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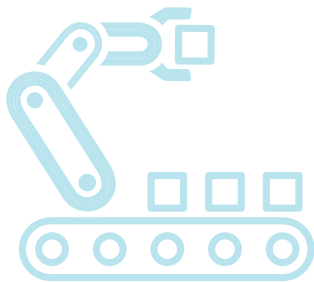
Industry 4.0

Now to



Executive Guide

Solutions to accelerate faster, smarter, and more secure industry automation solutions



Industry 4.0: Promise Meets Practicality

Industry 4.0 promises a lot: exponential improvements in productivity, flexibility, and safety; big advances in edge-to-cloud computing; powerful analytics; easy to adapt systems for mass customization; and more. You've read all the hype. The vision may seem clear but the path, and the timeline to get there, isn't. It can seem dauntingly complex and risky—not just for your business, but for your customers as well.

In his book *The Fourth Industrial Revolution*, World Economic Forum founder Klaus Schwab writes, “Contrary to the previous industrial revolutions, this one is evolving at an exponential rather than linear pace ... It is not only changing the ‘what’ and the ‘how’ of doing things, but also ‘who’ we are.”

This is much more than an accelerating technology arms race. Many business fundamentals are also in play. That's what amplifies the uncertainty. You can't afford to wait on the sidelines with first-mover advantages at stake. But you can't risk getting too far ahead of what your current customer base is willing to embrace, either. Nor can you afford to make big investments today that might quickly become obsolete and never pay off. Balancing the need for speed and risk is critical, as is the flexibility to accommodate customers across a very wide spectrum of brownfield and greenfield readiness. The need for expanded expertise in domains such as software, security, IT, and more are presenting manufacturers with difficult trade-offs and choices about where to invest, how to partner, and how to ensure organizational agility. There are no right answers or risk-free approaches in highly volatile environments like this. But there are smart, strategic options that can get you from now to next faster. This executive guide offers six effective business plays to make the most of today's Industry 4.0 opportunities supported by practical insights about what's possible today, what's coming tomorrow, and the smartest paths to get you from here to there.

In This Guide

- ▶ Industry 4.0: Promise Meets Practicality
- ▶ Tackling Big Questions
- ▶ Bridging the Standards Gap
- ▶ Product Flexibility Meets Systems Flexibility
- ▶ Intelligence Where the Data Is Born
- ▶ Security Where It Counts
- ▶ Looking Beyond the Tech

Plus, six accelerator strategies to help you navigate from now to next within these key focus areas.

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Tackling Big Questions

Industry 4.0 is simply a shorthand for a full cyber-physical integration of a company's operations. It's the Internet of (industrial) Things integrated with operations technology and business systems. This not only breaks down enterprise silos but, ultimately, enables ecosystems that link suppliers, partners, distributors, and users in a powerful value chain. This vision is being fueled by simultaneous advances in cloud computing, communications infrastructure, and edge technologies that bridge the physical and digital worlds. But connecting all those links is no simple task, especially given the tough conditions and demands of industrial environments and the interdependencies of all the individual building blocks. Today, technologies at the edge of the network (where data is born) are becoming increasingly vital to ensuring the integrity and value of information communicated throughout the system. They need to be designed with a system-level view of challenges up and down the technology stack. The technology itself is not enough. Realizing the vision of Industry 4.0 will require new approaches, engineering models, and expertise. The old conventions of "who does what" in the industrial ecosystem will be challenged and new partnerships will emerge.

These changes bring a lot of speculation about how Industry 4.0 will unfold: which emerging trends will stick and which won't; when and how critical barriers like standards and security will be solved; and how the ecosystem will evolve to allow existing and emerging players to capture value in new ways. There are plenty of thorny technological challenges to solve, but the business questions are equally significant.

Here's a sampling of typical business quandaries. Do these sound familiar?

Is there a real ROI today—for our business and our customers?

