NEWS FOR THE ELECTRONICS INDUSTRY

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POWERING THE SMART FACTORY EVOLUTION

SMART FACTORIES, SMARTER INDUSTRY

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DIGITAL FACTORY OF THE FUTURE

THE RISE OF SMART MANUFACTURING

FROM PROTOTYPE TO PRODUCT

EMBRACING INDUSTRIAL REVOLUTION

DEMOCRATIZING INDUSTRIAL IOT

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Editor-in-chief: Cliff Ortmeyer, Managing Editor: Ankur Tomar

WELCOME

Power is no longer confined to the circuit, it's woven into the very fabric of modern manufacturing.
The transformation of the factory floor into a smart, connected ecosystem is no longer a distant vision. It's a reality taking shape today. Across industries, digital infrastructure is evolving to deliver unprecedented levels of flexibility, efficiency, and scalability. From predictive maintenance powered by edge AI to robust industrial networks enabling real-time insight, the smart factory revolution is redefining how we design, build, and deliver.

At the heart of this transformation lies the seamless fusion of hardware and intelligence. Smart sensors, embedded processors, secure connectivity, and cloud analytics now work in concert to drive adaptive performance and resilient operations. Retrofitting legacy systems with modern interfaces and rethinking design architectures are vital steps on the path to true Industry 4.0.

In this edition of eTechJournal, we explore the theme **"Powering the Smart Factory Evolution."** Discover how forward-thinking manufacturers are turning digital ambition into tangible advantage, transforming challenges into opportunities for agility and growth. From advanced interconnects to intelligent compute platforms and from real-time control to scalable design, this issue showcases the technologies shaping the next generation of industrial systems. Whether you're building new automation solutions or modernising existing lines, now is the moment to align your innovation with the future of manufacturing.

Let's reimagine industry - one connection at a time.

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THE RISE OF **SMART FACTORIES**

MICROCHIP

VISIT MICROCHIP

At the core of the actual industrial transformation, smart factories—central to the vision of Industry 4.0—depend on advanced digital technologies to achieve autonomous, flexible and highly efficient production processes. These factories leverage a suite of innovations.

- Advanced automation: The deployment of robots, intelligent machines and automated systems enables continuous operation with minimal human supervision, driving productivity and consistency.
- Internet of Things (IoT): An intricate web of connected devices and sensors collect and exchange real-time data across the production floor, providing unprecedented transparency and responsiveness.
- Data Analysis: The continuous flow of data is systematically analyzed to optimize workflows, anticipate and prevent equipment failures through predictive maintenance, and drive ongoing quality improvements across the manufacturing process.
- Digital Integration: Seamless connectivity links departments and every stage of production through robust IT systems, breaking down silos, enhancing synchronized operations and enabling the creation of digital twins.
- Adaptability: Thanks to the flexibility of these digital systems, production lines can be rapidly reconfigured to accommodate evolving requirements or custom orders, empowering factories to meet diverse market demands.

Together, these pillars form the foundation for a highly adaptive manufacturing environment but realizing their full potential hinges on the efficiency and reliability of the underlying communication network. A challenge that becomes even more pronounced in the demanding conditions of industrial settings.

THE CHALLENGE: CONNECTIVITY IN INDUSTRIAL ENVIRONMENTS

In today's smart factories, connectivity spans both the Operational Technology (OT) and Information Technology (IT) layers, with seamless interconnectivity between these domains serving as a cornerstone of industrial digitalization. At the OT level, however, manufacturing environments are still characterized by a patchwork of non-compatible technologies.

Heterogeneous fieldbus systems—such as CANopen, PROFIBUS, RS485/Modbus RTU and other solutions such as IO-Link, HART(4-20mA) and 0-10V —operate alongside a diverse range of industrial Ethernet standards, including PROFINET, EtherCAT®, BACnet and Modbus TCP. Proprietary solutions from leading vendors add further complexity to the network landscape.

Consequently, production sites often rely on specialized gateways to facilitate communication among these disparate devices and protocols.

This fragmented approach not only complicates integration and maintenance but also poses significant barriers to meeting stringent cybersecurity requirements, such as those outlined in the European Cyber Resiliency Act (CRA), as traditional fieldbus networks often lack built-in security features.

Further complicating matters are the harsh realities of the factory floor: strong electromagnetic interference (EMI), long cable runs that can degrade signal integrity, the sheer difficulty of replacing or retrofitting cables in legacy infrastructure and exposure to high temperatures, high humidity, dirt and vibrations. These environmental challenges amplify the demand for robust, scalable and cost-effective networking solutions that can transcend legacy limitations, unify connectivity and future-proof smart manufacturing operations.

ETHERNET'S EVOLUTION IN INDUSTRY

In industrial automation, communication was initially dominated by proprietary protocols and fieldbus systems such as PROFIBUS, Modbus and DeviceNet™. These solutions were designed for real-time, deterministic communication but were often vendor-specific and lacked interoperability. Even when Ethernet had become widespread in office IT environments, it was still considered unsuitable for industrial use due to concerns about determinism, reliability and the ability to withstand harsh conditions. Thus, early industrial Ethernet applications were limited to non-critical tasks like data collection and monitoring.

In recent decades, Industrial Ethernet protocols have emerged to address these limitations, introducing features such as real-time communication, increased robustness and support for industrial topologies. Protocols like PROFINET, EtherNet/IP, EtherCAT, Modbus TCP, POWERLINK and Sercos III became common and hardware adaptations such as ruggedized switches, M12 connectors and industrial-grade cables were introduced to meet the demands of factory environments.

The convergence of IT and OT accelerated, enabling seamless data flow from the factory floor to enterprise systems. Ethernet became the standard for new installations, especially in complex or data-intensive applications like robotics, motion control and process automation.

With the advent of Industry 4.0 and the Industrial Internet of Things (IIoT), Ethernet adoption has been further boosted as factories required real-time data, cloud connectivity and interoperability. Technologies such as Time-Sensitive Networking (TSN) are now integrated and provide deterministic, low-latency communication over standard Ethernet. Today, Ethernet is used for both control and information layers, supporting everything from sensors and actuators to cloud-based analytics.

Current trends point toward unified networks, with a single Ethernet-based infrastructure serving both IT and OT needs. In this situation Single Pair Ethernet (SPE) revolutionizes the landscape. SPE is an innovative Ethernet Physical Layer implementation that uses just a balanced pair of conductors—a single pair of conductors instead of four pairs. Figure 1 lists the different SPE implementations and briefly summarizes the advantages of SPE.

Single Pair Ethernet (SPE) – T1

- **Physical Layer implementation**
- **IEEE802.3 Standards**
  - 10BASE-T1S (10Mbps Multidrop)
  - 10BASE-T1L (10Mbps P2P)
  - 100BASE-T1 (100Mbps)
  - 1000BASE-T1 (1Gbps)

- **IEEE Standard for optimal interoperability**
- **Single Pair instead of Four Pairs - Saves Weight and Cost**
- **Speeds From 10Mbps - 10Gbps**

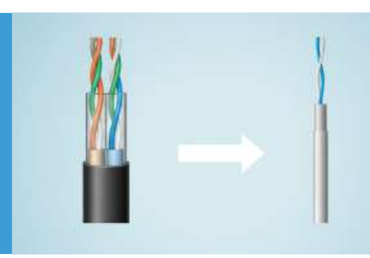


Figure 1: Single Pair Ethernet specifications. Multi-Gbps solutions are specified, but not implemented yet

WHAT IS 10BASE-T1S?

10BASE-T1S, specified in IEEE Standard 802.3™-2022, is the latest technology designed to extend Ethernet connectivity to the very edge of the network. It operates at 10 Mbit/s in half-duplex mode and supports a multidrop bus line topology, allowing multiple devices to share the same communication line.

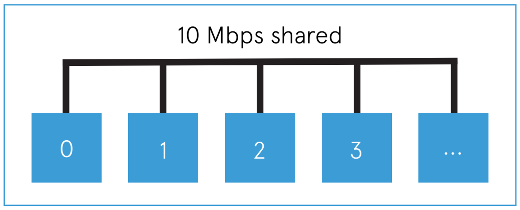


Figure 2: Bus Topology connectivity with 10BASE-T1S

The technology uses a single balanced pair of conductors and incorporates Physical Layer Collision Avoidance (PLCA) to prevent collisions on the network and achieve efficient data transmission.

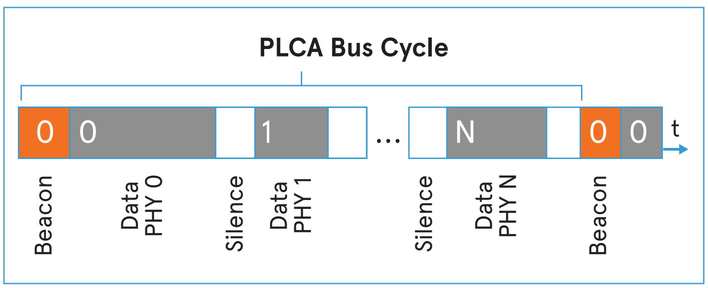


Figure 3: PLCA Bus Cycle in a 10BASE-T1S Network with N nodes

The PLCA cycle, Figure 3, makes possible 10BASE-T1S's reliable communication. This cycle divides network access into N transmit opportunities—one for each participating node. The coordinator node, typically assigned as node 0, initiates each cycle by sending out a synchronization signal known as the "beacon." This beacon marks the commencement of the cycle.

Each node receives a unique identifier and a corresponding transmit opportunity. When its opportunity arrives, only that node has permission to transmit data over the bus. If it has data ready, it sends it; if not, the slot is simply passed to the next node in line. This orderly procession continues through the entire sequence of nodes, ensuring collision-free communication.

Should a node miss its designated turn or join the network later, it simply waits for the next beacon to try again. Thanks to this method, PLCA offers equitable access for all devices and delivers bounded latency, which is critical in the time-sensitive environments of industrial automation and automotive systems.

PLCA is considered superior to CSMA/CD (Carrier Sense Multiple Access with Collision Detection) because it eliminates packet collisions on the network. If the coordinator node becomes defective and is no longer able to reliably transmit a beacon into the network, 10BASE-T1S ensures communication continuity by automatically switching to CSMA/CD mode after a specified timeout period. The following table provides a summary of the comparison between 10BASE-T1S and other implemented Single Pair Ethernet (SPE) technologies.

Name	Speed	Maximum Distance	Multidrop	Main Applications
10BASE-T1S	10 Mbps	Up to at least 25 meters	YES	Sensor networks, IoT devices, actuators, motors, racks, automotive
10BASE-T1L	10 Mbps	Up to 1000m	No	Industrial automation, building automation, distributed sensors and actuators
100BASE-T1	100 Mbps	Up to 40 meters	No	Industrial devices, transportation, automotive
1000BASE-T1	1 Gbps	Up to 40 meters	No	High-speed industrial devices, advanced automotive

Table 1: Comparison between different SPE implementations

As we can see from the comparison in Table 1, 10BASE-T1S is the only SPE implementation that supports multidrop. An Ethernet connection with multidrop capabilities is essential to take Ethernet to the edge and to connect the smart factory using a single standard technology.

