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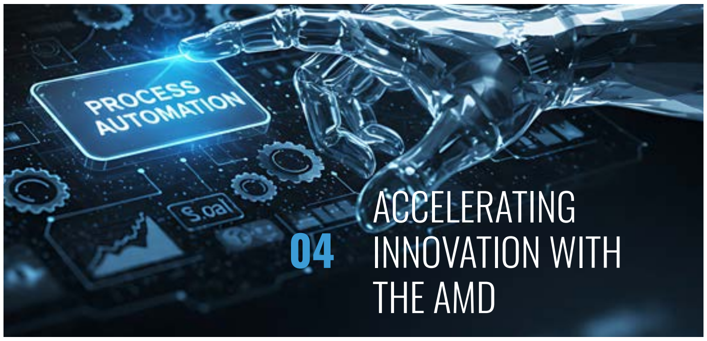

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WELCOME

Intelligent machines are becoming the defining force of modern innovation. What once relied on fixed, mechanical automation is transforming into a world of adaptive, perceptive, and collaborative robotics. From factory floors to surgical theatres, autonomous mobility to hyper-efficient warehouses, robotics is reshaping how we design, build, and interact with technology at every level. This evolution is driven by the powerful convergence of embedded intelligence, advanced sensing, and high-precision motion control. Today's robotic systems blend real-time data processing with AI-driven decision making and mission-critical hardware architectures, enabling unprecedented autonomy, accuracy, and safety. Engineers are pushing the boundaries of what machines can achieve—advancing motor control, sensor fusion, connectivity, and system integration to deliver platforms that move, sense, and think with remarkable agility.

In this edition of **eTechJournal**, *"Rise of the Intelligent Machine,"* we take you beyond the build to explore the systems, software, and silicon powering this new generation of robotics. From edge AI and next-level servo innovation to collaborative automation and predictive intelligence, we dive into the technologies accelerating smarter, faster, and more interconnected machines.

The future of robotics is not just mechanical, it's cognitive, responsive, and inherently collaborative. As intelligent systems become trusted partners in production, design, and decision-making, the boundaries between human ingenuity and machine capability continue to blur.

Let's shape the next era of robotics with intelligent machines!

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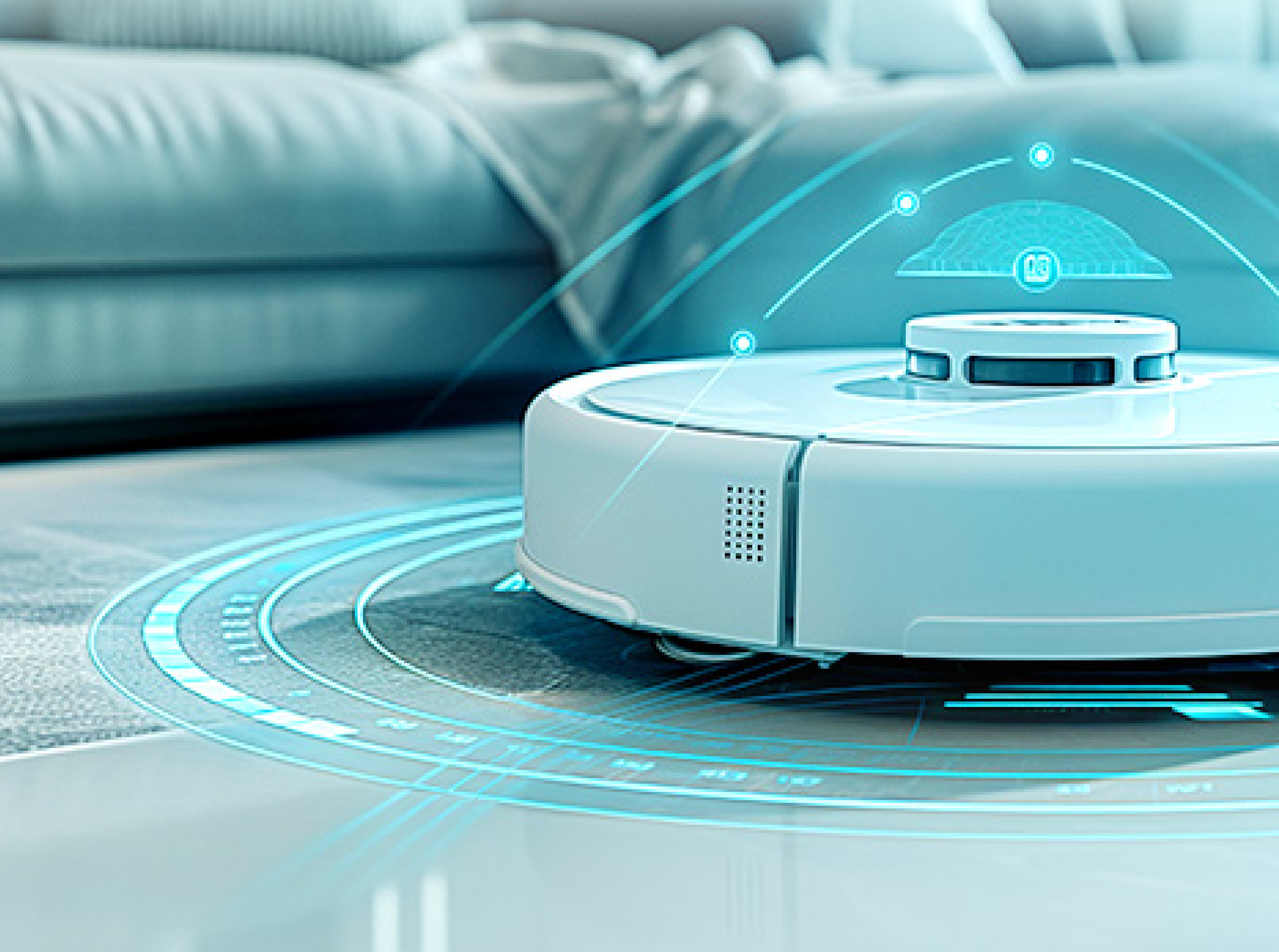
ACCELERATING INNOVATION WITH **THE AMD KRIA™ KR260 ROBOTICS STARTER KIT**

VISIT AMD



The demand for robotics is growing across various sectors due to the increasing adoption of automation. Businesses are increasingly turning to automation to address labor shortages, enhance efficiency, and improve the quality and consistency of their operations.

However, robots require specialized computing solutions because they process large amounts of sensor data and perform precise movements simultaneously. Adaptive computing platforms are crucial, as they offer the low latency and determinism required for safe, real-time control of multi-axis robots.

The AMD Kria™ KR260 Robotics Starter Kit is the easiest way to develop ROS 2-based robots with the attributes of adaptive computing and in adjunct applications involving industrial vision, communications, and control. This article discusses the KR260 Robotics Starter Kit and how adaptive computing, Robotics Operating System 2 (ROS), and particularly AMD Kria SOMs are the perfect compute platforms for next-generation robotics.

ROBOTIC STARTER KIT: A COMPREHENSIVE DEVELOPMENT PLATFORM FOR ROBOTICS, MACHINE VISION, AND INDUSTRIAL AUTOMATION

A robotics starter kit is a comprehensive development platform designed for beginners, engineers, and researchers to develop hardware-accelerated applications for robotics, machine vision, and industrial communication and control. It typically contains all the necessary components and instructions to assemble and program a basic robot.

The main components of a robotics starter kit typically include a microcontroller or system-on-module (SOM), memory, boot, and security modules. It also includes a power solution, multiple Ethernet interfaces, SFP+ connectivity, sensor interfaces, a cooling fan, and a microSD card. Some robot kits include power adapters and cables for connectivity and assembly. Sensors, motors, and software (e.g., Robot Operating System, known as ROS) are often included to enable environmental interaction and programming.

Robotic starter kits find their application across various fields, including education, industry, and research. In education, they help understand STEM (Science, Technology, Engineering, and Mathematics) subjects and offer a practical approach to learning complex concepts. In the industrial sector, robotics kits provide a cost-effective solution for prototyping and testing new technologies. They help engineers and designers to develop and refine their design or prototype before full-scale production.

These kits also provide them with a platform to test ideas and identify potential issues during the early stages of product development. A robotics starter kit also benefits researchers by providing them with a flexible and adaptable platform for experimentation. These kits allow them to develop new algorithms, test artificial intelligence applications, and explore innovative solutions to complex problems.

HOW AMD KRIA™ K26 SOM AND ROBOTICS CARRIER CARD POWER THE AMD KRIA KR260 ROBOTICS STARTER KIT

The KR260 Robotics Starter Kit is comprised of the AMD Kria K26 SOM (non-production) and a robotics application focused carrier card. The K26 SOM is featured in both the AMD Kria KV260 Vision AI and KR260 Robotics Starter Kits, customers can also design their own custom carrier card to target various applications.

The K26 SOM is a compact module built using a custom AMD Zynq™ UltraScale+™ MPSoC device. This adaptive SoC integrates Arm® processors (Processor System, PS) for running operating systems like Linux and high-level applications, and Programmable Logic (PL) / FPGA for custom hardware acceleration of demanding tasks such as AI inference or image processing. It also includes essential memory and power management.

The carrier card acts as the "interface" and expansion hub. The K26 SOM plugs into it, gaining access to the external world. The carrier card breaks out the SOM's high-density connectors into accessible ports, including Ethernet, USB, and crucial camera interfaces (MIPI CSI-2) for vision-based use cases. It also provides power distribution and application-specific peripherals like motor control interfaces and additional sensor connections.

Using Kria SOMs together with AMD development tools (such as AMD Vivado™ Design Tools and AMD Vitis™ Software Platforms) and open-source tools (such as the Linux Device Tree Generator/Compiler), developers can create and test their own custom applications and programmable logic (PL) functions. This modularity also allows them to leverage powerful, standardized SOM while customizing the carrier card for diverse robotic applications, accelerating development and reducing technical risk.