In surveys of corporate leaders, most are not wary of Industry 4.0 technologies and the opportunities they promise. Instead, the most common concerns have been about cost and feasibility. However, adoption trends and current expectations show growing confidence that the ROI potential is real. In one 2015 study, PwC surveyed more than 2,000 companies in industrial sectors from 26 countries. One-third of the respondents said their company had already achieved advanced levels of integration and digitization and 72% expected to reach that point by 2020. Over 85% of respondents expected to see both cost reductions and revenue gains from their advanced digitization efforts. Nearly 25% anticipate those

improvements, in both cost savings and revenues, to exceed 20% over the next five years. Throughout this guide, we'll also show you ways to think more broadly about ROI, and where system-level benefits and roadmap efficiencies help justify investments made at the product-level today.

Is this really the right time to invest?

Given today's uncertainty and pace of innovation, equipment manufacturers (and their customers) face a heightened risk of investments becoming obsolete before they can pay off. Balancing a sense of urgency around speed to market vs. the temptations of a more conservative wait and see approach can be challenging. The smartest investments capitalize on immediate opportunity while devoting careful attention to futureproofing and long-term roadmaps.

Is our organization ready?

There is no question Industry 4.0 will require organizations to think and work differently. It will require more agility, new skills, more collaboration between internal groups, and closer partnerships externally. And with new levels of connectivity and more interdependencies, it will require companies to adopt a more system-level approach to the problems their solving and the value they deliver.

Where do we start?

How do we integrate new capabilities and legacy systems? What about standards and security? Can we futureproof our investments as new technologies and standards emerge? How do we convince our customers we can do that for them as well? All great questions! The following guide identifies five smart plays to consider as opportunities for your business, sprinkled with practical strategies to accelerate your path.

- ▶ **Future-ready industrial Ethernet:** Bridging the standards gap
- ▶ **Software configurable I/O:** Product flexibility meets systems flexibility
- ▶ **Smarter edge technologies:** Intelligence where the data is born
- ▶ **Edge security, systems approach:** Security where it counts
- ▶ **Ecosystem allies:** Looking beyond the tech

Smart Play: Future-Ready Industrial Ethernet



Bridging the Standards Gap

The communications infrastructure is the backbone of the connected factory, so it should be no surprise that many key challenges and opportunities on the path to Industry 4.0 are related to network technology. A number of emerging trends are converging on the manufacturing environment, each adding its own layer of network demands and complexity—ubiquitous sensing, increasing numbers of connected devices, cloud computing, machine-to-machine communication, and more.

Accommodating all of this requires an unprecedented level of interconnectedness, where everything is connected to everything else (and the cloud), and where networks on the enterprise side (IT) and operations side (OT) converge. To enable this, industrial Ethernet is gradually replacing legacy fieldbus technology as the standard backbone of the industrial communication infrastructure. Its bandwidth and flexibility open the door to complex network architectures, faster and smoother operations, and more advanced analytics and automation. But since Ethernet doesn't have the inherent determinism and message reliability of fieldbus systems, OEMs have had to develop their own protocols to ensure real-time communication in time-sensitive applications. This works fine in simplified cases but when introducing multiple protocols on the same network, deterministic performance is often lost along the way. So, while industrial

Ethernet meets the core requirements for Industry 4.0, scaling it at a system or enterprise level, especially within a realistic piece-by-piece approach, still presents significant challenges.

Time sensitive networking (TSN) is a universal standard being developed at an industry level to eliminate these interoperability problems. It will unify current protocols to allow reliable deterministic communication and scalability across applications, bandwidths, across the IT/OT divide, and all the way to the edge node. However, the timing of TSN is uncertain, presenting a challenge for anyone trying to move fast with current product initiatives.

Opportunity

What can be done in the meantime to ensure new technologies integrate seamlessly into complex multiprotocol environments? And with TSN on the horizon, how do you ensure forward compatibility today to avoid further cost and disruption tomorrow? For many, it's either a choice to sacrifice deterministic performance or build customized switching technologies from the ground up. The former is often a deal-breaker and the latter can take significant time and resources, delaying time to market.