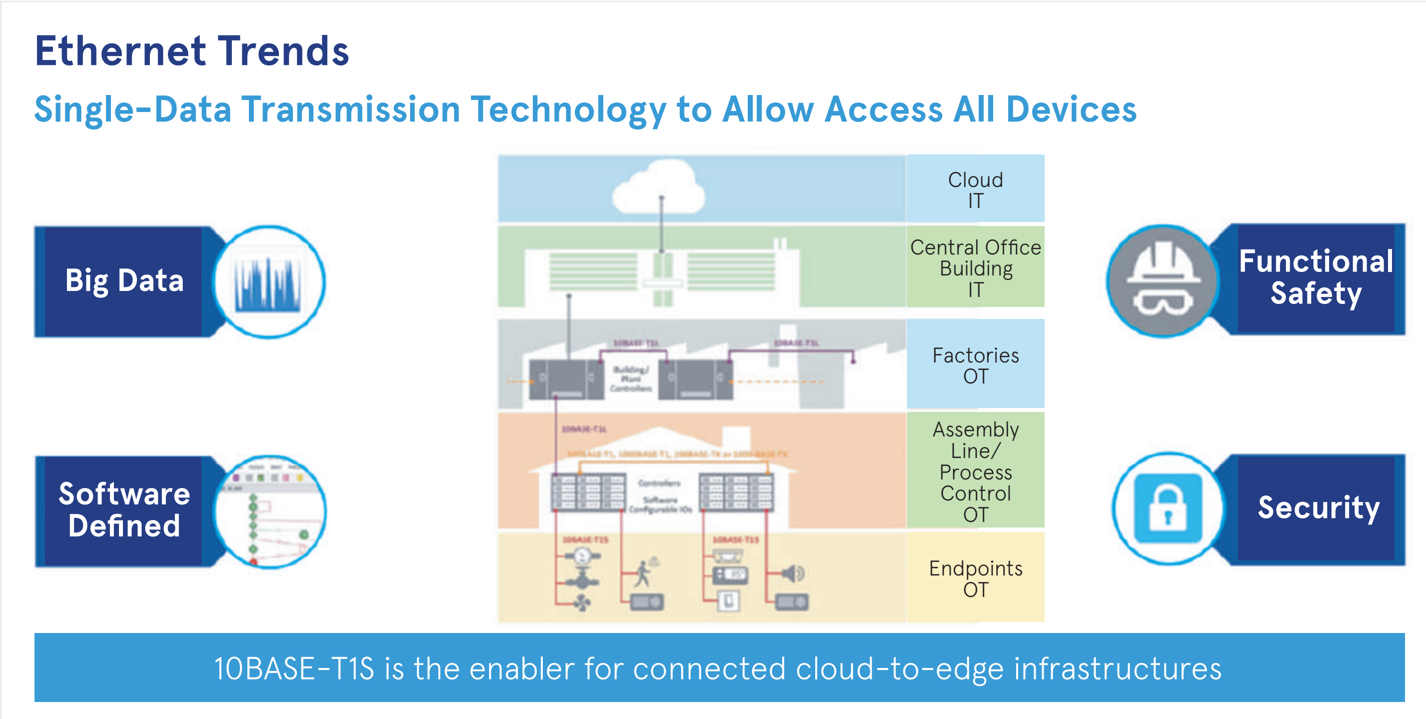
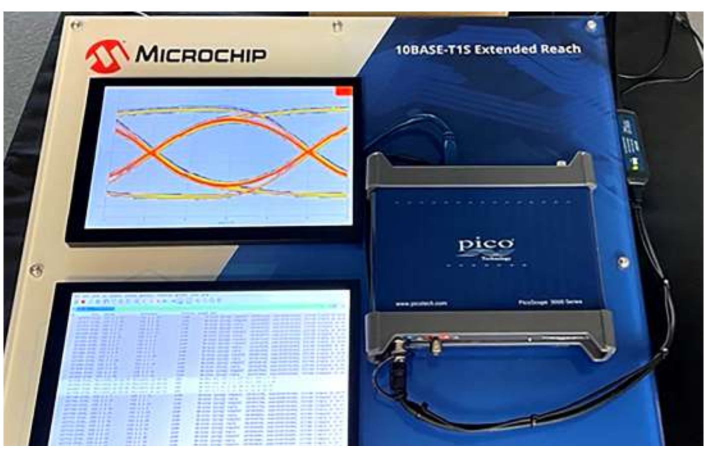


Figure 4: Ethernet connectivity from the cloud to the factory edge

Some implementers may be skeptical about 10BASE-T1S in industrial applications due to perceived limitations on bus length and number of nodes. However, the specification emphasizes signal integrity, allowing for bus lengths longer than 25 m and more than 8 nodes, provided signal integrity is maintained.

For example, Microchip Technology has developed the 10BASE-T1S Extended Reach Demo, which demonstrates connectivity of 50 nodes over a distance of 98 meters. Refer to Figure 5 for more details. The eye diagram indicates excellent signal quality within the signal integrity specifications of 10BASE-T1S. IEEE has also recognized the market needs for industrial application and has updated the specification increasing the guidelines for total network length up to at least 75 m and max number of nodes up to 16.



KEY BENEFITS OF 10BASE-T1S IN SMART FACTORIES

10BASE-T1S technology offers several key advantages for smart factory environments. Firstly, it enables significant cost savings by reducing the amount of cabling required, simplifying installation processes and lowering overall material expenses. The use of thinner cables not only contributes to cost efficiency but also enhances space utilization, allowing for easier routing in confined or complex industrial settings. Additionally, the multidrop topology permits multiple devices to connect via a single cable, which minimizes the need for numerous switch ports and reduces network complexity. This technology also ensures seamless interoperability with existing Ethernet infrastructure, facilitating smooth integration and scalability.

Furthermore, 10BASE-T1S supports Power over Data Line (PoDL), enabling both data transmission and power delivery over a single cable. This feature further simplifies installation and reduces the need for separate power supplies. Finally, 10BASE-T1S supports natively secure communication protocols that meet the requirements of the European Cyber Resilience Act (CRA), ensuring robust data protection and compliance with the latest cybersecurity standards for industrial environments.

PRODUCTS, USE CASES AND APPLICATIONS

10BASE-T1S is a standard technology and related products are implemented by different vendors. Microchip Technology currently offers PHY and MAC-PHY solutions and has many other very innovative 10BASE-T1S products on the road map that will inspire customers to develop cutting-edge, high-quality solutions with short time to market and low BOM cost.

In fact, Microchip has one of the most comprehensive 10BASE-T1S roadmaps available in the market, ensuring customers have access to a broad and versatile portfolio for their diverse application needs.

PHYs, shown in Table 2, can be connected to the microcontrollers over MII (Media Independent Interface), SC-MII (Serial Control Media Independent Interface) or RMII (Reduced Media Independent Interface).

Product	Key Features	Applications/Notes
LAN8670/1/2	- 10 Mbps, half-duplex - Single-pair, multidrop bus - Advanced PHY diagnostics - Sleep/wake functionality - Enhanced EMC/EMI - Time-Sensitive Networking (TSN) support - AEC-Q100 Grade 1 qualified - Functional safety ready (ISO 26262) - Support of MII, SC-MII and RMII (LAN8670) - Support of RMII (LAN8671) - Support of MII (LAN8672)	- Industrial, building automation - Automotive (zonal architectures, sensors, actuators) - Reduces cabling and switch ports - Connects low-speed devices to standard Ethernet networks

Table 2: 10BASE-T1S PHY products from Microchip

MAC-PHYs connect using a SPI interface and are suitable for edge device featuring a Microcontroller without a MAC.

Product	Key Features	Applications/Notes
LAN8650/1	- Integrated MAC and PHY - SPI interface for easy MCU connection - Enables 8-, 16-, 32-bit MCUs without built-in MAC to access 10BASE-T1S - Time-Sensitive Networking (TSN) support - AEC-Q100 Grade 1 qualified - Functional safety ready (ISO 26262) - Extended temperature range (-40°C to 125°C) - Integrated 1.8 V LDO (LAN8651)	- Industrial IoT -Building Automation - Industrial (sensors, actuators, motors) - Automotive (sensors, actuators, edge devices) - Reduces design complexity and cost - Connects basic MCUs to Ethernet networks

Table 3: 10BASE-T1S MACPHY products from Microchip

CONCLUSION

As smart factories evolve, seamless, secure and scalable connectivity becomes the backbone of Industry 4.0. Technologies like 10BASE-T1S are paving the way for cost-effective, multidrop Ethernet networks that bring intelligence to the very edge of the factory floor. Microchip driving this transformation with one of the most comprehensive portfolios of 10BASE-T1S PHYs and MAC-PHYs, empowering designers to simplify integration, reduce costs and accelerate time to market. Explore the full range of solutions and discover how Microchip can help you build the next generation of smart factories.

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DIGITAL FACTORY OF THE FUTURE TRANSFORMS MANUFACTURING

This article will review the key challenges in manufacturing today and explore the transformation that is taking place. This transformation is being driven by a new focus on resource-aware manufacturing, enabled by new technologies and capabilities including artificial intelligence, decentralized control, hybrid networking, and software-defined automation all combined to enable the digital factory of the future.

MANUFACTURING CHALLENGES

Manufacturing is going through a period of transformation driven by changes in consumer demand for more personalized products and reshoring post-pandemic supply chain crunch, to name just a couple of these challenges. At the same time, governments around the world are increasing regulations to reduce carbon emissions from manufacturing to meet their net zero greenhouse gas emissions targets. Navigating these challenges will create new opportunities for industrial manufacturing companies to embrace new technologies accelerating manufacturing productivity, scalability, and flexibility while lowering carbon emissions.

In today's brownfield manufacturing sites, there are challenges with interoperability of manufacturing and automaton equipment that have been deployed and expanded many times over the years. This has led to interoperability challenges and limited connectivity from one machine to another. Often there is no single unified network across the factory that connects all automation equipment.

To support increasing new product stock-keeping units (SKUs) requires increased setup and validation time of manufacturing production lines. For medical device manufacturing, this validation time is very expensive and time consuming. An increase in product SKUs also lowers operating equipment effectiveness (OEE) as manufacturing time and productivity is lost due to increased setup and validation time to support new product SKUs. Other manufacturing challenges include the lack of skilled workers in manufacturing.

By 2030, the manufacturing industry is expected to face a shortage of approximately 2.1 million skilled workers.1 With most manufacturing taking place today in brownfield sites, this issue leads to manufacturing capacity constraints, as these manufacturing sites look to increase manufacturing output in the existing building footprint. The digital factory of the future goal is to solve these challenges and deliver the next generation of manufacturing (Figure 1).

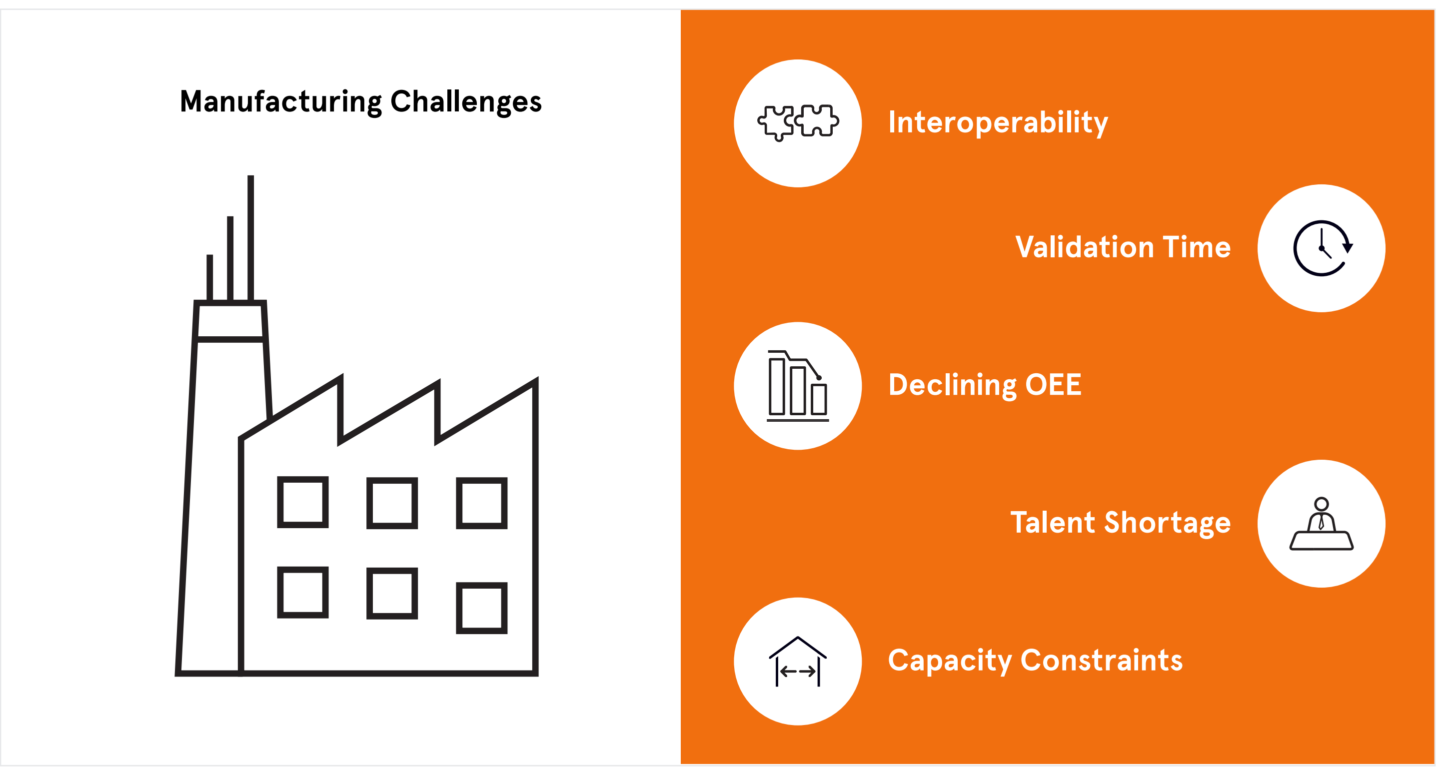


Figure 1. Industrial manufacturing challenges

TRANSFORMATION OF INDUSTRIAL MANUFACTURING

From a technological perspective, there have been significant advancements that are transforming manufacturing. Examples include sensor fusion from increased deployment of sensors on manufacturing assets and equipment to generate rich datasets that can then be used to optimize machines and increase OEE. Software-defined automation is being deployed to increase levels of manufacturing productivity, flexibility, and scalability, enabling faster setup and validation time.