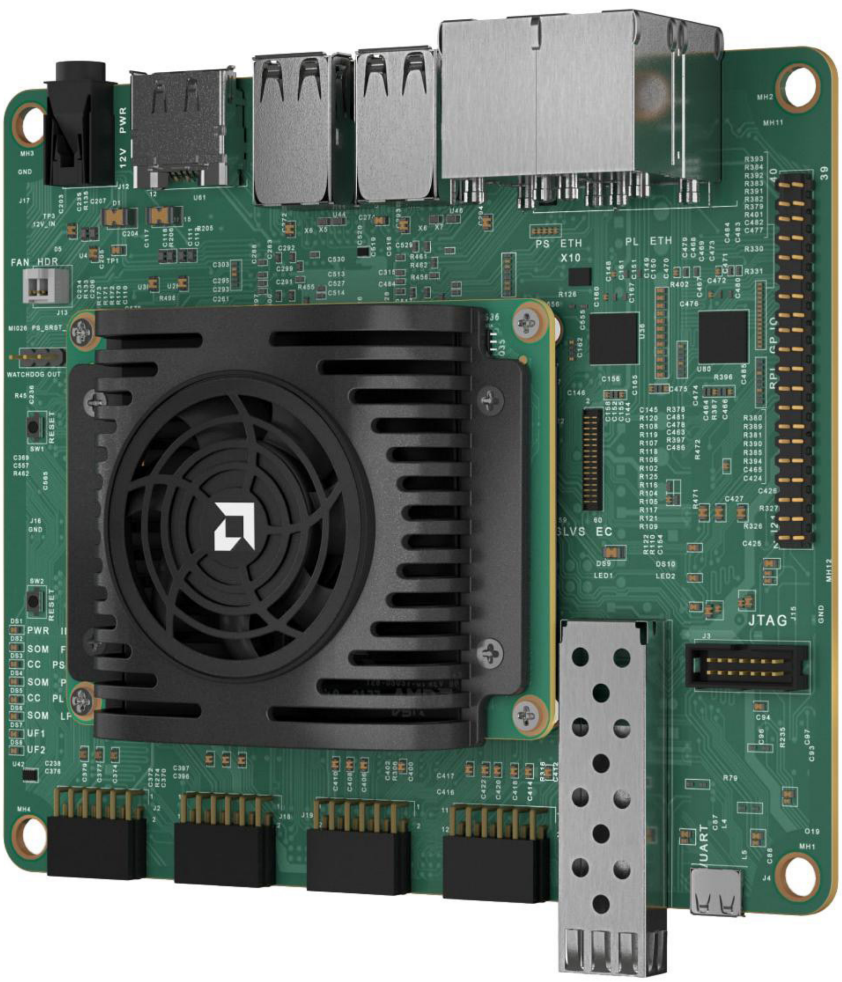


Figure 1: AMD Kria™ KR260 Robotics Starter Kit (Source: AMD)

NATIVE ROS 2 SUPPORT OFFERING IMPROVED RELIABILITY AND FLEXIBILITY TO ROBOTICS DEVELOPERS

ROS is an industry-standard software toolkit for developing robotics applications. It includes open-source software libraries (e.g., for motion planning and control) and tools (e.g., simulation, testing, and debugging) for building robotic applications.

ROS 2 is the latest version of ROS, with advanced communication capabilities and better performance than its predecessor. It is the de facto framework for robot application development, including current debugging and visualization tools, libraries, and communication frameworks. Most features are available for all supported operating systems (including Ubuntu, macOS, and Windows), the communication protocol - historically DDS with several implementations - and programming language client libraries (in C++ and Python).

The KR260 Robotics Starter Kit adopts the ROS 2 Software Development Kit (SDK), enabling a ROS 2-centric development approach with its open-source Kria Robotics Stack. The Kria Robotics Stack is a superset of ROS 2 that combines modern C++ and High-Level Synthesis (HLS) to integrate the AMD infrastructure into the ROS architecture.

Figure 2 represents a simplified view of the Kria Robotics Stack and how it encompasses a robust set of system layers to enable hardware-accelerated libraries.

One of the important features of Kria Robotics Stack is its optimization of the ROS 2 performance via FPGA-based hardware acceleration of some elements within the layers, such as TSN connectivity or packages within the perception stack. The Kria Robotics Stack can also be used by developers who do not use ROS, since most components are agnostic to the framework and can be used within traditional FPGA design approaches.

For robotics developers, the ROS 2 system has been upgraded with new tools like the ROS 2 build system (ament) and ROS 2 build tools (colcon), making it much easier to use hardware acceleration. This means the same simple commands and workflows they use for regular robot software development also work for building acceleration kernels. These improvements allow developers to quickly add powerful acceleration capabilities to their robots using ROS 2.

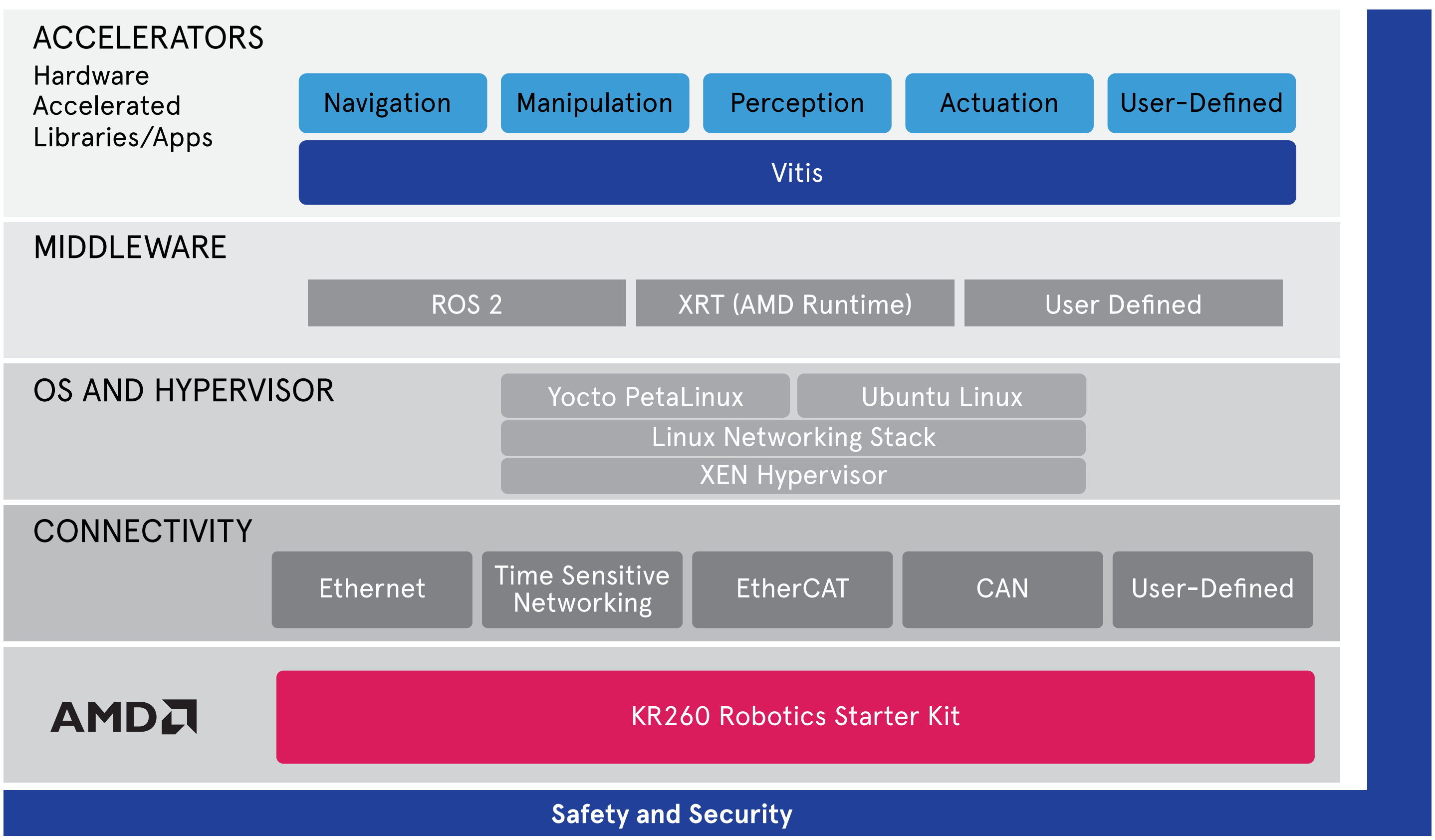


Figure 2: Simplified view of Kria Robotics Stack

HOW DO AMD KRIA™ SOMS AND ROS 2 DRIVE NEXT-GEN ROBOTICS INNOVATION?

Adaptive System on Modules (SOMs provide a ready-made, off-the-shelf solution for robotics by blending an adaptive SoC with industry-standard interfaces and components, allowing roboticists with little or no hardware expertise to use an adaptive platform immediately. Adaptive SOMs (like the K26 SOM) are ideal for next-generation robotics, integrating powerful SoCs with FPGAs, Arm processors, and standard interfaces to simplify system integration and meet high compute demands.

The Kria Robotics Stack enhances ROS 2-centric development and enables rapid prototyping with the KR260 Robotics Starter Kit. This allows developers to launch applications like the ROS 2 Perception Node faster. This out-of-the-box solution leverages FPGA flexibility for real-time performance without requiring deep hardware expertise, democratizing robotics development.

The KR260 Robotics Starter Kit pairs a K26 SOM with a carrier card that supports critical robotics connections. It offers a customizable foundation using familiar tools like Python, C++, or FPGA RTL.

Transitioning to a production-ready K26 SOM provides validated designs, pre-built firmware, and ecosystem resources, reducing hardware complexity and enabling roboticists to focus on sensors and actuators.

Adaptive SOMs accelerate design cycles for software and hardware developers by supporting deep-learning frameworks like TensorFlow and PyTorch and eliminating proprietary tools.