Accelerator strategy: Insist on determinism and invest in solutions that get you there faster

Determinism is an obvious requirement in many high speed applications today, but whatever the application, it can be a critical futureproofing strategy. As demand for high speed and precision operations continues to grow, today's automation and control networks should be ready to handle more critical applications in the very near term.

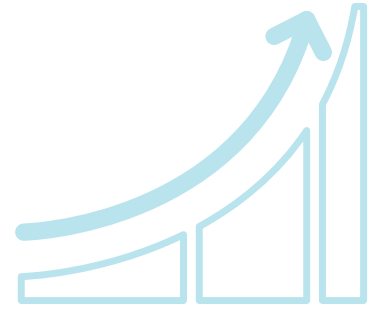
Invest in advanced multiprotocol switching solutions from partners who can help you navigate the integration challenges of today's rapidly evolving networks. These challenges cannot be underestimated—this a difficult place to go it alone without deep domain expertise. Not only is this a wise investment in speed-to-market and product reliability, but also an investment in a viable roadmap to TSN and system-wide determinism.

What to look for:

- ▶ The ability to support all major industrial Ethernet protocols in use today.
- ▶ Solutions tailored to your level of design resources and buy vs. build requirements. This is chip-level for some, and fully integrated solution-level for others.
- ▶ TSN-ready solutions with a roadmap of other enhancements to ensure your investments are part of a longer-term plan.
- ▶ Pretested and precertified solutions that reduce time-to-market and product certification risk.
- ▶ A supplier with deep domain expertise who can partner with you to solve design and integration challenges and support you throughout your roadmap.

Smart Play: Software Configurable I/O

Product Flexibility Meets Systems Flexibility



One of the driving forces behind Industry 4.0 is the increasing need for flexible systems that can quickly and easily adapt to changing requirements. This need is largely driven by changes in consumer shopping behaviors and demand for more product choices and individualization. Manufacturers can no longer rely on fixed, large-scale systems designed for mass-market products, and predictable demand. Instead they need flexible systems that can be reconfigured quickly with minimal down-time and capital investment.

A new generation of software configurable technologies is enabling OEMs to deliver unprecedented levels of flexibility to the factory floor while simultaneously reducing their own product complexity. In the case of control systems, new software configurable I/O capabilities can significantly reduce the entire control loop's dependency on costly customized I/O hardware and complex wiring. This creates a number of immediate opportunities for the end customer while laying the groundwork for the more scaled benefits of IT/OT convergence to come:

- ▶ **Flexibility and efficiency:** Machines and devices become more plug and play, allowing equipment upgrades and process reconfigurations to happen in minutes instead of hours or days.
- ▶ **Implementation speed:** New projects can be implemented much faster and at lower cost due to simplified design process and setup.
- ▶ **Seamless networking:** From field devices through to control, plant, enterprise, and cloud, allowing better analytics and more flexible automated control.

- ▶ **Mass customization:** Ultimately, the ability to quickly switch production assets from product to product, enabling small-batch production as efficiently as mass production.
- ▶ **New opportunities:** Software configurable I/O opens the door to virtualization and digital twin technologies, which promise many benefits typically afforded on the IT side of the business, but absent on the OT side.

Opportunity

Today's PLC and DCS systems are particularly good opportunities for software configurable I/O, as they are generally still reliant on big control cabinets with multiple I/O modules and specified wiring for each channel type. All that hardware requires space, power, maintenance, and significant downtime when reconfigured. Plus, from a design and implementation perspective the level of specificity and customization adds significant time, cost, and risk to a given project. The I/O hardware is designed specifically for the project, based on configurations identified early in the process. Any configuration changes over the course of the project, which are common, result in costly delays.

In contrast, software configurable I/O allows channels to be configured at any time, essentially allowing customization right at the time of installation. For OEMs, this means faster time-to-market, fewer design resources, and universal products that can be implemented broadly across projects and customers.

Industry 4.0 Delivers on Increased Productivity

See where ADI is accelerating the transition to the secure connected enterprise

Flexibility

The shift to more flexible architectures allows for greater capacity and faster reconfiguration. Using universal analog I/O (input/output) brings integration, robustness, flexibility, and efficiency with significant time and cost savings. All of which create opportunities for virtualization utilizing AI and digital twin technologies.