Finally, artificial intelligence (AI) is moving toward the edge (close to the sensor or actuator), where the data is being generated. Edge AI will transform manufacturing data into actionable insights through data-driven decision making that will enable autonomous manufacturing to unlock a step change in manufacturing productivity and competitiveness (Figure 2).

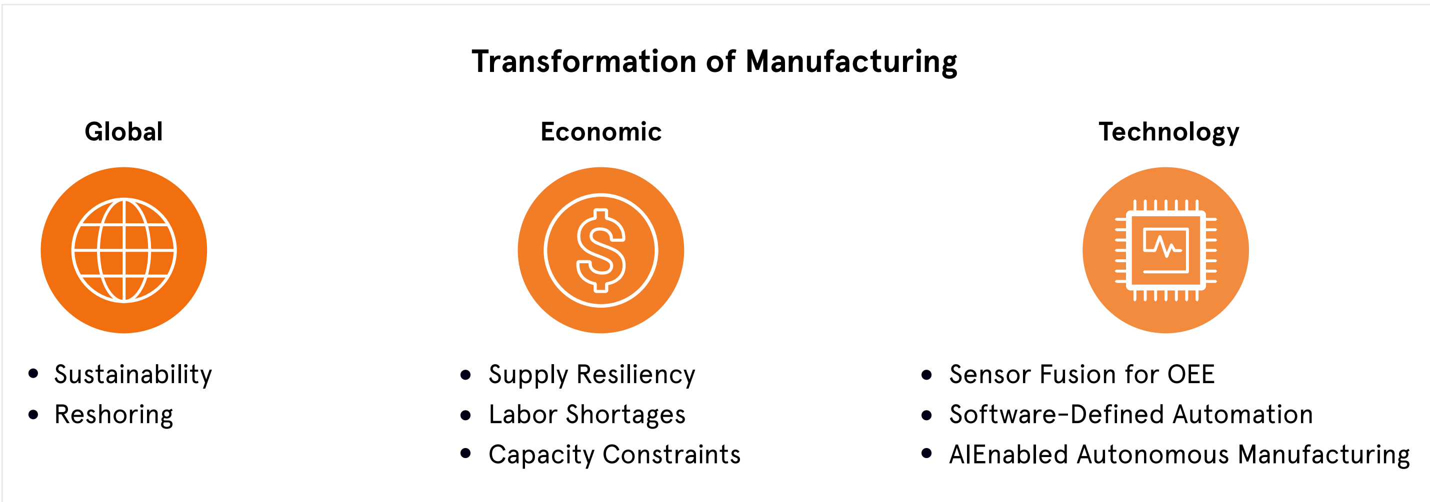
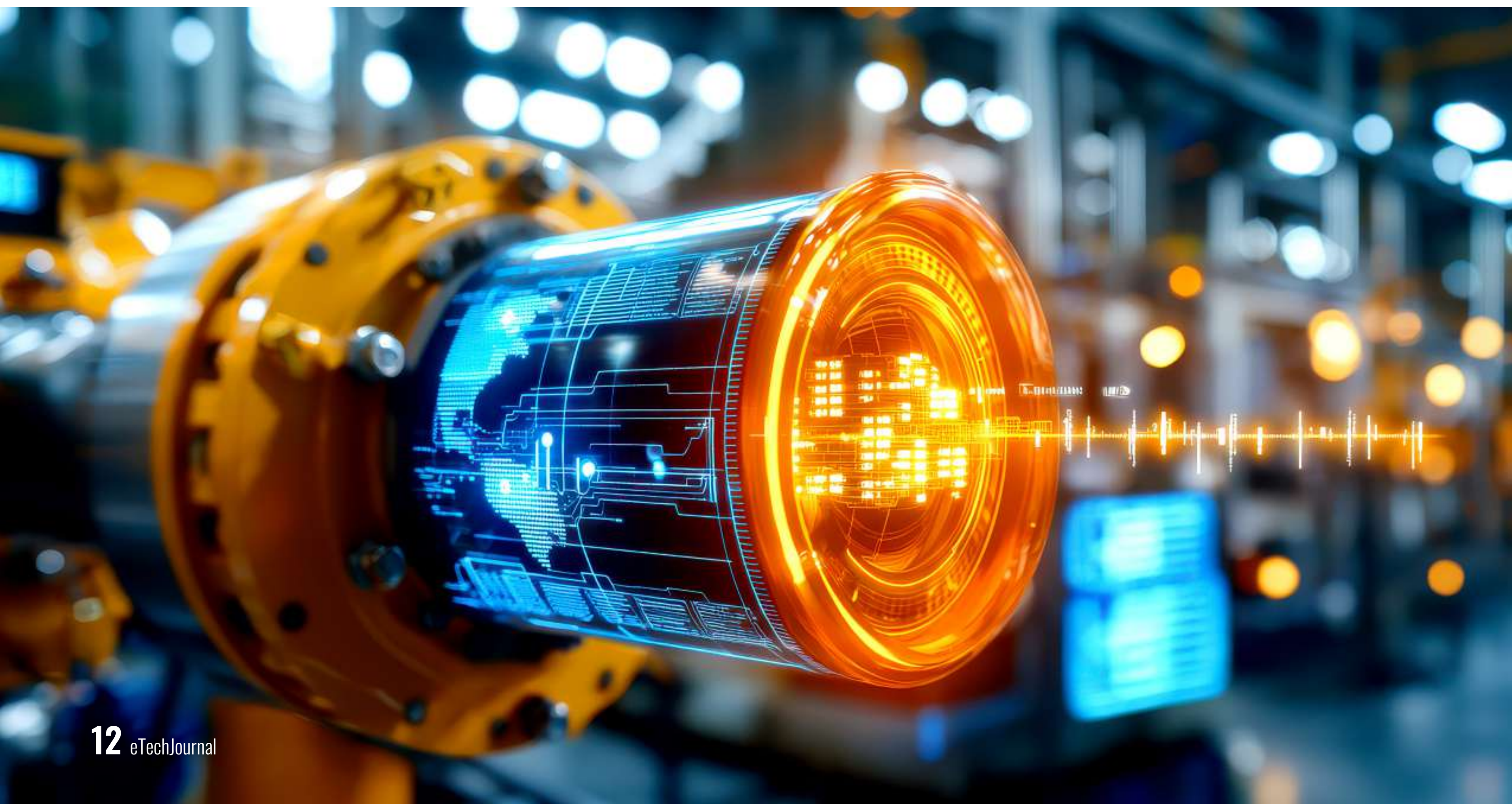


Figure 2. Transformation of manufacturing



RESOURCE-AWARE MANUFACTURING

Next-generation manufacturing needs to look more holistically at all areas of resource consumption. The four key resources required in manufacturing are capital, power, material, and human. The digital factory of the future needs to improve the efficiency of all these resources, in the context of resource-aware manufacturing.

With capital efficiency, all manufacturing capital expenditures need to show a return on investment (ROI). This may be a 1-, 3-, or 5-year ROI. One of the key goals of the digital factory of the future is to maximize profits from minimal capital expenditure to deliver the highest ROI. The second is

power efficiency—next-generation manufacturing must deliver more output with less energy consumption to meet the goals of reducing global carbon emissions. Key to reducing power consumption is the deployment of higher efficiency motor drives, replacement of pneumatic actuation with electromechanical actuation, and adaptive closed-loop control to increase manufacturing efficiency.

The third area for resource-aware manufacturing is material efficiency. Reducing material waste plays a critical role in improving sustainability in manufacturing along with reduced energy consumption. By minimizing raw material usage combined with increased manufacturing, quality controls will significantly reduce material waste throughout the manufacturing flow, with a goal of zero reject production.

The final area, and one of the most important, is human efficiency, with the current challenges around hiring skilled workers into manufacturing roles. Human intervention in manufacturing must be minimized where possible through more autonomous manufacturing and advanced robotics, along with automation solutions that are real-time aware and can quickly adapt to the changes in the operating environment and manufacturing requirements (Figure 3).

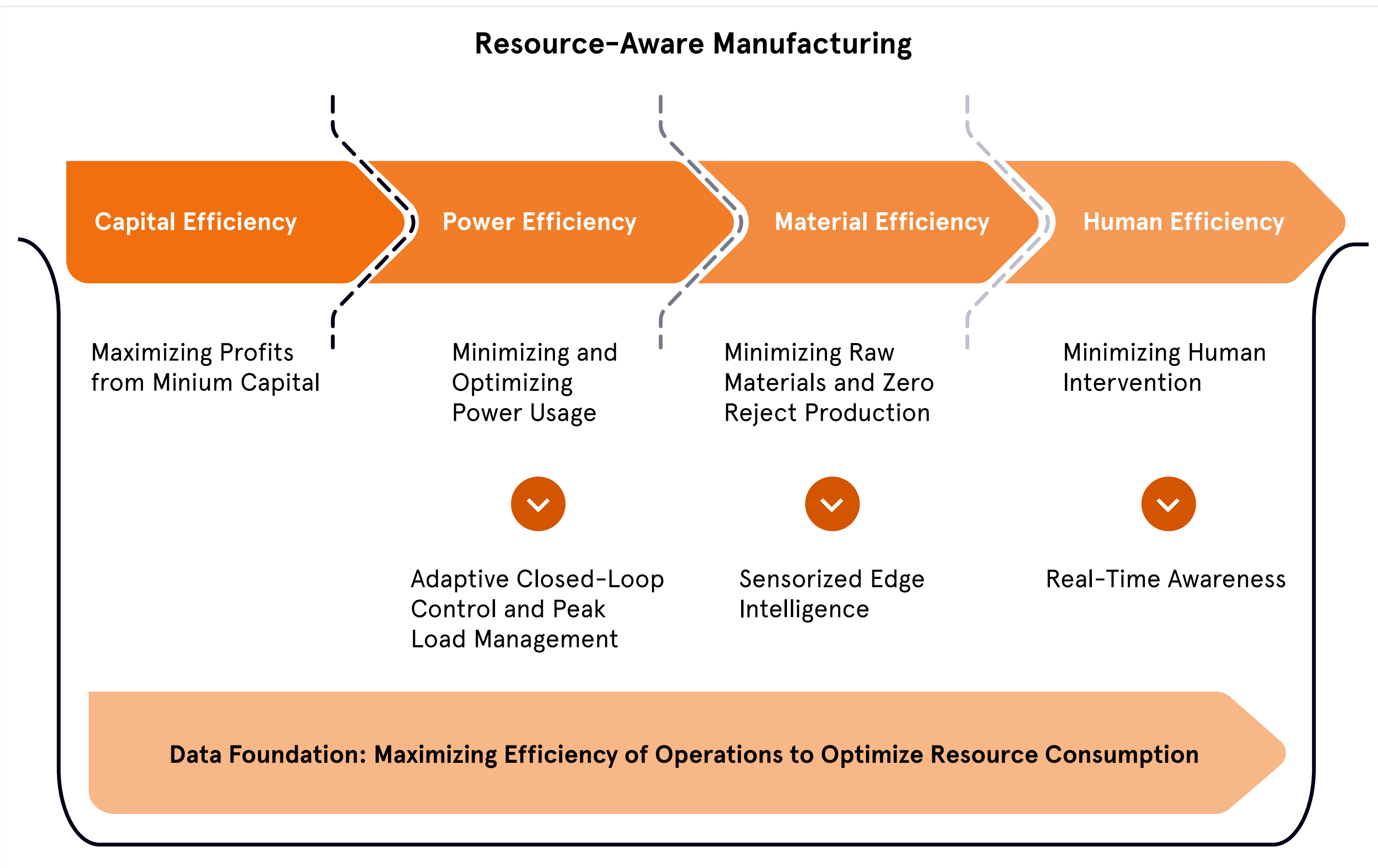
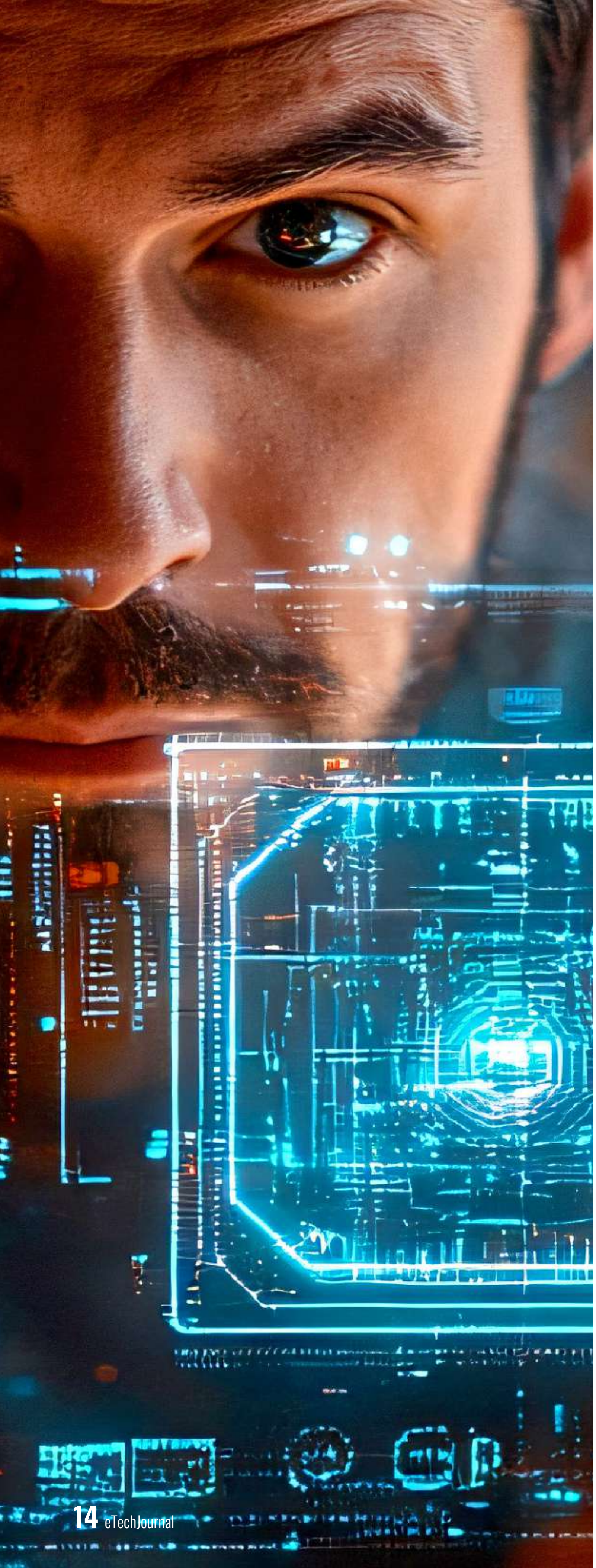