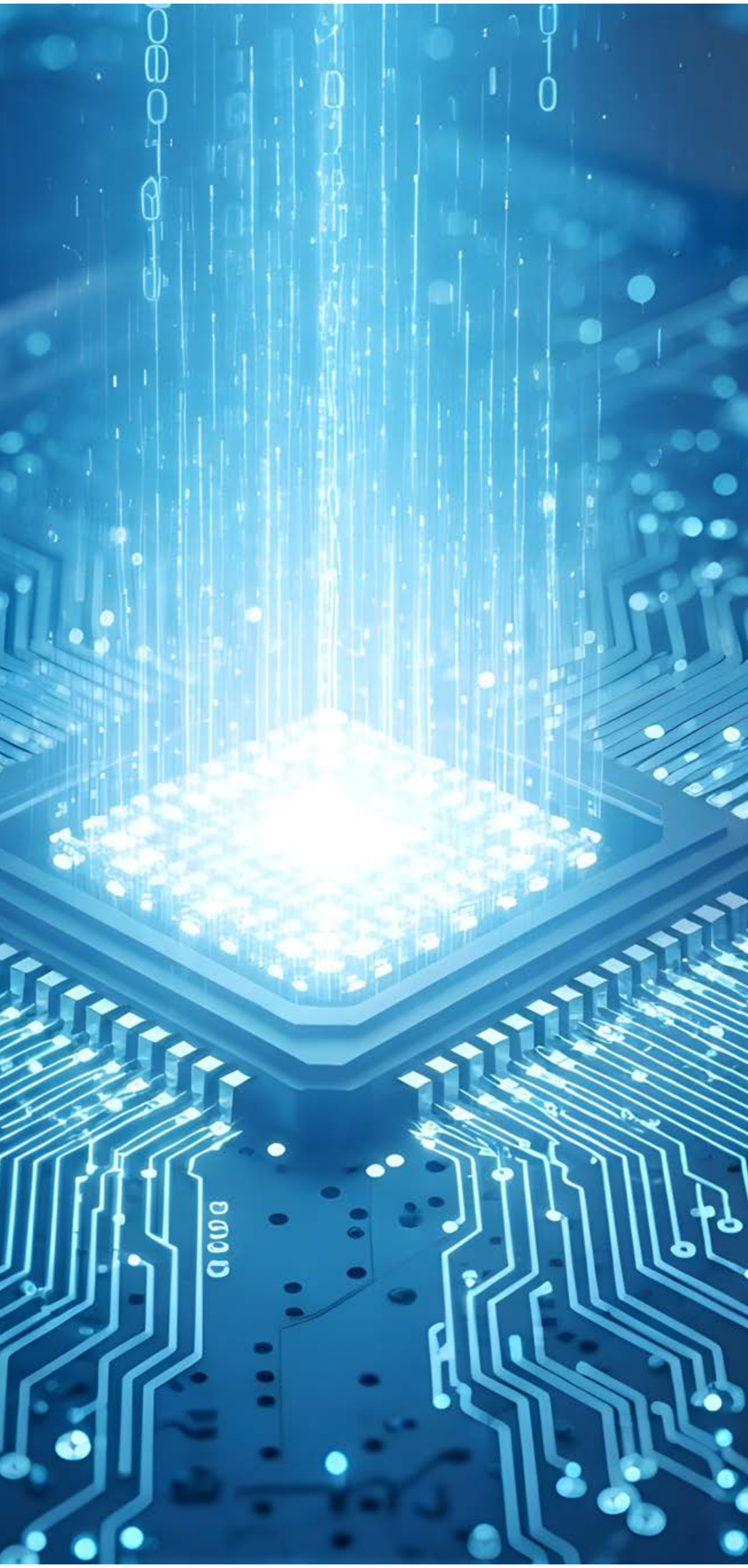
DETERMINISTIC COMMUNICATION ACROSS THE ROBOTICS INTERNAL NETWORK

The KR260 Robotics Starter Kit features multiple Ethernet connections supporting standard DDS-UDP communication protocols. It has built-in support for precise time synchronization across networks using IEEE 802.1AS standards and advanced Time-Sensitive Networking (TSN) capabilities. These are essential for real-time applications like motor control or sensor coordination.

The kit's TSN subsystem ensures that all connected devices operate in perfect synchronization with minimal timing variations. The system includes two external network interfaces, allowing it to connect directly to larger networks without requiring additional specialized TSN switching equipment.

VERSATILE CONNECTIVITY WITH AMPLE I/O SUPPORT

With four Pmod 12-pin interfaces and a 26-pin Raspberry Pi HAT, the KR260 Robotics Starter Kit allows developers to connect peripherals like GPS sensors, IMUs, motor drivers, or actuators. The kit's non-production K26 SOM, equipped with 240-pin connectors, supports robust interfaces: four RJ-45 Ethernet ports, a 10GigE SFP+ cage for high-speed networking, a 2-lane SLVS-EC RX interface for advanced vision sensors (e.g., Sony IMX547 5.1MP camera), four USB 3.0 ports for cameras or standalone use with a keyboard and mouse, and a DisplayPort 1.2a for 1080p monitor output.



CONCLUSION

The growing installation of robots is driving increased demand for accelerated high-performance computing at the edge.

The AMD Kria™ KR260 Robotics Starter Kit provides an excellent development platform for entry-level and experienced roboticists looking to create innovative ideas for ROS 2-based robotics and take them to production.

It also helps developers, especially in small and medium enterprises, get to market faster with reduced total cost of ownership (TCO).

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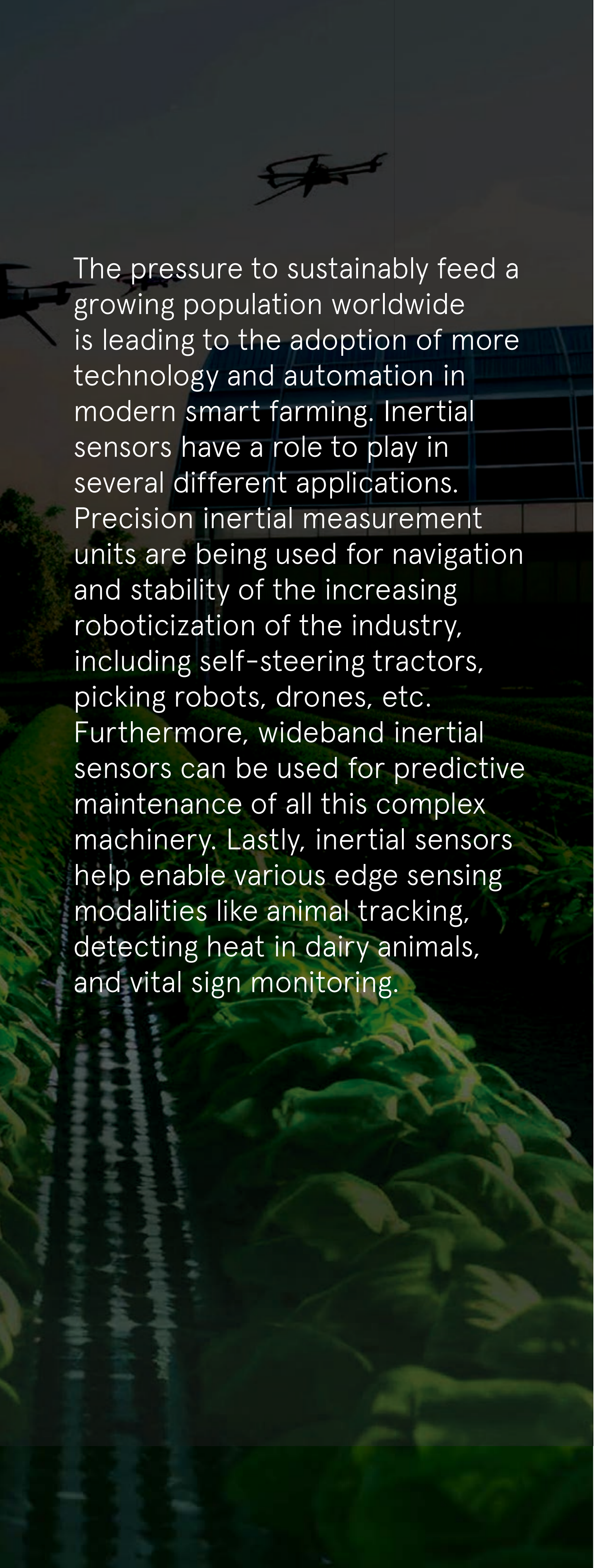
SMART FARMING REVOLUTION: HOW INERTIAL SENSING IS DRIVING PRECISION AND PRODUCTIVITY

TZENO GALCHEV
Director,
Product Marketing
and Applications



The pressure to sustainably feed a growing population worldwide is leading to the adoption of more technology and automation in modern smart farming. Inertial sensors have a role to play in several different applications. Precision inertial measurement units are being used for navigation and stability of the increasing roboticization of the industry, including self-steering tractors, picking robots, drones, etc. Furthermore, wideband inertial sensors can be used for predictive maintenance of all this complex machinery. Lastly, inertial sensors help enable various edge sensing modalities like animal tracking, detecting heat in dairy animals, and vital sign monitoring.

INTRODUCTION

The world's population is projected to reach nearly 10 billion by 2050, necessitating a 70% increase in food production worldwide as standards of living increase across the globe.1 Yet, the agri-market faces unprecedented challenges. Many developed and developing nations face a shrinking agricultural workforce. Younger generations are moving away from traditional farming, and labor costs continue to rise. Compounding the challenge is our changing climate, where unpredictable weather patterns, soil degradation, and water scarcity present daunting challenges to farmers across the globe. Agricultural businesses must maximize yields, reduce waste, and optimize costs to keep up with demand and remain competitive. This is where technology has a strong role to play. The rise of artificial intelligence (AI), machine learning (ML), robotics, and Internet of Things (IoT) has made automation in smart farming more feasible and cost-effective. Farmers now have access to data-driven insights that improve decision-making.

Automated systems, such as robotic harvesters and drone-assisted monitoring, allow for faster, more efficient farming operations and reduce dependence on manual labor. Precision farming techniques improve soil health, seed placement, and crop growth, leading to higher yields per acre. Smart irrigation and fertilization systems minimize water and fertilizer waste, leading to cost savings and resource conservation.

In the world of smart farming, inertial sensors play multiple critical roles. First and foremost, inertial sensors provide real-time data on acceleration, orientation, and position, improving the efficiency of autonomous and semi-autonomous (autosteer) farming vehicles. Inertial measurement units (IMUs), aided by GPS, are used to navigate and steer land and air vehicles such as tractors, robots, and drones, monitor their attitude and other inertial states, and enable these vehicles to follow precision paths for seeding, tilling, and spraying that ultimately reduce cost and improve the sustainability of farming. Second, in live-stock management, inertial sensors can be used to track animal movement and behavior, allowing farmers to monitor herd health and detect anomalies in activity patterns. Lastly, the integration of inertial sensors with AI-driven further improves the predictive maintenance of farm equipment, reducing downtime and maintenance costs.

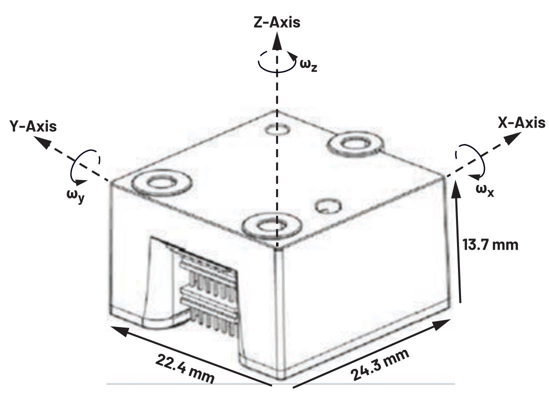


Figure 1. The ADIS16576 inertial reference frame

Advancements in micro-electromechanical systems (MEMS) technology have led to enhanced performance, making MEMS IMUs pivotal for scalable autonomous vehicle (AV) platforms. MEMS IMUs often serve as feedback sensing elements in motion control systems, such as guidance navigation control (GNC) in autonomous vehicles or in pointing control for smart implements (sprayers, seeders, scoops, blades). When used as a feedback sensing element, MEMS IMU performance has a direct impact on a system's accuracy.

The ADIS16576 is a recent example of a MEMS IMU that delivers advancement in both functional integration and core sensor performance (Figure 1). This device offers a substantial leap forward, with the most impactful behavior coming from a 10× improvement in gyroscope vibration rectification error (VRE) and a 50× improvement in accelerometer VRE. On the most basic level, MEMS IMUs provide triaxial angular rate sensing around three mutually orthogonal axes (roll, pitch, yaw) while also providing triaxial linear acceleration sensing along the same three axes.

The accelerometers provide mean (or static) angle estimation while integrating gyroscope measurements provides real-time angular displacement. System processors combine these two angle estimation sources to produce credible feedback control information for GNC or pointing control systems.