Efficiency

Even a 1% reduction in energy use can bring tremendous savings to a factory operator. These savings can be realized through the adoption of inherently lower power solutions that are then augmented by condition-based machine monitoring analytics.

Communications

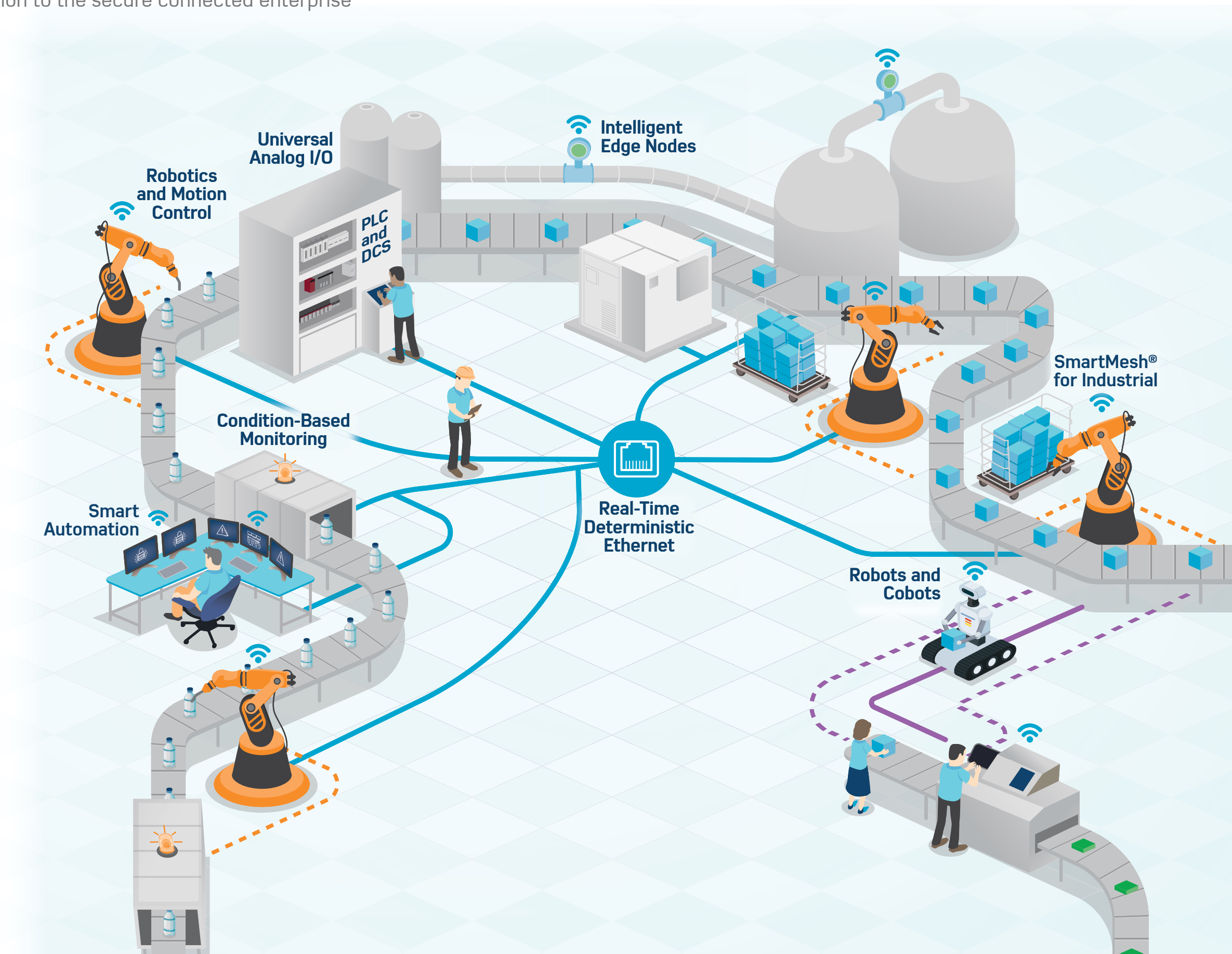
Central to the execution of Industry 4.0 is robust and secure wired and wireless communication that must support legacy standards and provide a clear path to Ethernet to the Edge and time sensitive networks (TSN).

