The IIoT requires local, distributed control. Given the number of sensors in a plant/process, it is not feasible to route each one of them to a central PLC. Instead many distributed MicroPLCs are located closer to the line that is being controlled and they drive each subassembly. This means that we need powerful, yet very small and power-efficient PLC system architectures.

The biggest problem with today's PLCs is one that no one actually sees: making the best use of the limited space on the board. Most engineers still believe that digital technology offers the best opportunity for spacing savings. Yet, digital chips typically consume a small fraction, just 15% to 20%, of the board space in PLC modules (Figure 6).

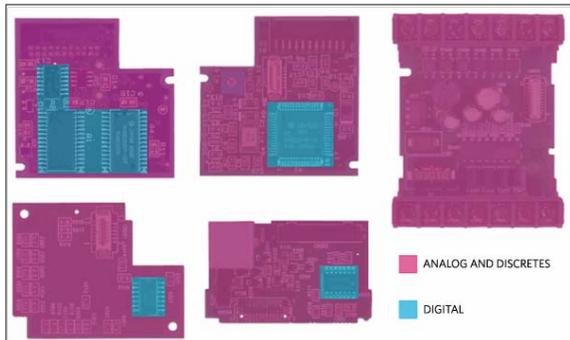


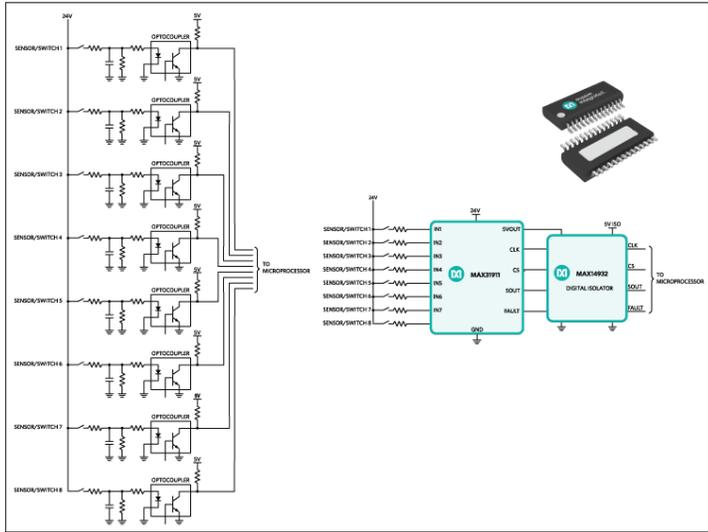
Figure 6. The system integration challenge in MicroPLCs is evident here where analog and digital components are visible on system boards.

Analog devices consume as much as 85% of available board space in PLC modules, but they do not scale like digital chips. Consequently, greater levels of analog integration are needed to conserve PCB space while delivering the required functionality. One way to shrink this tiny form factor is to use integrated analog devices instead of numerous—even hundreds of—discrete components. Board size shrinks, power consumption drops, and reliability increases.

How about an example? I/O modules are the essential link between PLCs and the countless sensors and actuators distributed throughout next-generation IIoT factories and plants. As manufacturers add more sensors across factory floors, equipment designers must push channel density ever higher, even as available space within a MicroPLC system continues to shrink.

Today, multichannel serializers like the MAX31911 can translate, condition, and serialize the 24V digital outputs of sensors and switches to the 5V, CMOS-compatible levels required by PLC microcontrollers. This approach reduces the number of isolated channels; it enables dramatic savings in power dissipation, parts count, and overall PCB footprint.

An assessment of a 32-channel digital-input module determined that multiple integrated devices lower the part count by 70% and the total solution size by 63% (Figure 7).



More detailed image.  
 Figure 7. A32-channel PLC I/O module integrates an 8-to-1 digital-input serializer (MAX31911) with an integrated digital isolator (MAX14932) to reduce part count by 70% and lowers solution size by 63%.

Analog integration is the only way to develop small-form-factor PLCs that can be sprinkled throughout the entire factory. A real-life example of this is the Siemens® Amberg factory recently visited by the German Chancellor Angela Merkel. This factory which is representative of the next-generation digital factory is controlled by 1,000 Simatic PLCs made by Siemens.<sup>17</sup>

### Conclusion

The two key next-generation system requirements for the IIoT can be broadly categorized as:

- Sensor proliferation which means smaller, intelligent, and more connected sensors. This requirement is leading to the growth in IO-Link and wireless protocols, and also to the proliferation of gateways that aggregate multiple sensors' data to a fieldbus/industrial Ethernet link.
- Distributed control of an assembly line affords low latency, flexible system control. This leads to the growth of high-I/O density, compact (or micro) PLCs located closer to the line that is being controlled. These systems have their own design challenges involving form factor, heat dissipation, and analog/mixed-signal integration.

These system requirements need innovations at both the device (IC) level as well as at the system architecture level. These newer systems are essential to realizing the promise of IIoT.

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<a href="#">MAX31911</a>	Industrial, Octal, Digital Input Translator/Serializer		<a href="#">Free Samples</a>

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