Figure 3. Resource-aware manufacturing



DIGITAL FACTORY OF THE FUTURE

Analog Devices' vision for the digital factory of the future is centered on three key pillars: connect, control, and interpret. The connect strategy aims to deliver the promise of the factory of the future by accelerating manufacturing productivity, scalability, and flexibility while lowering carbon emissions. Ensure all manufacturing assets and machines are connected to a unified network to enable transparent access of manufacturing data. This data is then used to drive continuous process improvements across the manufacturing site. A manufacturing environment must have real-time seamless edge-to-cloud connectivity enabled through a hybrid wired and wireless factory network. For the wired control connectivity, gigabit industrial Ethernet is being deployed for higher bandwidth factory networks with time sensitive networking (TSN) for determinism of real-time traffic control. This is being complemented by flexible private 5G networks for mobile applications such as autonomous mobile robots (AMRs) and to connect to remote sensors and actuators that cannot easily be connected to a wired Industrial Ethernet network.

The second key strategy is focused on control. Decentralized autonomous control provides more flexibility through new modular automation solutions that will support increasing new product SKUs with reduced setup and validation time. By moving away from the traditional centralized programmable logic controller (PLC) of a manufacturing line to a decentralized PLC control, advanced edge computing is integrated directly into the machines. Edge-based autonomous control increases manufacturing flexibility through more reconfigurable production lines, as each machine now becomes a complete, self-contained modular manufacturing block that can be easily configured and re-deployed with significantly less human intervention. Through the increased deployment of flexible, modular manufacturing solutions, enabled through decentralized autonomous control, we can better support the goals of the digital factory of the future.

The final strategy is focused on interpret. The interpret strategy is about transforming manufacturing data into actionable insights to enable the goals of the factory of the future. Manufacturing is estimated to generate approximately 1,812 petabytes (PB) of data every year2 and the interpret strategy uses AI to transform this manufacturing data to drive productivity improvements. Key to the interpret strategy is the deployment of AI at the edge (where the data is generated). Edge AI will enable autonomous optimization in manufacturing through proactive decision making combined with sensor fusion from real-world measurement modalities (industrial vision, temperature, pressure/force, inclinometer, position, vibration, humidity, etc.). Edge AI will reduce the dependency on skilled labor by automating routine tasks and enabling more personalized and complex manufacturing with the highest yields. Key applications include guided actuation (mobile robots), defect or anomaly detection (machine health), continuous process improvements, pattern recognition (quality control), and, finally, as part of the automation control loop.

Digital Factory of the Future

Connect

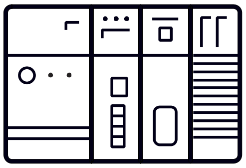
Transparent Access to Data

Access to Manufacturing Equipment Data and Insights Through Real-Time, Seamless Connectivity for Continuous Optimization

Control

Decentralized Autonomous Control

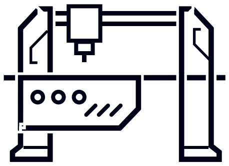
Support Ever Increasing Products SKUs with Limited Skilled Work Force



Interpret

Increased Machine OEE

Increase Machine OEE Through Sensor Fusion and Edge AI



CONCLUSION

SiC and GaN wide-bandgap semiconductors represent the new faces in the field of power electronics. SiC-based devices find their use in robust, high-powered applications because of their high-voltage and high-efficiency capability, while GaN applies to compact and low-power systems owing to its high-frequency performance. As cost and manufacturing continue to get overcome, wide adoptions are inevitable across the industries, including EVs, telecom, and renewable energy.

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SMART FACTORIES WITH **ADVANCED INTERCONNECT SOLUTIONS**

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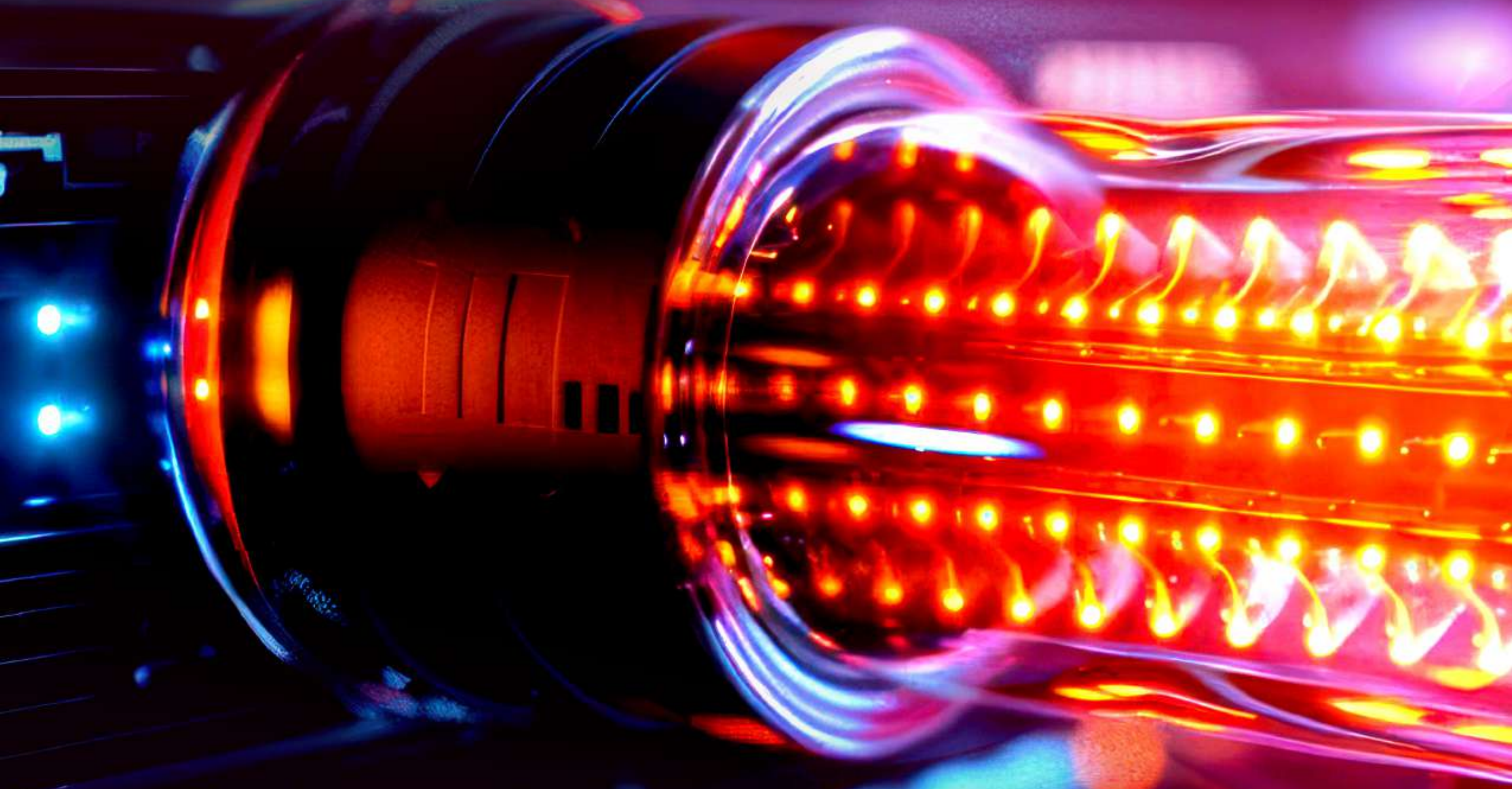


INTRODUCTION TO SMART FACTORIES

Welcome to the age of Industry 4.0, where smart factories epitomize the cutting edge of manufacturing innovation. Coined as the fourth industrial revolution, Industry 4.0 represents a seismic shift toward automated, interconnected, and self-optimizing production facilities.

The traditional manufacturing landscape is rapidly progressing into realms where intelligent systems not only streamline operations but facilitate unprecedented levels of productivity and efficiency. In an era where real-time data and seamless connectivity are paramount, smart factories are equipped to turn opportunities into reality, leveraging sophisticated technologies that blur the line between the virtual and physical worlds.

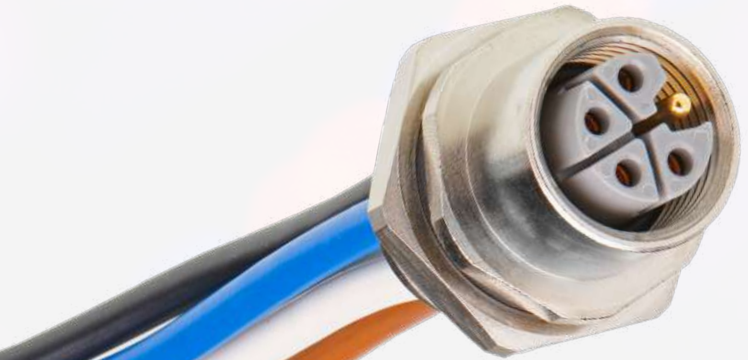
The transition to Industry 4.0 technologies is at an inflection point globally. Organizations are keenly embracing automation, not as a mere addition to their existing processes, but as an essential, transformative element that will shape future industry standards. According to a recent survey by Molex, a leading advocate for Industry 4.0 integration, an astounding 87% of respondents expressed excitement about the potential of these advancements over the next decade. This enthusiasm underscores a collective drive to harness automation, artificial intelligence, and advanced data analytics to build factories that are not only smart but strategically equipped for the future.

THE ROLE OF ADVANCED INTERCONNECT IN MODERN MANUFACTURING SOLUTIONS

At the heart of this transformation lies advanced interconnect technology—the backbone of modern smart factories. It is the critical enabler of connectivity that allows disparate systems, machines, and devices to communicate seamlessly, thus bringing the principle of the Internet of Things (IoT) into practical application on the factory floor.

Central to this revolution is Molex's role as a pioneer in Single Pair Ethernet (SPE) technology, which simplifies design and dramatically streamlines the integration of smart devices. SPE provides a scalable, cost-effective means to ensure that machines and sensors within factories can communicate over long distances without compromising the fidelity of the data they transmit. Imagine a factory floor where machines autonomously exchange information, synchronizing operations without human intervention to minimize downtime. That is the promise SPE offers, signifying a leap towards smarter, more connected manufacturing processes.

Furthermore, the next horizon is being explored with the advent of 5G communications, which offers incredibly high data rates with reduced latency. This wireless technology presents a particularly attractive feature for factories looking to eliminate physical cabling, thereby increasing operational flexibility and enabling faster, dynamic reconfiguration of manufacturing systems.



BENEFITS OF INDUSTRY 4.0 TECHNOLOGIES

The integration of Industry 4.0 technologies ushers in a multitude of benefits, significantly fortifying the competitive edge of manufacturing enterprises. Foremost among these advantages is the enhanced efficiency and flexibility that smart factories can bring to production lines. With systems capable of gathering and analyzing vast datasets, smart factories can make real-time adjustments, optimizing production processes and preemptively addressing potential bottlenecks.