Safety

A system is not smart if it is not safe. Functional safety is ubiquitous in automation systems with strict standardization and certifications requirements.

Security

Greater connectivity of smart machines with Industry 4.0 brings with it risks from cyber attacks. Factory operators and solution providers need to develop stronger cybersecurity strategies that are more vigilant and resilient to attack.



Smart Play: Software Configurable I/O

Accelerator strategy: Platformize product offerings to get ahead of the market with reduced risk

Software configurable I/O certainly has great potential at the operations level, but as with most new Industry 4.0 capabilities, it will take time to achieve broader adoption and convince customers of the full value. The intention of this guide is to discuss what can be done today to get ahead of the market, and software configurable I/O is a great opportunity for OEMs to begin capturing value even before creating it fully for their customers. The opportunity to “build once, adapt often” can provide immediate business benefits to the OEM, while preparing you to respond rapidly when demand catches up or (even better) take a more proactive approach to testing the market. Think of it as a way to de-risk your investment by leading with value capture instead of trying to back into it.

Delivering as much of the customization as possible in software allows you to develop hardware platforms that are significantly more universal. While it may not be realistic to develop a single I/O module that meets the performance requirements of every project, a given product line may require only ¼ the number of variants traditionally needed by giving a single module the ability to accommodate all 4 channel types (digital in, digital out, analog in, analog out). Now, as long as your module has the right total number of channels for a given project, specific channel types can be designated at the time of installation. This has a number of benefits to the equipment manufacturer:

- ▶ Faster time-to-market and lower development cost (see *By the Numbers* below)

- ▶ Ability to accommodate a wider range of customers and project types
- ▶ Streamlined inventory management (materials, components, and finished goods)
- ▶ Frees up engineering resources to work on other new opportunities, helping manage the resource volatility of your Industry 4.0 strategy
- ▶ Ability to respond faster to service and warranty issues
- ▶ Sales and marketing efficiencies
- ▶ Streamlined and de-risked product certification

As with many Industry 4.0 capabilities, which by nature derive system-level benefits from product-level features, proving ROI to customers may not be as straightforward as a simple performance vs. cost evaluation. Equipment manufacturers will need to become skilled at identifying and quantifying the hidden ROI realized elsewhere in the system, or occasionally realized later in the customer's roadmap as futureproofing strategies pay off. Equally important, manufacturers themselves will have to think more holistically about ROI, as product gross margins won't always paint an accurate picture of the opportunity. In some cases, this may even involve factoring organizational benefits as measures of return. What's the value of organizational agility and flexibility afforded by platformizing products and reducing complexity?

By the Numbers

Typical number of I/O module variants for a PLC product:

50

Typical development cost for a single module:

18 months
(man hours)
at **\$350,000**

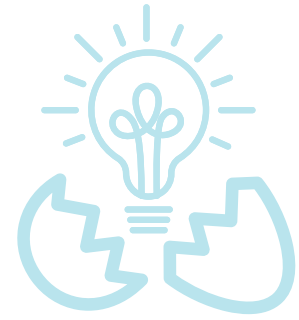
Number of module variants using software configurable I/O:

~10

Potential development savings:

\$14M

Smart Play: Smarter Edge Technologies



Intelligence Where the Data Is Born

Industry 4.0 brings sophisticated intelligence from individual elements to the entire value chain of production. These processes provide mountains of data. But if you can't make sense of it and use it in meaningful ways, much of the effort is wasted. In fact, McKinsey¹ research suggests that as little as 1% or 2% of cloud data is actually used. So, successful systems must be able to capture, sort, analyze, and report data at lightning speed with complete reliability.