When operating in this way, having an accelerometer VRE of 1.3 mg, under 4 g rms of vibration, means that the GNC platform can preserve an attitude angle of better than 0.1° without requiring assistance from any other sensing function. This can be very useful for UAVs that may experience substantial changes in vibration, depending on thrust levels.

In gyroscopes, VRE can create quick and persistent changes in bias, which can result in erroneous motion correction and, in the worst cases, can lead to instability in the platform. In prior generation devices, VRE responses could exceed 300°/h, under 8 g rms, while the ADIS16576 offers a response of 12°/h, which greatly reduces the burden of estimation/correction by other system sensing modalities.

One of the most important functional improvements of this MEMS IMU is in the scalable external synchronization. By including a user-programmable, clock scaling function, system developers can now drive 4000 Hz IMU data sampling with slower system-level references, such as the GPS or a video sync.

This offers both tight coupling with pulse per second (PPS) or perception sensing references while preserving all the digital processing options that higher data sampling provides. Figure 2 and Figure 3 illustrate an example where an autonomous vehicle platform will use a 20 Hz GPS reference and a 200× scale factor to produce an internal sample rate of 4000 Hz.

In addition, this system illustrates the use of an on-board decimation filter to reduce the output data rate by a factor of 20× (200 Hz). In more dynamic situations, such as a crop inspection drone operating in windy conditions, the system processor may need to read and process the data at the maximum sample rate to assure stability and maneuverability.

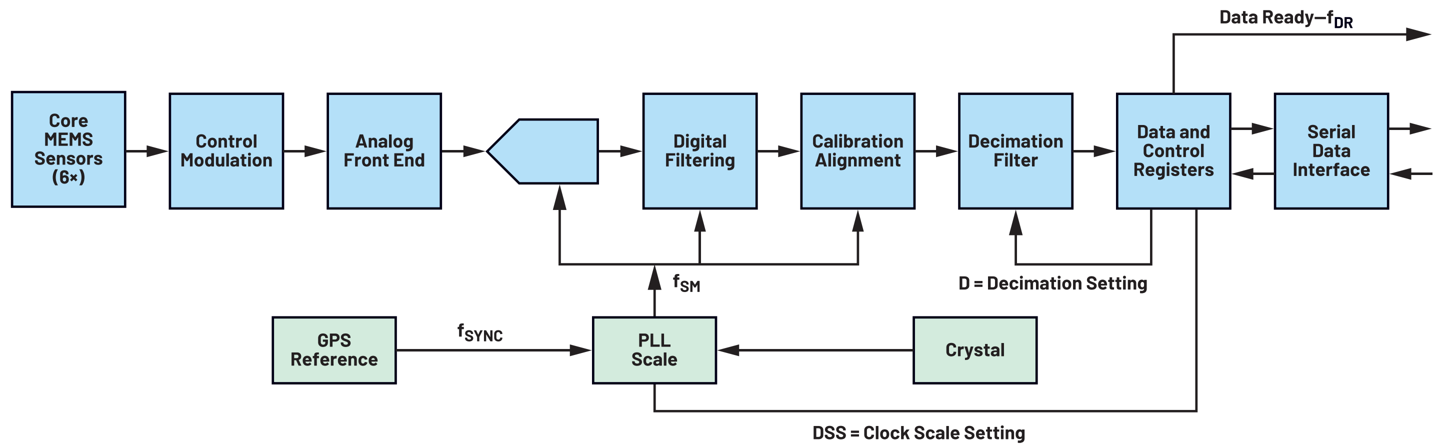


Figure 2. The ADIS16576 signal chain and external synchronization inputs

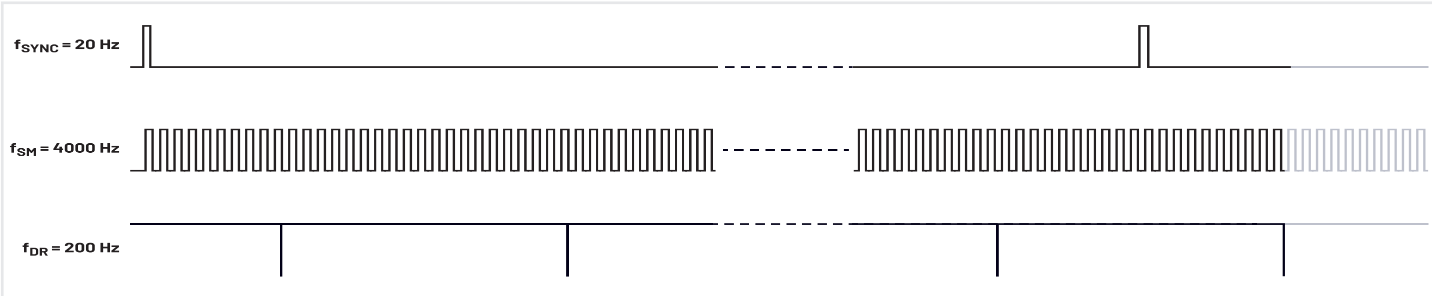


Figure 3. Timing diagram of the ADIS16576 in scale sync mode

Another area where inertial sensors are providing critical capability is in the use of IoT systems, which are used to continuously monitor animal location and physiological conditions. Typical embodiments include either tags, tacked to the ear, tail, or body, and smart collars worn around the neck. These tags can help manage herd location and, more importantly, give continual insights into animal welfare, such as activity, feeding time, and respiration rate, and newer capabilities that offer the ability to track heart rate and other vital signs.

Neck-mounted collars have become invaluable tools for detecting estrus (heat) in cattle, rumination, lameness, and other conditions. A core requirement in these IoT systems is power consumption because maintaining batteries (rechargeable or primary) in large herd populations is an intractable chore. The ADXL366 offers unprecedented capability in this respect.

This triaxial accelerometer can directly connect to a battery because it is internally regulated, can operate down to 1.1 V, and can deliver motion data at 100 Hz using approximately 1 µW of energy. At this level, energy consumption is lower than the self-discharge of a coin cell battery. When used in a neck-worn collar, the accelerometer can scale between low power and low noise modes, providing a minimum signal in the range of 3 mg and 8 mg rms—enough to distinguish between the chewing, rumination, and respiration rate (R-R).

An enhanced vital-sign monitoring capability is offered by the ADXL380, which operates with noise levels that are almost two orders of magnitude lower over a 4 kHz bandwidth. For a fair comparison at 200 Hz bandwidth, the equivalent noise for this accelerometer would be 0.4 mg rms.

Such a signal-to-noise ratio (SNR), coupled with the wide bandwidth, can turn this tri-axial accelerometer into a stethoscope that can collect heart rate information through a ballistocardiogram or various noises associated with breathing, digestion, and other physiological functions. A comparison between the two accelerometers can be found in Table 1. Another core capability offered by ultralow power inertial sensors is in the system-level power management of IoT nodes.

The ADXL366 offers a dedicated wake-up mode that can be used to power cycle electronic systems by issuing interrupts based on detected motion profiles. A typical configuration can be found in Figure 4. The accelerometers offer a rich set of programmable parameters to configure the desired motion profile and, most importantly, wake and sample at full bandwidth.

This capability is important to avoid aliasing and false detections. In wake-up mode, the ADXL366 consumes only an astonishing 180 nA. By leveraging this capability, energy hungry sensors, radios, and other components can be powered down when not needed to increase the sensor's node useful lifetime.

Table 1. Side-by-Side Comparison Between Ultralow Power and Ultralow Noise Accelerometers

Product	Full Scale Range (g)	Resolution (bits)	Wake-Up Current (µA)	Operating Current (µA)	Noise (200 Hz) Bandwidth (mg rms)	Bandwidth (Hz)
ADXL366	2 to 8	14	0.18	0.89	8	200
ADXL380	4 to 16	16	33	340	0.4	4000

Therefore, for predictive maintenance, accelerometers need to deliver three important parameters. They need to have low noise (earlier prediction), high bandwidth (to detect all spectral content and aid in the classification of the fault), and a sufficiently high measurement range.

The last one is often overlooked, however, as the magnitude of acceleration is proportional to the frequency □2, and high frequency spectral content can saturate the sensor if not considered.

The new ADXL382 triaxial, digital accelerometer offers all three requirements in a compact package. The product has a full-scale range of up to 60 g, 8 kHz bandwidth, and ultralow noise < 55 µg/√Hz.

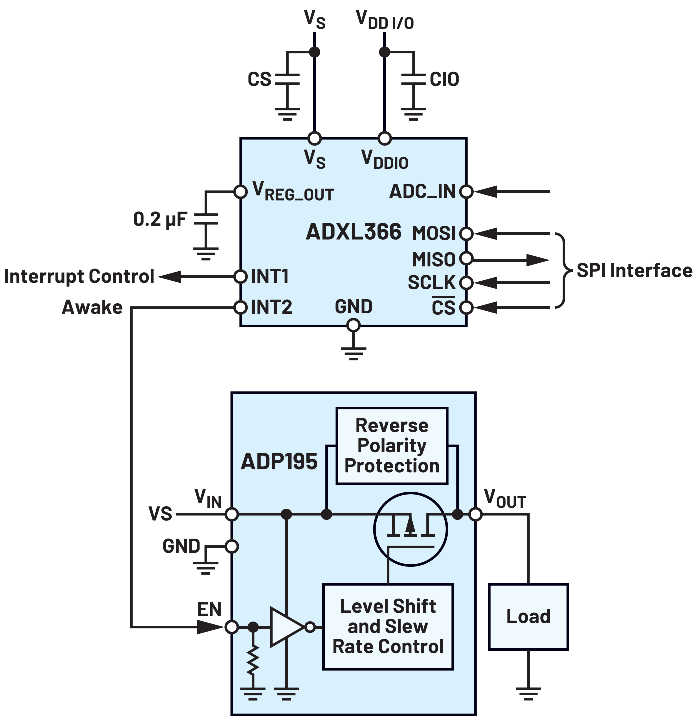


Figure 4. The ADXL366 configured as a motion switch within IoT systems

The last topic is regarding the integration of inertial sensing and AI analytics for predictive maintenance in smart farming. As the scale of modern farms increases, they are having to rely on high capital expense machinery for production. This type of equipment must deal with precision operation while undergoing strenuous conditions and the rigors of seasonal farm life. Breakdown during the short planting or harvesting season can have a serious financial impact.

For example, precision-controlled instruments, such as seeders or harvesters, often have to operate through rain, wind, dust, mud, rock fragments, and many other environmental hazards. In these environments, changes in key vibration artifacts can offer advanced prediction of problems, which can be addressed through maintenance, at times that have minimal impact on peak-demand productivity. Vibration analysis in machinery (analogous to the vital sign monitoring in livestock) can pinpoint the failure mode and timing of different problems in mechanical elements, such as faulty bearings, axle misalignment, imbalance, looseness, gear faults, and other issues.

Consider a bearing defect, such as a chip out or any physical deviation from the perfect spherical shape. This will create a bump in the platform every time this defect contacts the machine's surface, resulting in a complex vibration profile that contains both fundamental and broadband content. See Figure 5 for an illustration of a complex vibration profile in spectral terms.