A primary goal for any modern manufacturer is to elevate the agility of its operations. With advancements like machine-to-machine (M2M) communication, machine learning, and predictive analytics, smart factories are now capable of more than just automation; they can preemptively respond to changing conditions on the production line. This ability to make data-driven decisions autonomously markedly improves resource utilization and reduces wastage, contributing to better sustainability practices in an era increasingly defined by the need for ecological mindfulness.

Moreover, by reducing the need for manual equipment adjustments, smart factories allow for rapid configuration changes. For instance, shifting production from one product variant to another can be achieved with minimal disruption, exemplifying the concept of flexible manufacturing—a necessity in today's highly dynamic market environment.

CASE STUDIES AND REAL-WORLD APPLICATIONS

The benefits of smart factory technologies are already being realized in various industries. The automotive sector, a hallmark for technological advancement, has emerged as a frontrunner in implementing smart manufacturing systems. Automotive manufacturers are adopting highly modular and flexible assembly lines, facilitated by innovations in robotics and IoT. Such configuration not only elevates the capacity for customization but also enhances productivity, responding swiftly to market demands.

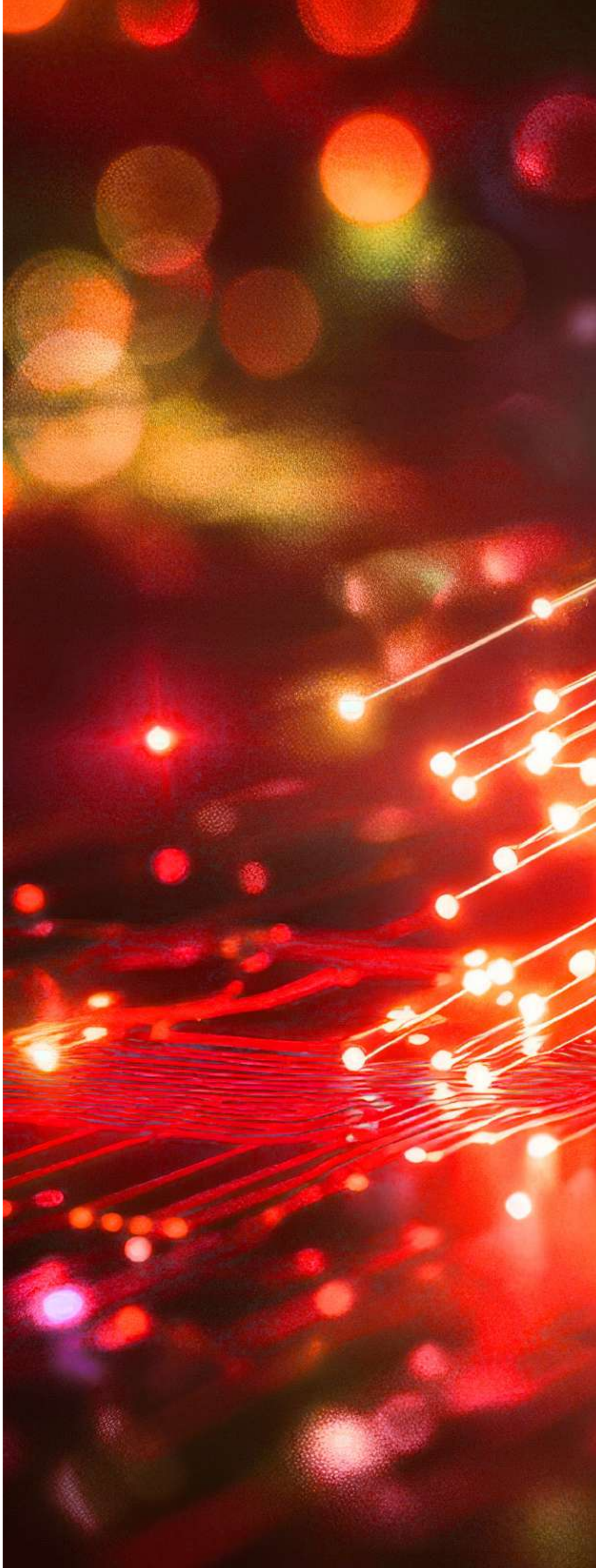
Another promising technology, the IO-Link, is gaining traction across multiple sectors, further exemplifying the practical benefits of Industry 4.0. As a standardized I/O technology used for connecting sensors and actuators, IO-Link is actively deployed to meet the goals of predictive maintenance and effective process monitoring. With the seamless integration of temperature and humidity data across production data landscapes, factories can now gain new insights into optimizing the entire manufacturing process, thereby enhancing quality control and minimizing production waste.

FUTURE TRENDS AND INNOVATIONS

Looking ahead, the future of manufacturing is poised to embrace even more groundbreaking innovations. The transition toward distributed control architecture heralds a new era of manufacturing intelligence, enabling factories to decentralize their control systems to improve safety and operational resilience.

This evolution will drive factories to bring intelligence closer to the point of need, conducting dynamic, real-time processing and ensuring that control systems are as responsive and adaptive as possible.

As the digital tide rises, increased integration of IoT and cloud-based solutions will characterize the next phase of manufacturing evolution. An interconnected data ecosystem will offer manufacturers the opportunity to exploit machine-learning algorithms and advanced analytics, empowering them to optimize their production processes continually.



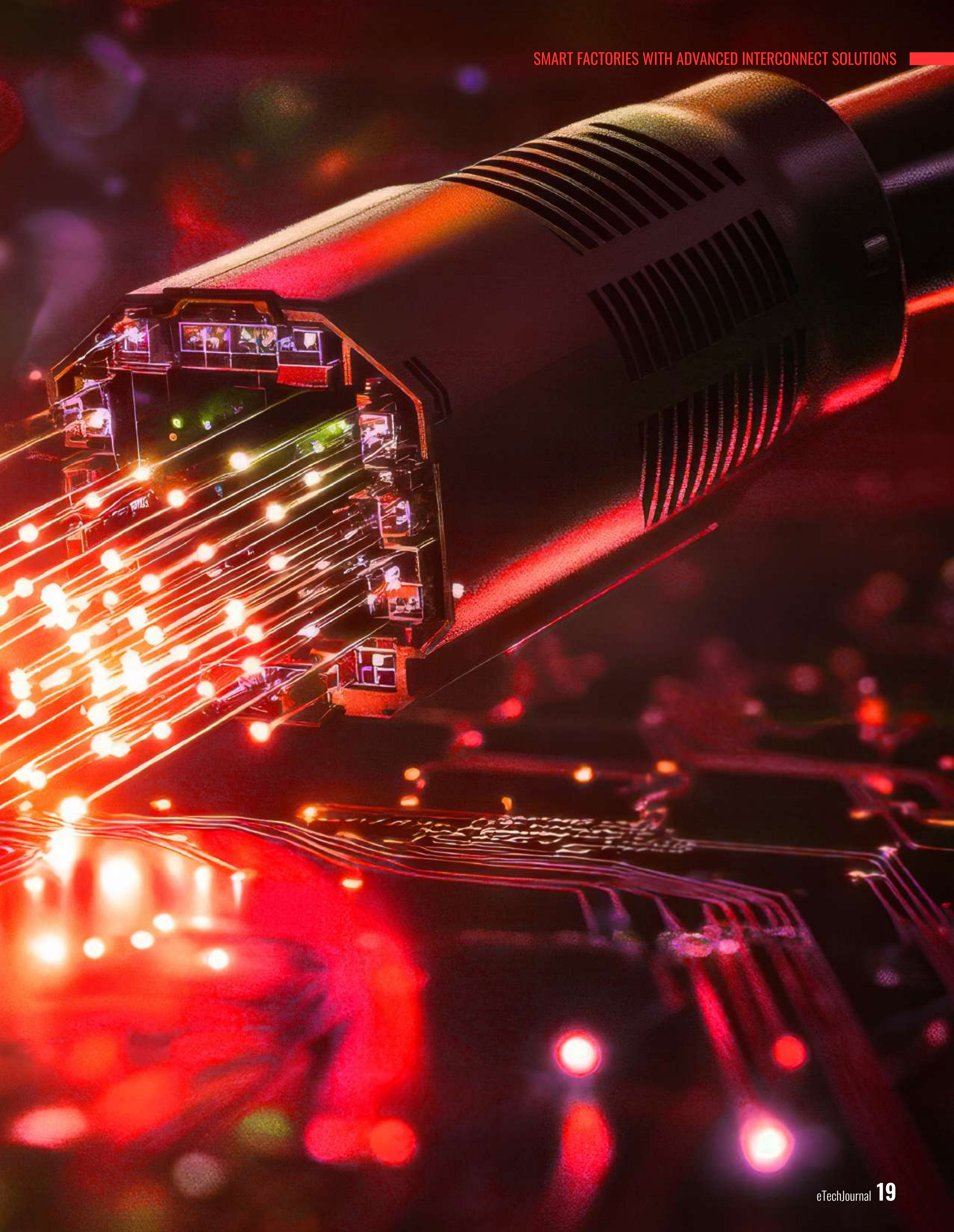
CONCLUSION

The future of manufacturing lies with smart factories, where advanced interconnect technology catalyzes extraordinary efficiency and innovation. As we stand at the precipice of this new industrial era, there is a compelling call for manufacturers to adopt and plunge into Industry 4.0. By embracing the transformative power of sophisticated interconnect technologies, manufacturers can build a resilient and dynamic operational framework that anticipates the demands of tomorrow's market.

Molex stands ready to lead this charge, offering an array of cutting-edge interconnect solutions that simplify the journey towards a completely digitized manufacturing process. With decades of expertise, Molex's solutions serve as catalysts for manufacturers, designers, and system integrators, ensuring they are not just participants in Industry 4.0 but pioneers of it.

The time to evolve is now. Embrace the change, harness the power of intelligent connectivity, and revolutionize your manufacturing capabilities today. Let Molex guide you on your journey to smart factory excellence.

CLICK HERE

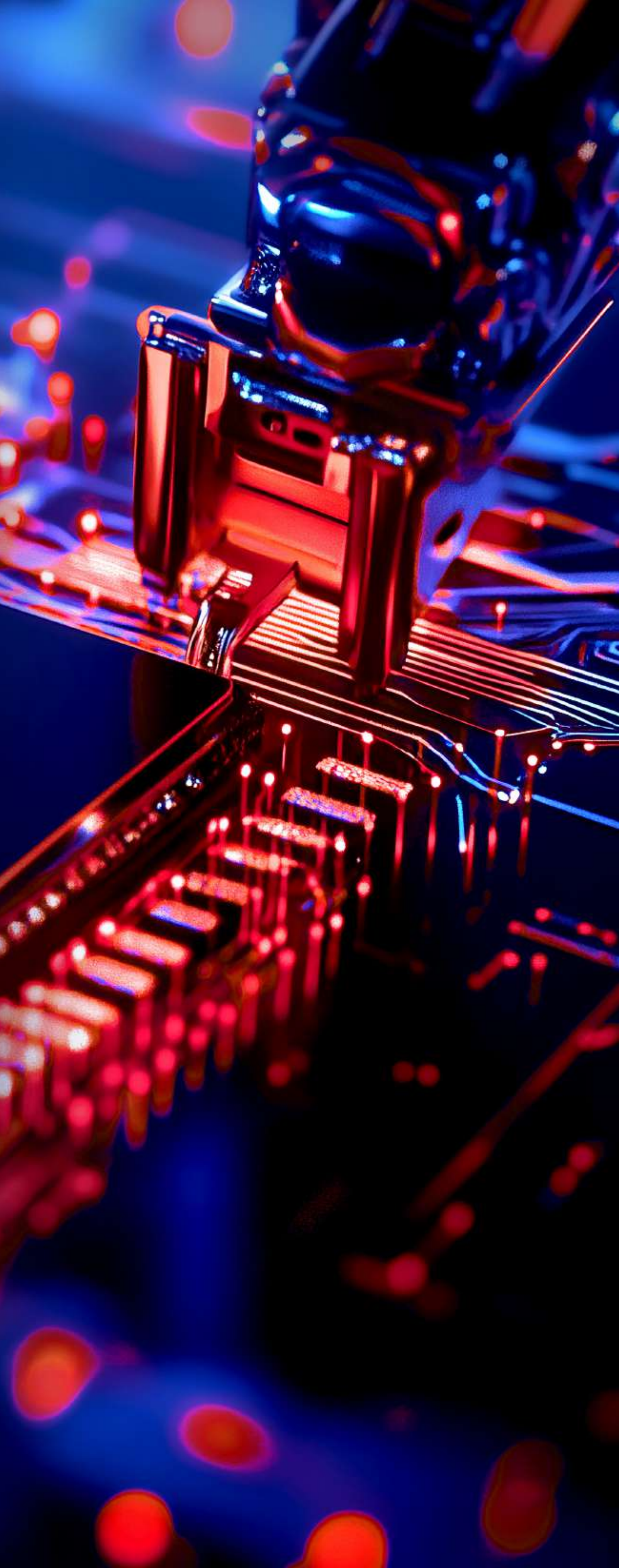


Raspberry Pi®

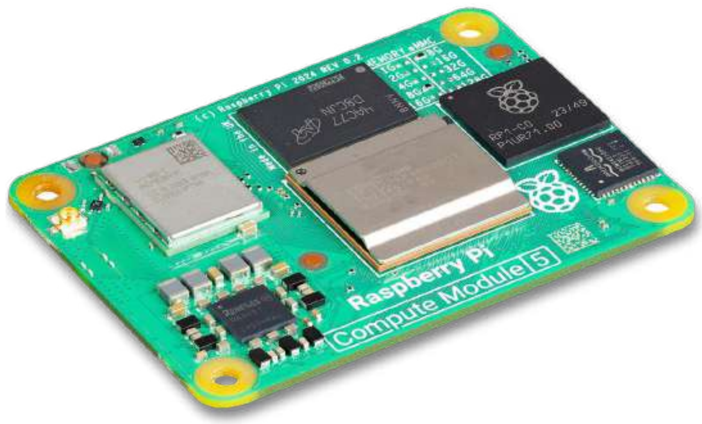
VISIT RASPBERRY PI

FROM PROTOTYPE TO PRODUCT

HOW RASPBERRY PI 5 AND COMPUTE MODULE 5 EMPOWER PROFESSIONAL DESIGN ENGINEERING



For many years, Raspberry Pi has been a go-to platform for prototyping and innovation. But today, it's far more than a development tool. With the introduction of Raspberry Pi 5 and Compute Module 5 (CM5), engineers now have a production grade platform that's flexible, powerful, and robust enough for serious end-product design.