Ideally, we want machines to be continuously monitoring their own physical states, environments, and processes to anticipate and communicate when there are problems. We also want them making better, faster localized decisions, often in conjunction with the other machines around them. This involves massive amounts of data, of varying types and sensitivities, serving a number of different needs in different places. It's an obvious burden on the communications infrastructure and often exceeds the capabilities of cloud software and processing to sort out that 2% of useful data with enough speed and accuracy. It also introduces considerable security risk. So as information volume and complexity continue to grow, it will be increasingly important that intelligence be distributed and optimized throughout the system instead of being overly reliant on the cloud.

By partitioning analytics throughout the system depending on where it's most needed, you create highly optimized data flows. Edge devices can deliver useful insights right where the data is born, enabling faster localized decision-making while forwarding other data to the cloud for heavier analytical needs and reporting. The result is a streamlined and highly efficient process providing more reliable outcomes and alleviating network challenges along the way.

Opportunity

Intelligence at the edge is yet another example of why it's so important take a system-level approach to problem solving and ROI opportunity, and ensure your R&D processes are able to connect the dots across domain, system, and embedded levels. Commodity-level sensing is cheap and creates the illusion that we can just put sensors everywhere and start collecting data. But if we can't trust the outcomes, it's at best a waste and at worst a huge risk. As many failed pilot programs will attest, the cheap often comes out expensive in the end.

¹McKinsey "What's new with the Internet of Things?" May 2017

Accelerator strategy: Invest where the data is born to improve the whole system

The idea of edge analytics often carries assumptions of expensive, power-hungry processing requirements. But this isn't always the case. Cutting-edge sensing technologies are now more able to extract valuable signals from the noise with extreme accuracy, and leverage embedded algorithms for real-time interpretation with minimal additional processing. So you're developing valuable insights right from the source without sending loads of raw data throughout the network. And with today's advanced MEMS technologies, this can often be done so efficiently that it actually conserves power by reducing the amount of data travelling over power-hungry communications infrastructure. Select a partner with the right mix of domain, system-level, and signal chain expertise to help you identify where investments in better sensing and measurement can provide disproportionate savings and efficiency elsewhere in the system.

Smart Play: Edge Security, Systems Approach

Secure Where It Counts

Security is one of the most critical concerns impacting the adoption rate of Industry 4.0. In an effort to create an open flow of information throughout the enterprise and unlock the potential of data, new machines and devices are being connected, operational technology (OT) is converging with IT networks, and internet connectivity is being enabled from the cloud all the way to the edge. While openness is an essential enabler for the promises of Industry 4.0, it's also creating an unprecedented level of vulnerability. And with so much at stake—from operational reliability, to safety, to confidentiality of information and IP—security breaches can seemingly outweigh the benefits of connectivity.

Security should be a fundamental risk management consideration in planning your Industry 4.0 strategy, assessing implementation readiness, and moving forward. But building security into today's increasingly complex networks is far from an established science. There is no single right way, and questions of how, where, and how much often require a case-by-case approach.

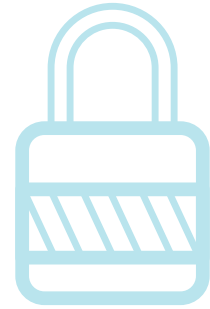
Opportunity

The increasing number of connected devices at the edge of the network is drastically expanding the threat surface for most industrial operations, which become even more exposed as IT and OT networks converge. This disrupts the traditional model of security within industrial settings, where the physical isolation of the OT network was assumed to provide inherent security. As a result, devices were not designed with security to protect themselves. Today, with potentially every device being connected and sharing data, the traditional security approach has no chance of being effective. Thus it's becoming critical that networks be protected at the device level, right where the data is born, so decisions can be made about where that data should be sent and which data should be trusted.

The edge of the network can be one of the most impactful and effective places to add security due to its simplicity. The edge generally has fewer access points, less processing, fewer lines of code, and less interoperability. Since complexity often equals opportunity for a skilled hacker, the simplicity at the edge provides a higher level of assurance that security measures will be effective.