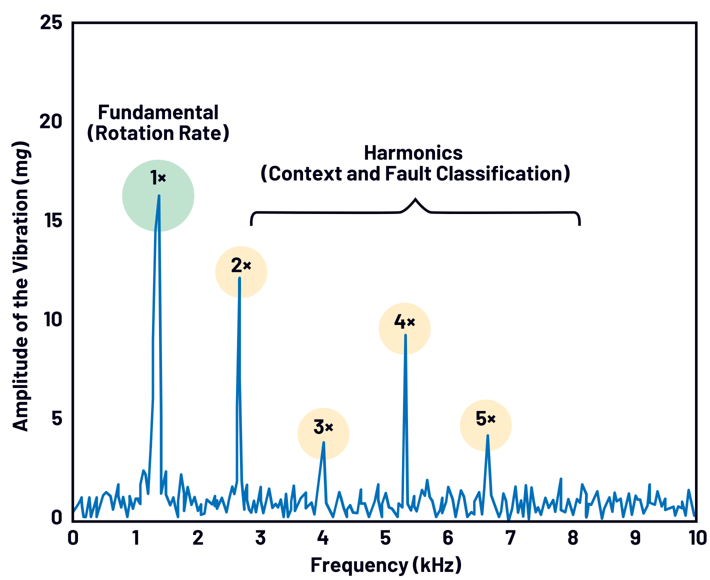


Figure 5. Wide bandwidth, spectral representation of common machine faults

REFERENCE

1 "Global Agriculture Towards 2050." Food and Agriculture Organization of the United Nations, October 2009.

CONCLUSION

Automation and technology in agriculture address critical global challenges, including food security, labor shortages, and environmental sustainability. By embracing innovations such as AI, robotics, and precision farming, the agricultural sector can enhance efficiency, reduce costs, and ensure a more sustainable future for food production. Inertial sensors have a key role to play in this ecosystem since they provide enabling sense capabilities. However, care must be taken to choose sensors with appropriate fit and function.

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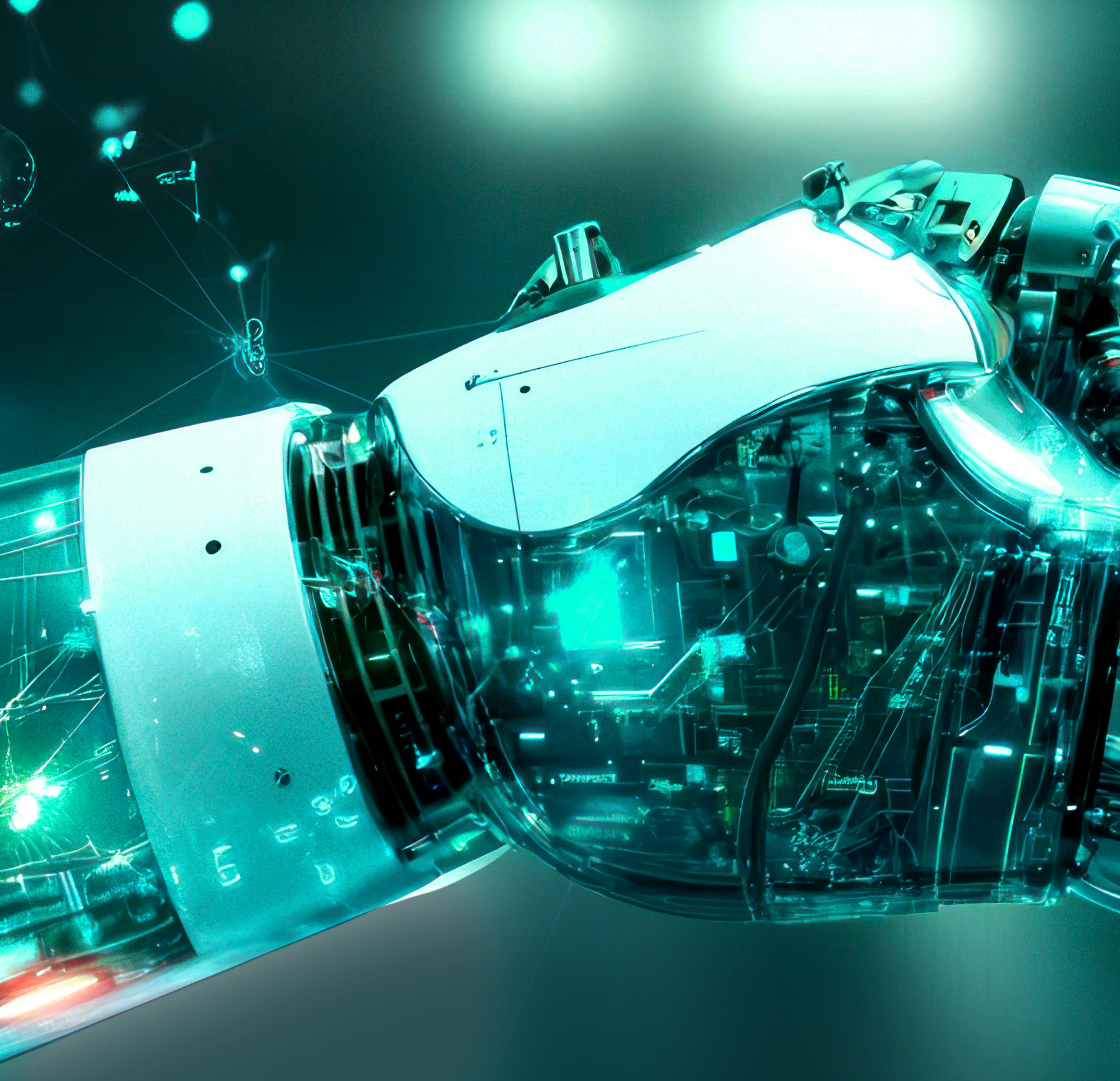
ABOUT THE AUTHOR

Tzeno Galchev is the director of marketing and applications engineering for inertial sensing solutions at Analog Devices. In this role, he oversees ADI's business in inertial sensing, including strategic marketing, product definition, and applications engineering.

He received B.S. degrees in both electrical and computer engineering in 2004, and M.S. and Ph.D. degrees in electrical engineering in 2006 and 2010, respectively, all from the University of Michigan, Ann Arbor. He has over 30 publications in MEMS and patents and is a frequent lecturer and speaker on topics related to MEMS, energy harvesting, and sensors.



OPTIMISING ROBOTIC PERFORMANCE

BEST PRACTICES FOR INDUSTRIAL ENGINEERS

In the future, machines or robots will significantly increase the efficiency of industrial processes. Robots have evolved from performing repetitive, simple tasks to handling complex operations across various industries, such as manufacturing, logistics, healthcare, and more.

They have higher precision, reliability, and cost-effectiveness. Industrial engineers must ensure that these robotic systems always operate at peak performance. Optimising robotic performance requires a deep understanding of the technology, meticulous planning, and continuous improvement.

In this article, we will explore best practices for industrial engineers to enhance the efficiency and effectiveness of robotic systems in industrial settings.

DEFINITION OF ROBOTIC PERFORMANCE

Robotic performance, in the context of industrial engineering, refers to the ability of a robot to perform its designated tasks efficiently and effectively with precision and reliability. It encompasses a range of critical parameters, including speed, accuracy, repeatability, and adaptability. A well-optimised robot should exhibit consistent and exceptional performance across various operational scenarios, increasing productivity and reducing errors. Achieving optimal robotic performance is enhancing a robot's speed or accuracy and fine-tuning it to operate seamlessly within its intended environment.

Industrial and service robots are two categories classified according to their application.

- Industrial robots are machines used in industrial automation that can autonomously control, move, and rotate along numerous axes. These robots, such as hand-guided and serial manipulators, can be mobile or fixed.
- Collaborative robots (Cobots) have enhanced industrial robots. These robots work along with humans and interact with them using end effectors. A device that interacts with the environment is known as an end effector.

FACTORS AFFECTING ROBOTIC PERFORMANCE

1. **Robot type:** Different types of robots demand different amounts of energy. For example, an enormous, heavy-duty robot could need more energy than a minuscule, lightweight robot.
2. **Task performance:** A robot's energy usage is determined by its task. Tasks requiring a lot of movement or heavy lifting may require more energy than static tasks.
3. **Operating conditions:** A robot's energy consumption might be influenced by operating conditions such as temperature, humidity, dust, or other contaminants.

BEST PRACTICES FOR OPTIMISATION OF INDUSTRIAL ROBOTIC PERFORMANCE

The first step in optimising energy usage is to measure the robot's energy consumption while in operation. Installing energy monitoring sensors and meters on the robot or its power supply allows the process to be carried out. The experimental setup for detecting temperatures (joints 1-3, gearbox and ambient joint 2) and obtaining motor current data from the industrial robotics (IR) controller is given below.

3. **Robot arm reach area:** Select a robot with sufficient arms to do tasks without unwanted movements. A robot with an excessively extended reach will use more energy.

4. **Robot arm speed:** Choose a suitable robot arm speed for the application. A robot that moves quickly consumes more energy than needed, whereas a slow robot may take longer to complete.

5. **Energy efficiency features:** A robot with energy efficiency characteristics is recommended. Regenerative braking, energy recovery, and low-friction bearings reduce robot energy use.

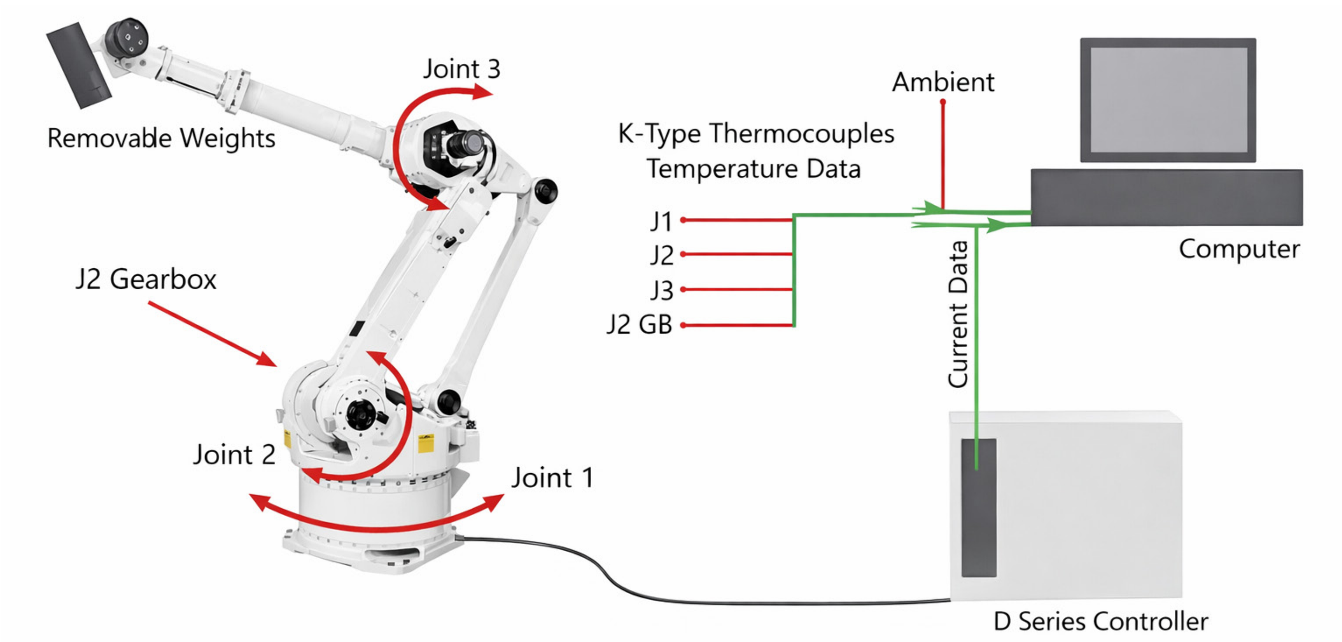


Figure 1: Configuration for detecting temperatures and collecting motor current data from the industrial robot controller

After measuring energy consumption, data must be analysed to detect patterns and trends in energy usage. This research can be used to find opportunities to optimise energy usage throughout robot operating times.