Whether you're building smart edge devices, industrial control units, or intelligent consumer electronics, Raspberry Pi is now a viable choice not just for proof of concept, but for full-scale deployment.

In this article, we will unpack the transformative capabilities of the Raspberry Pi 5 and CM5, and explore how engineers can leverage them to accelerate design cycles, reduce BOM costs, and bring robust edge-computing products to market more quickly.

NOW LIVE: THE RASPBERRY PI INDUSTRY HUB BY FARNELL

To help design engineers get the most from Raspberry Pi 5 and CM5, Farnell have launched the Raspberry Pi Industry Hub, a one-stop platform built specifically for professional and industrial use.

Here's what it offers:

- **Raspberry Pi 5 and CM5 Selector Tool**

  Quickly find the right Compute Module 5 by filtering RAM, eMMC, and wireless options, no more navigating complex part numbers. It's designed to simplify your selection and help you buy exactly what you need, fast.

- **Essential Accessories & HATs**

  Access a curated list of official and compatible accessories - Raspberry Pi AI HAT+, AI Camera, M.2 HAT, multitouch display, PoE modules, metal/ABS enclosures and thermal solutions, tailored for serious embedded development.

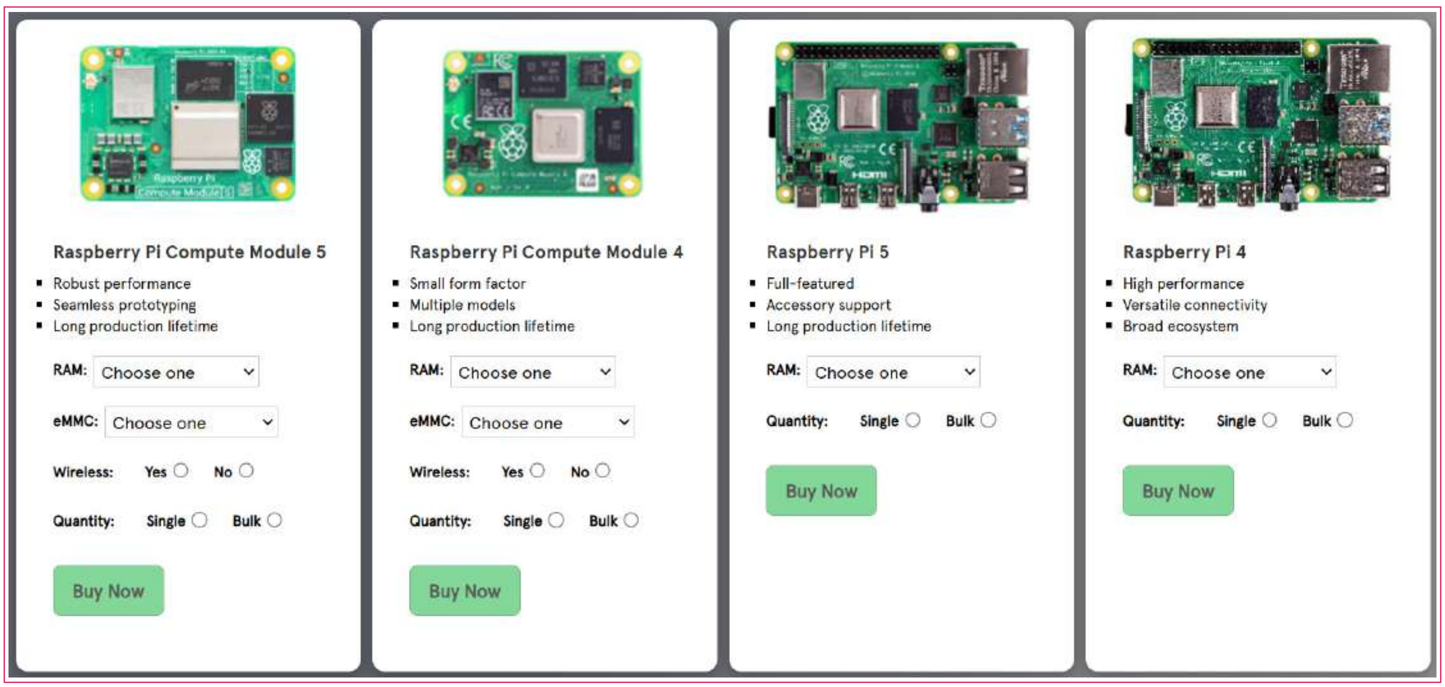
- **Documentation - Datasheets, Compliance Docs, and Application Notes**

  Everything you need to design with confidence: user manuals, design files, datasheets, certifications – all in one place.

- **Customer Use Cases and Reference Designs**

  Learn from others already shipping products with Raspberry Pi at the core. From smart energy gateways to DIN-rail controllers and digital signage systems, see what's working in the field.

For more information, explore the Raspberry Pi Industry Hub



WHY RASPBERRY PI 5 & CM5 MATTER NOW IN PRODUCT DESIGN

2025 signifies a tipping point in edge intelligence and IIoT adoption. Engineers are no longer simply connecting sensors, they are building AI-powered, real-time, secure systems within space and power constrained environments. This shift necessitates:

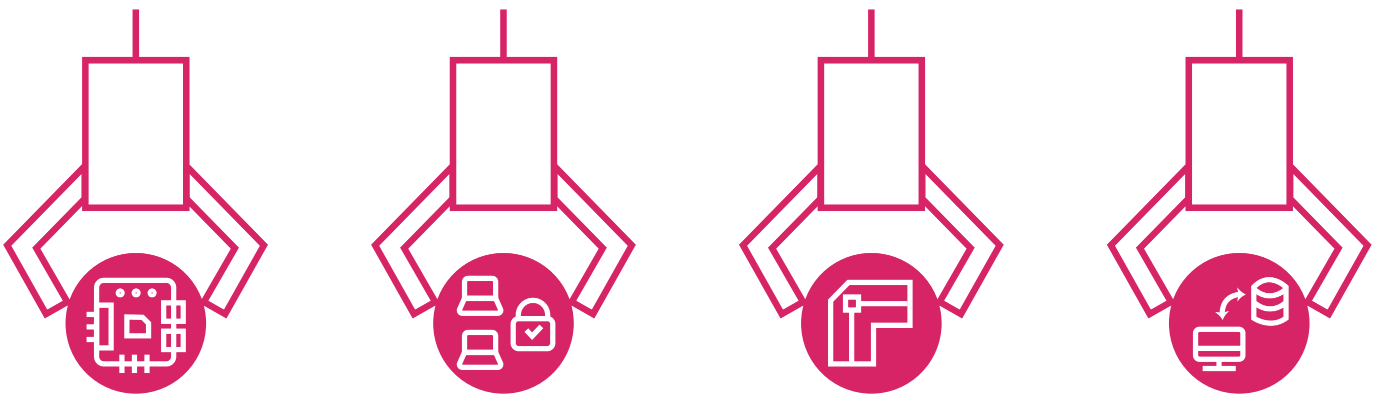
The Raspberry Pi 5 and CM5 were designed with these exact needs in mind.

Powered by a quad-core Arm Cortex-A76 CPU at 2.4GHz, paired with up to 8GB LPDDR4X RAM, PCIe 2.0, dual 4Kp60 HDMI outputs, and Gigabit Ethernet, it delivers the kind of compute horsepower that modern embedded applications demand.

The Compute Module 5 takes that same power and packages it into a compact SoM with industrial I/O access, making it ideal for industrial and commercial products.

This isn't about tinkering. It's about building real systems that run 24/7, interface with complex peripherals, and operate reliably in the field.

Edge Computing Requirements



High-Performance Compute

Enables demanding applications at the edge

Reliable Connectivity

Ensures consistent data flow in industrial settings

Flexible Form Factors

Offers adaptable designs for diverse deployments

Software Ecosystems

Provides production-ready software for edge solutions

BUILDING BLOCKS OF A PRODUCTION-READY EMBEDDED SYSTEM

1. COMPUTE AT THE EDGE: WHY PERFORMANCE MATTERS

Edge workloads are growing. Object recognition in digital signage, AI-driven motor control in IIoT, and local decision making in smart buildings all demand more processing headroom.

CM5 with Cortex-A76 and VC7 GPU handles:

a. Real-time ML inference (e.g., YOLOv5 via Hailo AI HAT+)

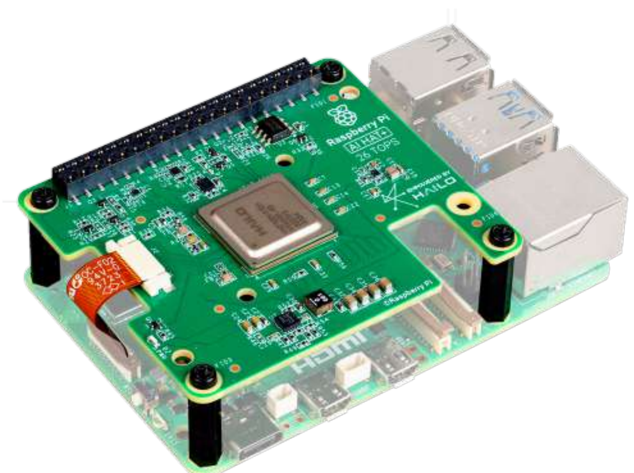
b. 4K60 video streaming & encoding

c. Multi-sensor data fusion and analytics

d. Secure, OTA-capable applications

Use Case: Industrial Vision System

A CM5-based inspection system processes 4K video streams from dual CSI cameras, performs on-board AI segmentation, and communicates results over Gigabit Ethernet, all without touching the cloud.



2. DESIGN FREEDOM: TAILORED FORM FACTOR AND INTERFACE FLEXIBILITY

The CM5 is available in eMMC (up to 64 GB) and Lite variants, giving engineers design flexibility for cost, storage, and compliance. Its IO interface via high-density connectors enables integration into bespoke carrier boards for specialised applications like:

e. DIN-rail industrial controllers

f. Edge gateways for energy grids

g. Comp

Real-World Product: RevPi Connect 5

Built by Kunbus, this DIN-rail industrial PC leverages CM5 to deliver edge computing, PLC logic, and real-time CAN FD communication in harsh industrial environments.