However it's important to understand that simplicity does not equal easy in this case. In fact it's quite the opposite. First, since the chain of security is only as strong as its weakest link, building security at the edge without understanding vulnerabilities further up the stack can mean the difference between eliminating a threat and simply moving it around.

In addition, edge technologies are subject to significant constraints that often impede the ability to add new capabilities without significant cost. Power, size, weight, processing, and data management capabilities are typically more restricted at the edge than further up the stack, especially in distributed-control and field applications. So care must be taken to evaluate trade-offs and to develop a balanced and layered approach to ensure the cost of security at the edge doesn't outweigh the benefits.



Accelerator strategy: Invest (or partner) for system-level security expertise

Optimizing security requires a system-level approach instead of thinking about the requirements of any particular device or endpoint. Security can be delivered in a variety of ways throughout the system—within edge devices, controllers, gateways, or further up the stack. Before focusing on the how at any given point in the network, focus on questions of where and how much. This should be less about where the threat is and more about where there's opportunity to add effective security with the fewest trade-offs in power, performance, and latency. A layered approach will result in a superior overall security posture.

This approach requires a mix of skillsets that generally only comes together through intense collaboration. On one hand you need a deep understanding of network architectures and the ability to map and evaluate vulnerabilities across the network. On the other hand you need the domain and application knowledge to understand where and how data must be collected, processed, and used throughout an operation, and all the potential scenarios and implications of a security breach. When these factors can be looked at holistically, you can begin to triage and prioritize security requirements throughout the system.

Accelerator strategy: Build-in vs. bolting-on

The additional benefit of system-level security design is that it allows you to build-in more reliable security measures from the outset instead of over-relying on add-ons and patches down the road. While add-ons can be effective (and necessary) in some cases, built-in security is often less susceptible to workarounds and vulnerability. At the edge node, for example, embedded hardware-based security can be far less susceptible to hacks than simply adding code and complex monitoring on top of existing processing capabilities. This is a far superior and more cost-effective approach than to simply bandage and monitor for abnormalities after the fact.

The bottom line is that security is far from a simple one-size-fits-all solution, and manufacturers are wise to invest time and resources, either organically or by choosing the right partners, in a system-level approach that expands security expertise beyond the machine-level. This allows you to form a right-sized approach, minimize trade-offs, and root your security right at the data source—providing a secure foundation on which to build further.



Looking Beyond the Tech

“Industry 4.0 is not a group of technological platforms that can easily be adopted as a purely operational upgrade. It requires a clear strategy and top management commitment; the transformation of key operational activities; and a deep understanding of collaboration, across internal company boundaries and likely with other companies that share the same platforms and technologies.”—*strategy+business*, Autumn 2018

As the saying goes, never mistake a clear view for a short distance. Industry 4.0 is far more than a series of operational upgrades. This is a business revolution enabled by the convergence of powerful cyber-physical technologies that eliminate age-old boundaries. It's happening now, in real time. And there's too much at stake to stand on the sidelines. The core opportunities and challenges are rooted in bridging physical and digital worlds. The big question is how to get from now to next in a way that makes most sense for your business, your customers, and your markets. And that's rarely a question you can answer alone. Tapping into the evolving Industry 4.0 ecosystem to build alliances is a necessity. Finding the right allies—organizations that can complement, amplify, and enrich your internal expertise from both a business and technology perspective—will help you build a more robust, pragmatic strategy and accelerate your path forward.

Accelerator strategy: Partner with Analog Devices

Industry 4.0 is about building and leveraging cyber-physical systems to enable new possibilities. It is rooted in our ability to bridge the physical and digital worlds in unprecedented new ways, a domain in which Analog Devices has been a leader and pioneer for over 50 years. But we're not a typical semiconductor company—we push the boundaries of silicon technology, investing heavily in software, systems expertise, and domain knowledge within our key markets. And we combine this knowledge with an unmatched set of analog-to-digital capabilities—sense, measure, interpret, connect, power, and secure—to approach your challenges at the system-level and help you find the most optimized way to deliver outcomes and business results.

Let us help you get to market faster, create and capture more value, and make sound investments with a roadmap to tomorrow.

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