Proper robot selection: It is critical to select the right industrial robot for the specific operation in the manufacturing process energy consumption during working hours. Larger and heavier robots frequently use more energy than smaller and lighter robots. Using energy-efficient components, motors, batteries, and sensors can reduce energy consumption during robot operation. Here are some essential variables to consider:

1. **Payload capacity:** Select a robot with a payload capacity that matches the application's needs. A robot with a higher payload capacity will use more energy, whereas one with a smaller payload may need to work harder to complete the task.

2. **Minimise robot weight:** Weight significantly affects energy consumption. Minimising the robot's weight and payload reduces its energy needs.

6. **Maintenance:** Well-maintained robots use less energy. Maintenance and calibration of the robot's joints and bearings reduce friction and energy losses. To reduce robot maintenance time and cost, choose an easy-to-maintain robot. Look for a robot with an easy-to-use interface for diagnostic and repair.

7. **Application-specific features:** Robots with application-specific features may include vision systems, force sensing, and sophisticated sensors. These features can reduce energy usage by improving the robot's precision and efficiency.

8. **Flexibility:** Choose a robot that can be reprogrammed and repurposed for various jobs, reducing the need for additional robots and saving energy.

9. **Decrease inertia of moving arms:** Inertia is the resistance to motion changes. Robot arms and joints require less energy when their inertia is reduced. This can be done by adopting lightweight materials or optimising robot component design.

Energy-efficient motors in industrial robots: Electric motors control the axes of industrial robots, which execute activities such as grabbing, moving, and manipulating things. The robot's size, weight, and power requirements determine the amount of energy consumed by these motors. Using energy-efficient motors is critical in optimising energy usage in industrial robots. Industrial robots frequently require large amounts of energy, and motors are one of the most energy-intensive components.

Energy-efficient motors are built to be highly efficient, converting more of the electrical energy they receive into mechanical energy. Energy-efficient motors can cut energy usage by up to 50% in industrial robot operating times compared to traditional motors. The following actions can be taken to include energy-efficient motors in industrial robots:

1. Determine the motor types currently used in the robot and the energy consumption associated with each motor.
2. Investigate and find energy-efficient motors to replace the robot's current ones.
3. Calculate the possible energy savings by comparing the energy consumption of present motors to energy-efficient motors.
4. Evaluate the performance of the energy-efficient motors to ensure they fulfil the robot's operating criteria and standards.
5. Replace the current motors with more energy-efficient motors and undertake performance testing to confirm that the robot works adequately.

Robot programming optimisation: The way a robot's motions are programmed can have an impact on its energy consumption while in operation. Industrial robot route and motion optimisation to minimise superfluous movement can reduce energy consumption in working schedules. Avoid needless motions, quick acceleration, and deceleration, as these might waste much energy. Motion planning that is smooth and efficient might help to reduce total energy use.

Optimising robot path algorithms to provide energy-efficient paths can significantly reduce energy consumption. Techniques such as trajectory optimisation, path smoothing, and factoring energy costs during path design can be used to reduce energy consumption. Simulation tools can be utilised to model and analyse the energy consumption of various robot behaviours, algorithms, and system configurations.

This can assist in identifying energy-intensive locations and directing optimisation efforts. Machine learning and artificial intelligence techniques can teach robots energy-efficient behaviours and adapt their actions to the environment and task requirements. As a result, efficient working programming and intelligent working schedules for industrial robots can help to reduce energy consumption by minimising superfluous movements and optimising the robot's path.