3. SCALABILITY IN DESIGN AND PRODUCTION

From prototyping on Raspberry Pi 5 to deploying a CM5-based custom PCB, engineers benefit from:

h. Identical software stack (Raspberry Pi OS, Linux drivers, GPIO)

i. Same SoC architecture, means minimal firmware rework

j. Broad community and commercial ecosystem

Use Case: Smart EV Charger Design

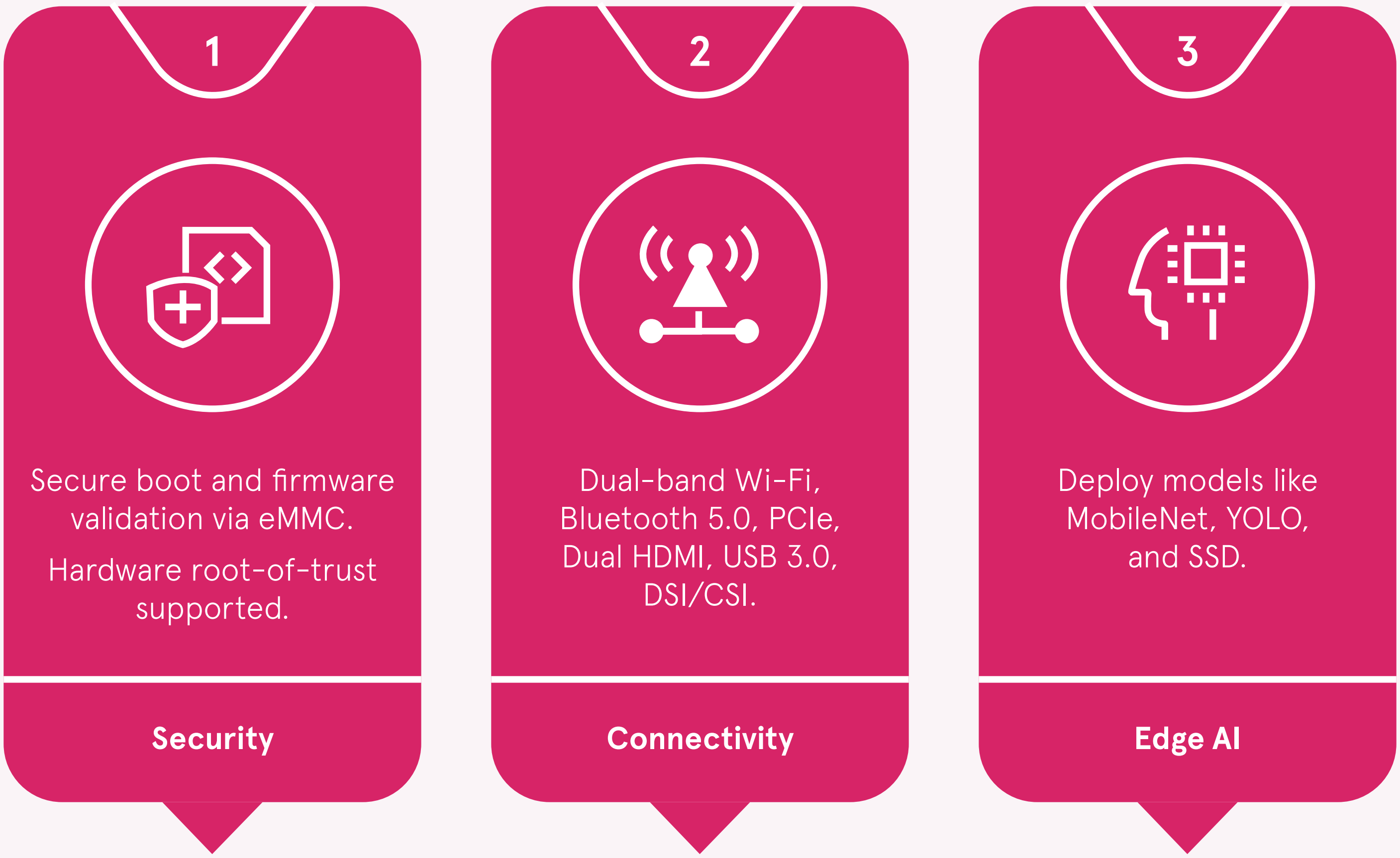
A startup begins with a Pi 5 to validate power management algorithms and UI workflows. Upon field success, they migrate to CM5 with custom I/O to create an IP65-rated charger with 4G, CAN, and Modbus interfaces. Ready for volume production.

SECURITY, CONNECTIVITY, AND EDGE INTELLIGENCE

Designing modern connected products goes beyond performance. It's about trust, interoperability, and control.

- **Security Built In**
  - Secure boot and firmware validation via eMMC
  - Hardware root-of-trust supported through TPM or secure HATs
  - VPN, firewall, and encrypted OTA updates supported natively in Pi OS
- **Robust Connectivity**
  - Dual-band Wi-Fi, Bluetooth 5.0
  - PCIe expansion for LTE, 5G, or M.2 NVMe
  - Dual HDMI, multiple USB 3.0, and DSI/CSI for display and vision interfaces
- **AI at the Edge**
  - With the Raspberry Pi AI HAT+, engineers can deploy models like MobileNet, YOLO, and SSD at up to 26 TOPS—without breaking power budgets or BOM targets.

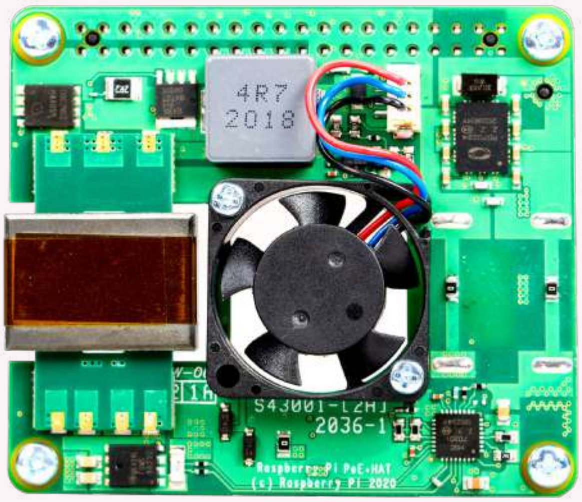
Raspberry Pi – Industry Ready

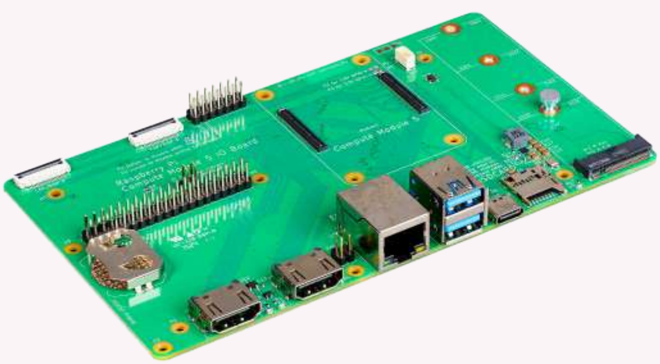


DEPLOYMENT-READY ECOSYSTEM: FROM LAB TO FIELD

Designing end products on Raspberry Pi 5/CM5 is supported by a robust set of accessories and software:

- CM5 IO Board: Full I/O breakout for development and testing
- AI HAT+ , PoE+ HATs, RTC add-ons, and secure elements (e.g., Infineon OPTIGA)
- Docker support, RT-patched Linux, and Kubernetes for clustered deployments
- Field-proven solutions like RevPi, Homey Pro, Yodeck, and Screenly





NOT JUST A DEVELOPMENT TOOL - A PRODUCTION GRADE PLATFORM

Let’s dispel the myth: Raspberry Pi 5 and CM5 are not just prototyping toys. They are now central to real, deployed solutions in:

- Industrial Automation (RevPi Connect 5, Sfera Labs Strato)
- Smart Energy Systems (EpiSensor’s VPP Gateway)
- Commercial Digital Signage (Yodeck, Screenly)
- Home Automation (Homey Pro)

Product engineers can start lean with Raspberry Pi 5 and seamlessly scale to volume production with CM5, all while tapping into a massive developer community, extensive documentation, and ongoing support from Farnell.

Homey Pro

KwickPOS

EpiSensor Energy Management

FARNELL: YOUR PARTNER IN EMBEDDED INNOVATION

Whether you're building your next-gen IoT gateway, AI-powered inspection system, or connected home controller, Farnell provides:

- Immediate access to Raspberry Pi 5 and Compute Module 5 stock
- Official CM5 development kits and carrier boards
- Support for compliance, prototyping, and design-in services
- Technical documentation, resources and webinars to upskill your team

Explore the full range of Raspberry Pi 5 and CM5 solutions at Farnell Global.

Why Engineers Should Consider RPi 5/CM5 for Product Design

Feature	Raspberry Pi 5	Compute Module 5 (CM5)
CPU/GPU	2.4 GHz Cortex-A76 / VC7	Same as Pi 5
RAM Options	2-16 GB	2-16 GB
Storage	microSD	eMMC(upto 64 GB) or microSD (Lite)
Expandability	PCIe 2.0 x1, USB 3.0	Full I/O access via carrier board
Use Case	Prototyping, light production	Embedded systems, high-volume
Target Design	Smart devices, kiosks, dev units	Industrial control, IIoT, signage

CONCLUSION

Design smart. Build fast.
Deploy at scale.

Raspberry Pi 5 and CM5 are ready for your next breakthrough product and Farnell is here to support you every step of the way.

Explore the full Raspberry Pi 5 and CM5 range, access development kits, and leverage Farnell's technical resources to take your next embedded project from idea to production.

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VISIT FARNELL

EMBRACING INDUSTRIAL REVOLUTION

RETROFITTING LEGACY SYSTEMS FOR THE FUTURE

The evolution of industrial automation has seen transformative changes over the past few decades, marked by significant advancements. These advancements are driving Industry 4.0 enablement and even moving towards Industry 5.0.

This shift, which focuses on smart technologies, data analytics, and human-machine collaboration, presents numerous challenges for existing industrial setups. Retrofitting legacy systems to embrace modern technologies is a crucial step for businesses aiming to stay competitive. This article explores the challenges faced by industrial design engineers and system integrators in this process and recommends technology solutions to overcome these hurdles.

UNDERSTANDING INDUSTRY 4.0 AND 5.0

Industry 4.0: Emphasizes connectivity, data, and automation. It involves integrating cyber-physical systems, the Internet of Things (IoT), cloud computing, and artificial intelligence (AI) into manufacturing processes.

Industry 5.0: Builds on Industry 4.0 advancements, focusing on the collaboration between humans and smart systems. It aims to create more personalized and sustainable manufacturing processes, emphasizing human creativity and environmental sustainability.

WHAT ARE THE KEY CHALLENGES IN RETROFITTING:

1. **Compatibility with Legacy Systems:** Integrating new technologies with existing infrastructure can be complex due to compatibility issues and the need for seamless communication between old and new systems.
2. **Interoperability:** It is crucial to ensure seamless communication between diverse devices and systems. Standardization of protocols and interfaces, such as OPC UA and MQTT, is essential for achieving interoperability.
3. **Data Management:** Effective data collection, storage, and analysis are critical. Legacy systems often lack the capacity for advanced data analytics, making it challenging to derive actionable insights.
4. **Security:** Enhancing cybersecurity is essential as increased connectivity exposes systems to potential cyber threats. Legacy systems might not be equipped to handle modern security protocols.
5. **Skill Gap:** The shift towards digital requires upskilling the workforce. Resistance to change and a lack of digital literacy can hinder the adoption of new technologies.
6. **Cost:** The initial investment required for retrofitting can be substantial. Businesses must balance the cost with the potential long-term benefits and return on investment (ROI).

RECOMMENDED TECHNOLOGY SOLUTIONS

AI AND MACHINE LEARNING

AI and machine learning can analyze vast amounts of data to optimize processes, predict failures, and personalize production.

Applications:

- **Predictive Maintenance**: AI algorithms can predict equipment failures before they happen.
- **Quality Control**: Machine learning models can identify defects in products with high accuracy.

INDUSTRIAL IOT (IIOT) GATEWAYS

IIoT gateways are essential for connecting legacy systems to modern networks. They enable data collection from old equipment and transmit it to cloud-based platforms for analysis.

Benefits:

- Seamless data integration from various sources.
- Real-time data processing and analysis.

Example:

Feature	Legacy System	Retrofitted with IIoT Gateway
Data Collection	Manual	Automated, Real-time
Data Transmission	Limited	Wireless, High-Speed
Maintenance	Reactive	Predictive

EDGE COMPUTING

Edge computing brings computation and data storage closer to the data source, reducing latency and bandwidth use.

Benefits:

- Faster decision-making.
- Reduced cloud dependency.

Example:

A manufacturing plant can use edge devices to process data from sensors on the shop floor, allowing for immediate adjustments to machinery without waiting for cloud processing.

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ADVANCED SENSORS AND ACTUATORS

Upgrading sensors and actuators can significantly enhance the capabilities of legacy systems. Smart sensors provide more accurate and real-time data, crucial for advanced analytics and automation.

Types of Sensors:

- Temperature Sensors: Monitor and regulate temperature in real-time.
- Vibration Sensors: Predict mechanical failures.
- Proximity Sensors: Enhance safety by detecting human presence.

CLOUD PLATFORMS

Cloud platforms offer scalable storage and processing power, enabling advanced analytics and AI applications.

Benefits:

- Scalable data storage.
- Advanced analytics capabilities.

Major Providers:

- Amazon Web Services (AWS)
- Microsoft Azure
- Google Cloud Platform (GCP)

Table: Comparison of Cloud Platforms

Feature	AWS	Azure	GCP
Storage Solutions	S3, Glacier	Blob Storage	Cloud Storage
AI/ML Tools	SageMaker	Machine Learning	AI Platform
IoT Integration	IoT Core	IoT Hub	IoT Core
Security Features	IAM, KMS	Active Directory	Cloud IAM

CYBERSECURITY SOLUTIONS

As connectivity increases, so do the risks. Implementing robust cybersecurity measures is crucial.

Key Solutions:

- Encryption: Protect data in transit and at rest.
- Access Controls: Implement strict access controls to sensitive data.
- Regular Audits: Conduct regular security audits to identify vulnerabilities.

Interested in the latest advancements and insights in Industrial Automation? Check out:

Industrial Automation Hub

A comprehensive guide to proximity sensors for industrial applications

Retrofitting small medium enterprises for Industry 4.0 with IO-Link

CONCLUSION

Transitioning to Industry 4.0 through retrofitting is a complex but essential process. Overcoming challenges such as compatibility, data management, skill gaps, cost, and interoperability requires strategic investment in technologies like IIoT gateways, edge computing, advanced sensors, cloud platforms, AI, and robust cybersecurity measures.

Addressing these issues enables companies to fully harness the potential of smart manufacturing, resulting in increased efficiency, reduced downtime, and enhanced product quality.

By carefully selecting and implementing these technologies, businesses can transform legacy systems into smart, efficient, and sustainable production environments, ready for the future of Industry 4.0 and 5.0.

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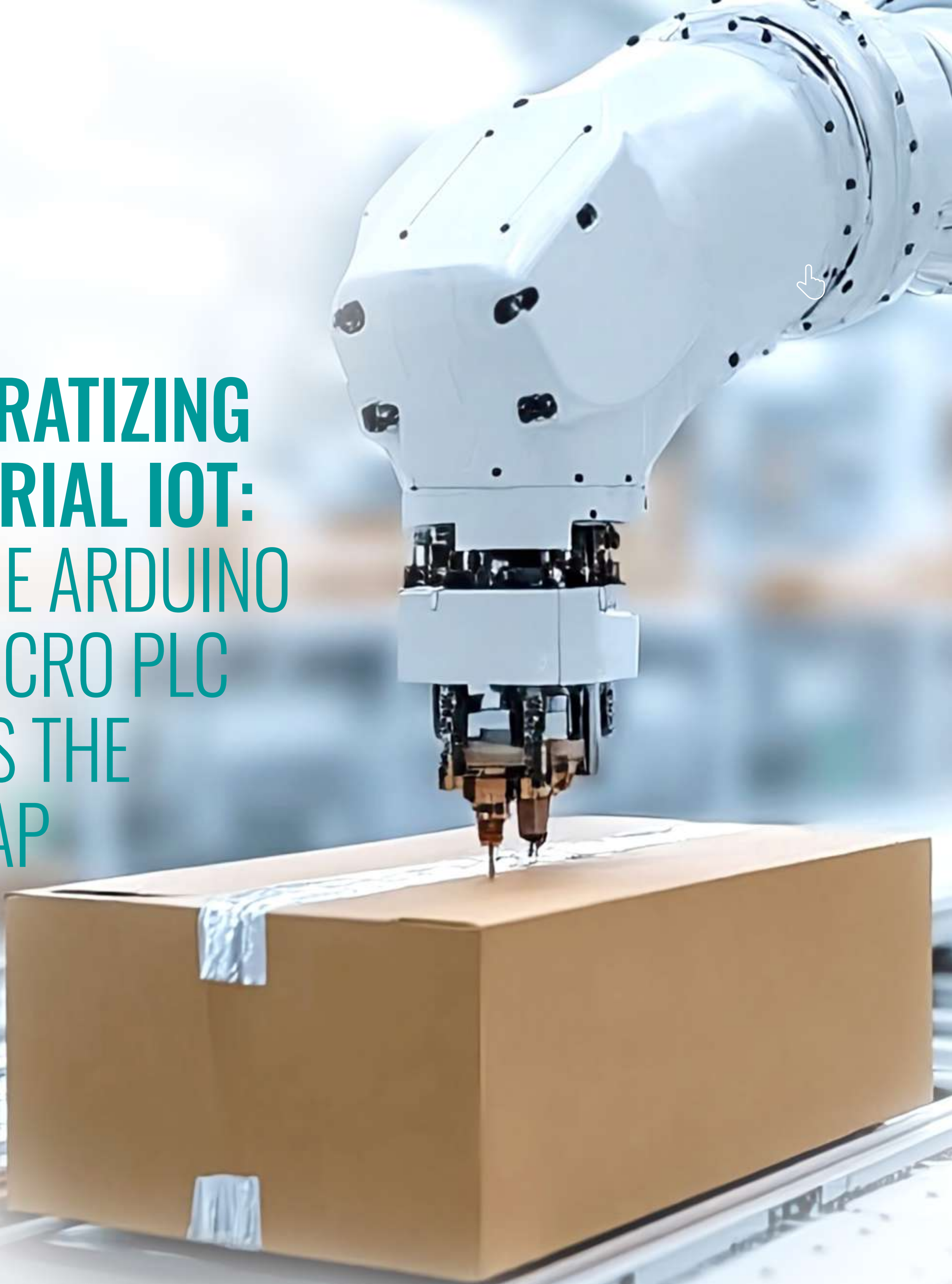
VISIT ARDUINO

DEMOCRATIZING INDUSTRIAL IOT: HOW THE ARDUINO OPTA MICRO PLC BRIDGES THE OT/IT GAP



In the heart of modern manufacturing, a silent revolution is brewing—one where machines don't just operate but communicate, predict failures, and optimize themselves in real time.

Yet, this vision of Industry 4.0 often crashes against a stubborn divide: the chasm between Operational Technology (OT), the rugged world of factory floors with its legacy PLCs and real-time control, and Information Technology (IT), the scalable realm of cloud computing, data analytics, and cybersecurity. Bridging this gap has traditionally meant navigating a maze of expensive gateways, proprietary software, and specialized expertise, locking out smaller enterprises and innovative makers.

Enter the Arduino Opta Micro PLC, a game-changing device born from the collaboration between Arduino and industrial relay expert Finder. This isn't your typical hobbyist board; it's a professional-grade powerhouse designed to democratize Industrial Internet of Things (IIoT) by fusing industrial durability with open-source accessibility.

With native support for protocols like OPC-UA and seamless integration with cloud giants such as AWS IoT Core and Azure IoT, the Opta empowers engineers to connect the physical world of sensors and actuators to the digital expanse of the cloud—effortlessly and affordably.

This article delves into how the Opta tackles the OT/IT divide, drawing from practical tutorials that showcase its interoperability on the factory floor and scalability in the cloud. Whether you're a control engineer retrofitting legacy systems or a data scientist building predictive models, the Opta is your bridge to a smarter, more connected future.

THE CORE CHALLENGE: THE OT/IT DIVIDE

Imagine a bustling assembly line where PLCs hum in harmony, controlling robots and conveyors with split-second precision. This is OT: focused on reliability, safety, and protocols like Modbus or Profibus to keep production uninterrupted. But to unlock true value, such as remote monitoring or AI-driven maintenance, data must flow to IT systems, where clouds like AWS or Azure process petabytes of information, apply machine learning, and enable global access.

The hitch? These worlds speak different languages. OT hardware is often vendor-locked, resistant to change, and prioritized for uptime over innovation. IT, meanwhile, thrives on agility but lacks the ruggedness for industrial environments. Integrating them can cost thousands in custom solutions, not to mention the skills gap between OT technicians and IT developers. The result: siloed data, missed opportunities, and a slow march toward Industry 4.0.

INDUSTRIAL-GRADE RELIABILITY MEETS OPEN-SOURCE FLEXIBILITY

The Arduino Opta shatters these barriers by delivering hardware tough enough for the factory while embracing the software freedom that made Arduino a global phenomenon. At its core is the STM32H747XI dual-core microcontroller from STMicroelectronics, blending a high-performance Cortex-M7 for complex computations with a real-time Cortex-M4 for control tasks. This enables edge processing, where decisions happen locally to reduce latency.

Physically, the Opta screams "industrial." It's DIN-rail mountable for easy integration into control panels, operates in temperatures from -20°C to +60°C, and features high-power relays (up to 250 VAC/10 A) courtesy of Finder's expertise, perfect for switching motors or valves.

Variants include Wi-Fi for wireless connectivity, RS-485 for fieldbus integration, and Ethernet for robust networking. Unlike fragile development boards, the Opta is built to endure electrical noise, vibrations, and the demands of 24/7 operation.

What truly sets it apart is its dual programming paradigm. For OT pros, the Arduino PLC IDE supports IEC 61131-3 standards: Ladder Logic for intuitive visual programming, Function Block Diagrams for modular designs, and Structured Text for advanced scripting. This means seasoned PLC engineers can deploy the Opta without relearning everything.

On the IT side, the familiar Arduino IDE allows C++ sketches, tapping into thousands of open-source libraries for tasks like JSON parsing or MQTT communication. Better yet, mix them, run Ladder Logic for core control while C++ handles cloud uploads.

Security isn't an afterthought. The onboard Microchip ATECC608B Secure Element stores keys, enables secure boot, and supports X.509 certificates, ensuring encrypted data from edge to cloud. This compliance with industrial standards like IEC 62443 makes the Opta a trustworthy node in sensitive IIoT networks.

INTEROPERABILITY FOR THE FACTORY FLOOR: THE OPC-UA ADVANTAGE

No bridge is complete without solid foundations on both sides, and for OT, that means mastering industrial protocols. The Opta excels here, particularly with OPC Unified Architecture (OPC-UA), the gold standard for secure, platform-agnostic data exchange in automation.

As detailed in Arduino's application note, the Opta can function as an OPC-UA server, monitoring voltage levels from analog inputs and serving that data in real time to clients like Inductive Automation's Ignition HMI.

Setup is straightforward: Upload a pre-built sketch via the Arduino IDE, configure network settings, and the Opta exposes variables, like voltage readings or relay states, in a self-describing model. This semantic richness means HMIs or SCADA systems can discover and interpret data without custom mapping, slashing integration time from days to hours.

Picture this: In a water treatment plant, an Opta reads sensor voltages indicating pH levels, publishes them via OPC-UA, and Ignition visualizes trends on a dashboard. No proprietary converters needed, just plug and play.

For legacy compatibility, the Opta supports Modbus RTU over RS-485 for serial devices and Modbus TCP over Ethernet, acting as a gateway to modernize old equipment. This versatility positions the Opta as an ideal retrofit tool, breathing new life into aging infrastructure while paving the way for IIoT upgrades.

By standardizing data at the edge, the Opta ensures OT systems aren't isolated islands but connected hubs, ready to feed insights upstream.

SCALING TO THE CLOUD: A MULTI-CLOUD GATEWAY

With OT data unlocked, Opta propels it into the IT stratosphere through native cloud integrations, turning raw readings into actionable intelligence.

Take AWS IoT Core: Arduino's tutorial guides users through secure MQTT connections, leveraging the Secure Element for certificate authentication.

Start by provisioning the Opta in AWS, generating certificates, and uploading a sketch that publishes telemetry, like temperature or relay status, to topics.

Bidirectionally, AWS can send commands to toggle outputs, enabling remote control. Once in the cloud, data flows to services like S3 for storage, Lambda for processing, or SageMaker for ML-based predictions, such as forecasting equipment failures.

Similarly, the Azure IoT tutorial showcases integration with Azure IoT Hub or Central. Configure device twins for synchronized settings, stream telemetry for real-time dashboards, and receive commands for actuation.

Security is paramount: X.509 certificates ensure authenticated, encrypted channels, compliant with enterprise policies.

This multi-cloud agnosticism is revolutionary. Whether your stack is AWS for its ML prowess or Azure for Microsoft ecosystem ties, the Opta fits seamlessly, avoiding lock-in.

In a logistics warehouse, for instance, Optas on conveyor systems sends vibration data to Azure for anomaly detection, triggering alerts via Power BI, all while maintaining OT reliability.

The payoff? Scalable IIoT applications like predictive maintenance, where cloud analytics spot patterns in voltage fluctuations to prevent downtime, or energy optimization in smart buildings.

CONCLUSION:

A Catalyst for Inclusive Innovation

The Arduino Opta transcends its role as mere hardware to become a catalyst for inclusive innovation. By seamlessly integrating OT's steadfast reliability, featuring DIN-rail toughness, IEC programming, and OPC-UA interoperability, with IT's boundless potential through open-source C++ and secure cloud gateways to AWS and Azure, it breaks down barriers that once limited Industry 4.0 to industrial giants. For small manufacturers, the Opta offers an affordable gateway into IIoT without the need for costly system overhauls. For innovators, it serves as a versatile platform to experiment with edge AI and hybrid control systems. Ultimately, the Opta democratizes automation, enabling diverse teams to unite: OT engineers manage the factory floor, IT developers orchestrate cloud solutions, and together, they create resilient, intelligent factories. As we move toward a hyper-connected future, devices like the Opta demonstrate that industrial evolution thrives on smart, accessible solutions rather than disruptive revolutions.

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