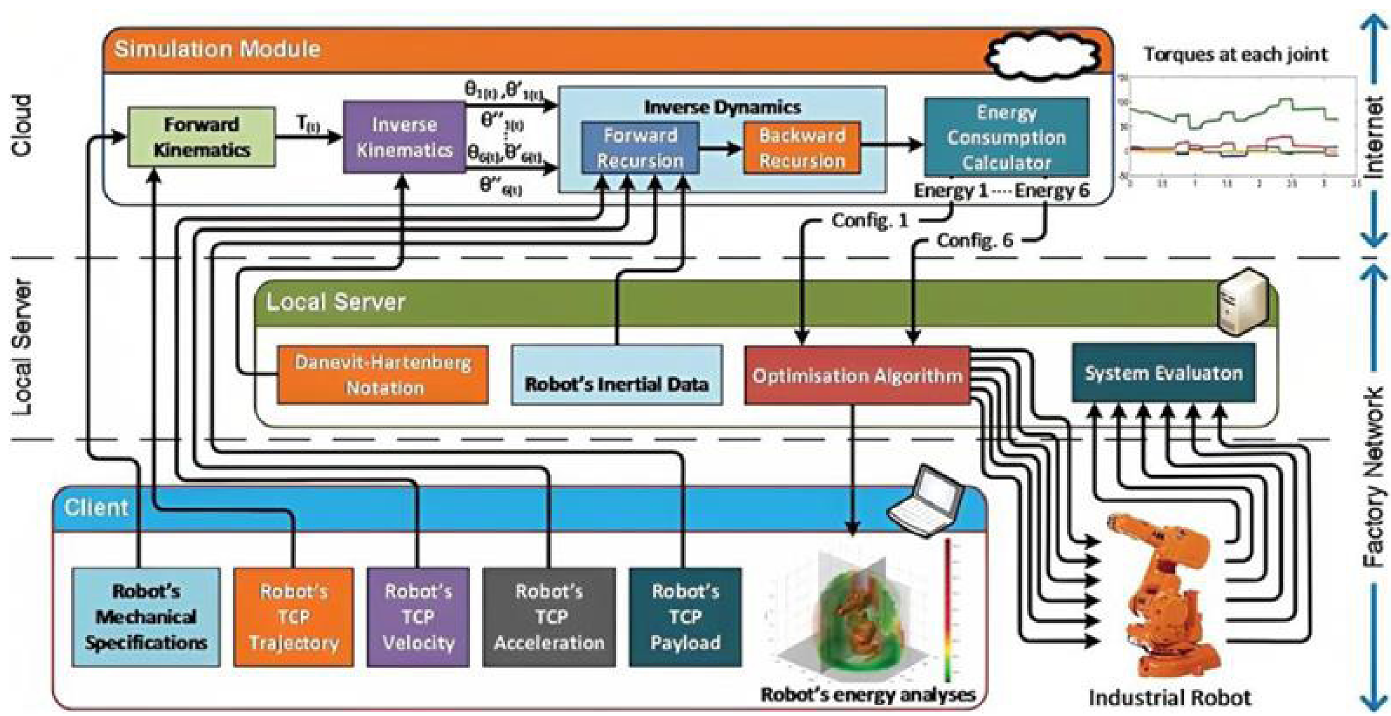


Figure 2a: Minimising energy for robot arm movement

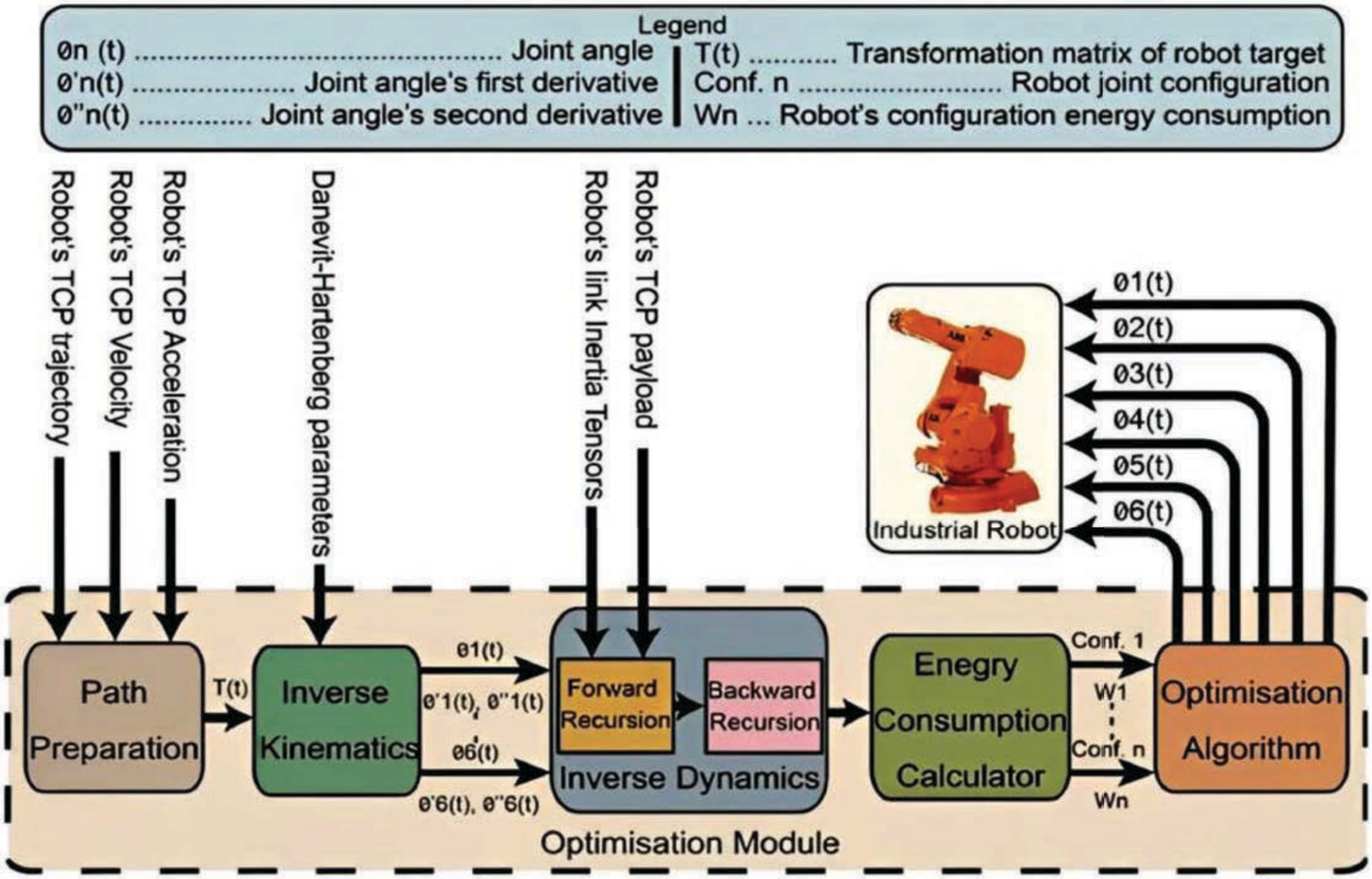
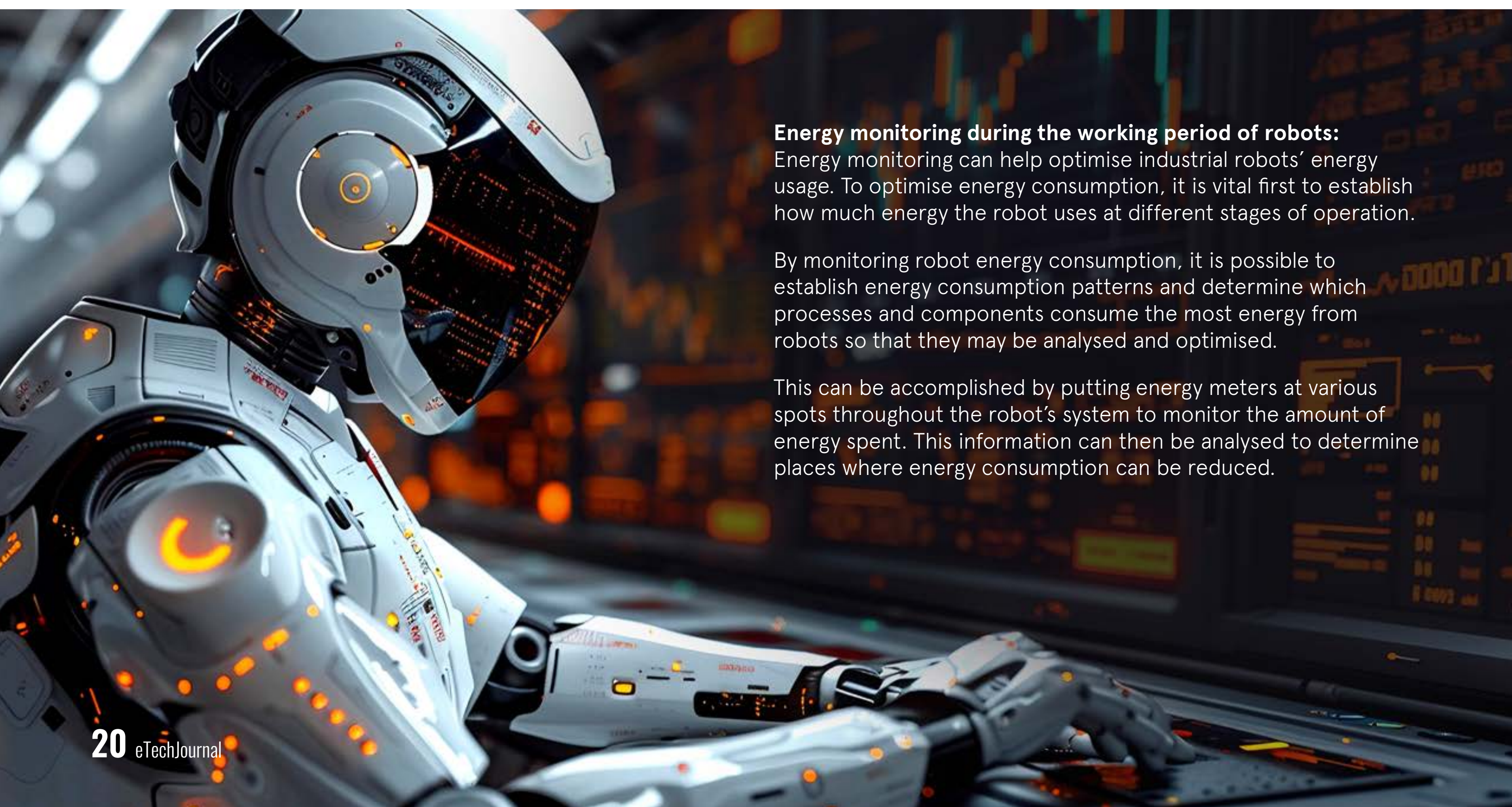


Figure 2b: An energy-efficient cloud-based mode of operation for robotic applications



Energy monitoring during the working period of robots: Energy monitoring can help optimise industrial robots' energy usage. To optimise energy consumption, it is vital first to establish how much energy the robot uses at different stages of operation.

By monitoring robot energy consumption, it is possible to establish energy consumption patterns and determine which processes and components consume the most energy from robots so that they may be analysed and optimised.

This can be accomplished by putting energy meters at various spots throughout the robot's system to monitor the amount of energy spent. This information can then be analysed to determine places where energy consumption can be reduced.

REGULAR MAINTENANCE OF INDUSTRIAL ROBOTS

Regular maintenance ensures that industrial robot components perform effectively during working hours, reducing energy usage. This includes inspecting and maintaining worn parts and lubricating the robot. Industrial robot energy efficiency and consumption depend on regular maintenance. Tips for maintaining energy-efficient robots:

5. To maximise robot efficiency, monitor and optimise its programming and control system. Reduce computations, idle time, and superfluous movements with algorithms and logic [135].
6. Train operators and maintenance staff on energy efficiency. Energy optimisation and best practices should be promoted throughout the robot's lifecycle.
7. Replace worn or damaged parts immediately to save energy.
8. Clean the robot's workspace to reduce energy use and maintain smooth operation.
9. Regular energy audits can discover energy efficiency improvements.

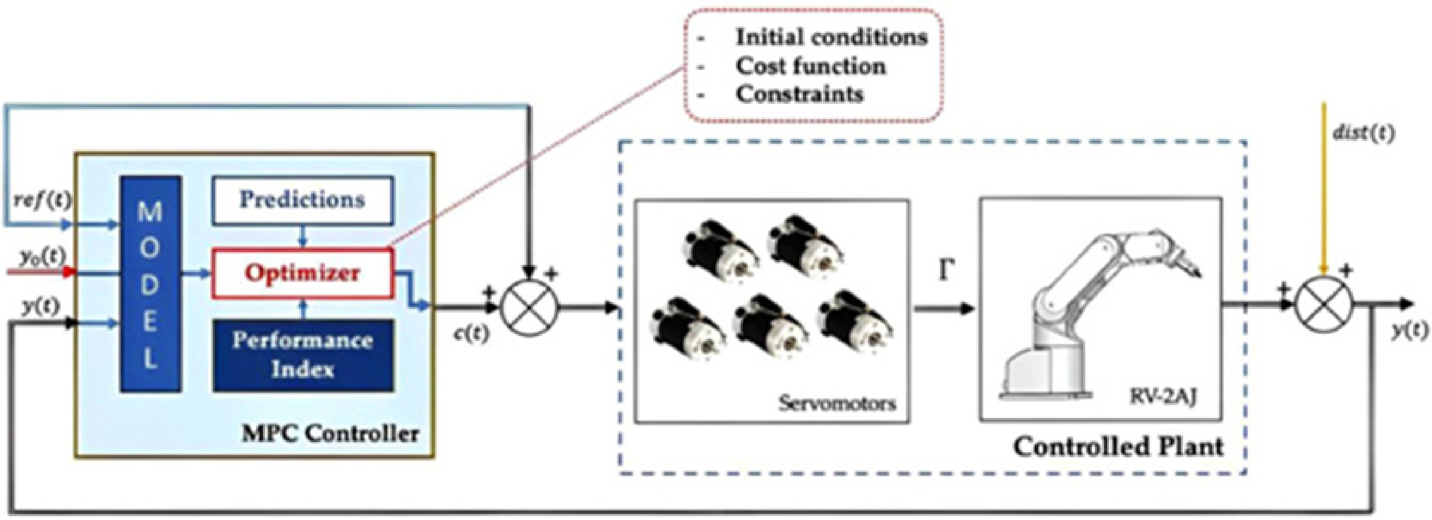


Figure 3: The closed-loop control of MPC (Model predictive control) in terms of energy consumption monitoring of industrial robots

1. Implement predictive maintenance: Check and maintain the robot's gears, bearings, and belts. Poorly maintained robot mechanical parts use more energy. Industrial machinery and devices need regular maintenance to avoid malfunctions and maximise energy use. Predictive maintenance methods like robot performance monitoring and issue detection can help keep the robot running efficiently.
2. Clean air filters: Dirty filters can impair robot cooling system efficiency and increase energy usage. Robots cool better when air filters are cleaned or replaced regularly.
3. Keep robot motors and sensors clean and debris-free. Electrical components that are dirty or damaged might increase robot energy use.
4. Reduce friction to save energy by lubricating robot parts. Lubricating robot joints reduces friction and improves movement efficiency. This reduces energy use and extends robot life.

CONCLUSION

Industrial engineers play an essential role in enhancing robot performance by performing duties such as selecting equipment, programming, and calibrating robots, seamlessly integrating sensors and visual systems, and prioritising safety and data-driven analysis. By practising these standards, engineers ensure that robotic systems perform to their full potential, resulting in efficiency, quality, and competitiveness in today's industrial operations.

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ARDUINO

INNOVATION DEVELOPMENT TECHNOLOGIES

VISIT ARDUINO

A NEW STANDARD FOR END-OF-LINE QUALITY CONTROL

IDT SMARTFIXTURE

Modern assembly lines require flexibility, speed, and adaptability. Traditional dedicated inspection systems with fixed sensors can no longer keep up with small lot sizes, high product variability, and constant configuration changes. A universal and reconfigurable solution is needed to inspect multiple products without mechanical redesign.

The answer - IDT now has an industrial-ready application called smartFixture that performs quality and presence checks on different automotive interior plastic components.

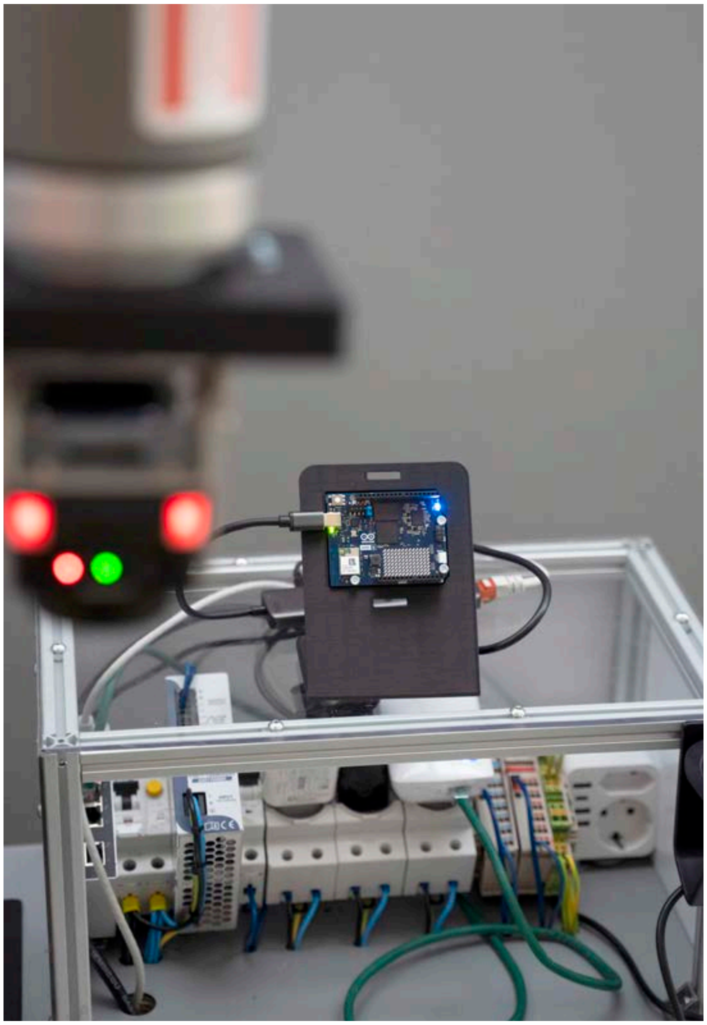
IDT smartFixtures are compact inspection cells combining a collaborative robot, smart cameras, the IDT cell-control and traceability software platform based on the new Arduino® UNO Q. The Arduino UNO Q not only controls the complete cell but also has the AI computation module system that validates completeness, visual quality, and correctness of assembly for every component passing through the station.

IDT SMARTFIXTURE_COBOT

The collaborative robot delivers maximum flexibility by reaching any point of the component, eliminating dedicated fixtures and fixed sensors. Smart cameras provide multi-angle inspection and detailed analysis. Together, they enable 360° adaptive and repeatable inspection workflows ideal for frequent product changes.

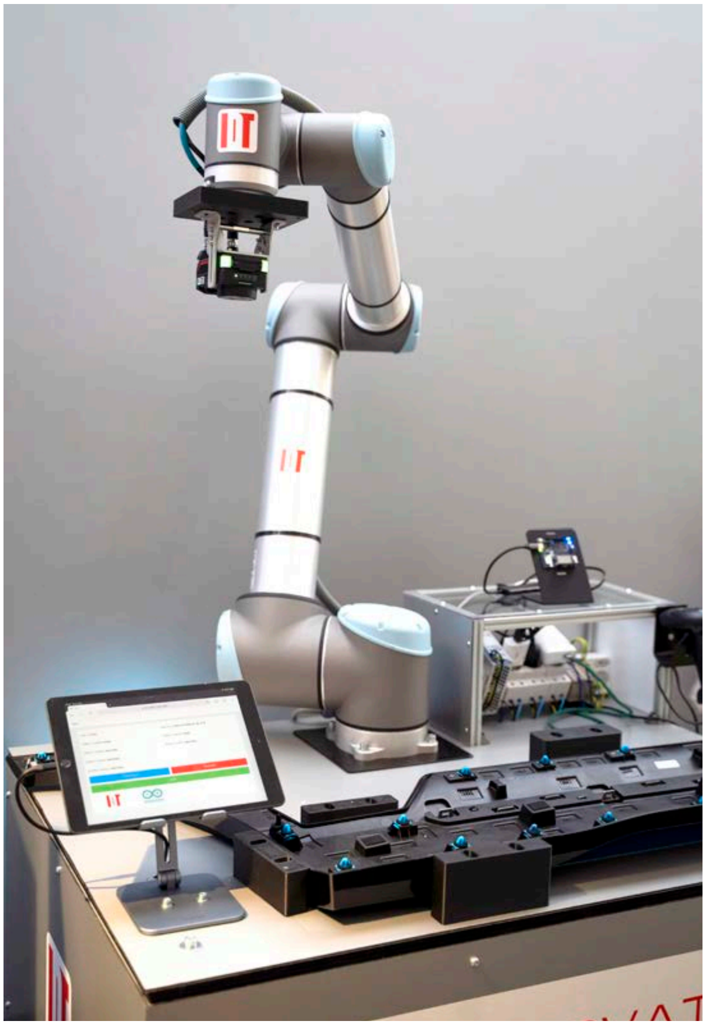
"With Arduino UNO Q, Arduino is giving us exactly what we need. Indeed, it not only has a microcontroller, but also a microprocessor with an integrated GPU optimized for AI purposes. A simple board to do everything you need on a small automation" – Margherita Ferragatta, CEO of IDT.

IDT SMARTFIXTURE_UNO Q



The Arduino UNO Q introduces edge AI capabilities that significantly enhance the smartFixture. It enables accelerated vision AI inference, detection of micro-defects, pattern mismatches, and surface anomalies, quick deployment of new AI models, and scalable multi-camera management. This transforms the smartFixture into an AI-driven quality system.

IDT SMARTFIXTURE_FULL SOLUTION



IDT smartFixtures set a new standard for end-of-line quality control by combining collaborative robotics, smart vision systems, AI processing with Arduino UNO Q, and the powerful IDT software platform. They are the ideal solution for highly variable, customized, and quality-driven production environments.

Benefits for Production

- Total flexibility: one cell handles multiple product families.
- Fewer defects and rework: AI reduces false positives.
- Fast setup: no mechanical adjustments needed.
- Complete traceability: every component is photographed, analyzed, and logged.
- Future-proof: AI models can be updated to support new products.

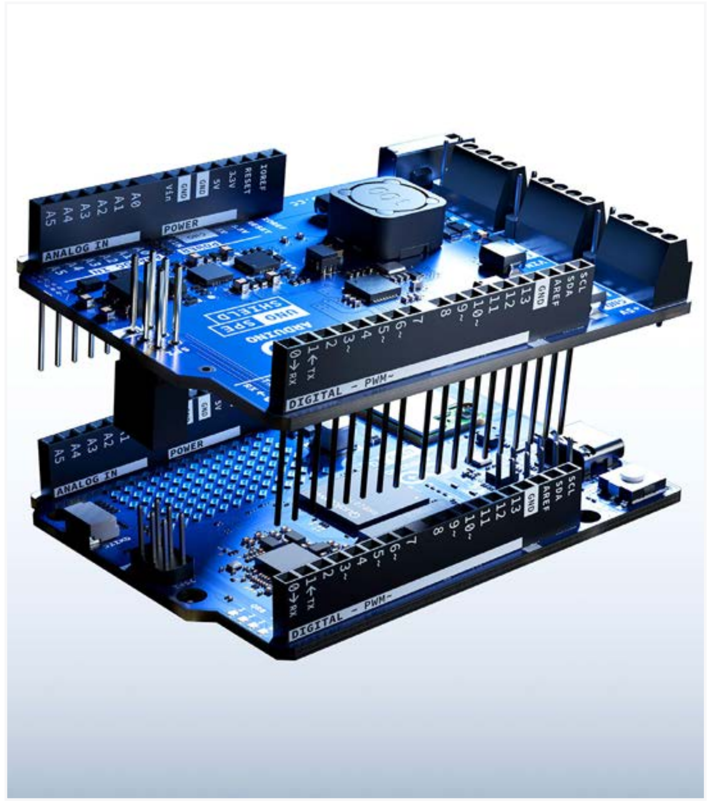
MORE ABOUT ARDUINO UNO Q

UNO Q MICROCONTROLLER BACKGROUND

Arduino UNO Q blends the high-performance Qualcomm® QRB2210 MPU, running a full Linux environment, with the real-time precision of the STMicroelectronics® STM32U585 MCU – all on a single, compact board.

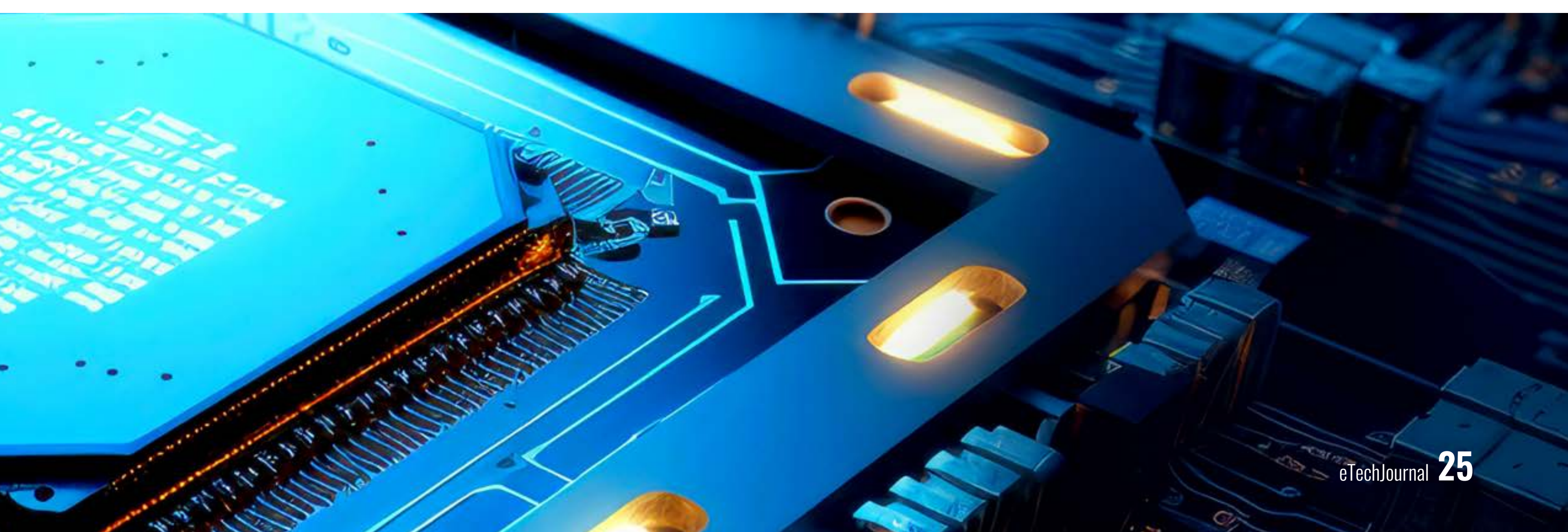
A built-in Remote Procedure Call (RPC) library (i.e. Arduino Bridge) brings together the MPU running Linux and the microcontroller, so you can create powerful and responsive applications in both worlds. This mixed architecture delivers the power and responsiveness needed for AIoT, machine learning, and advanced automation applications.

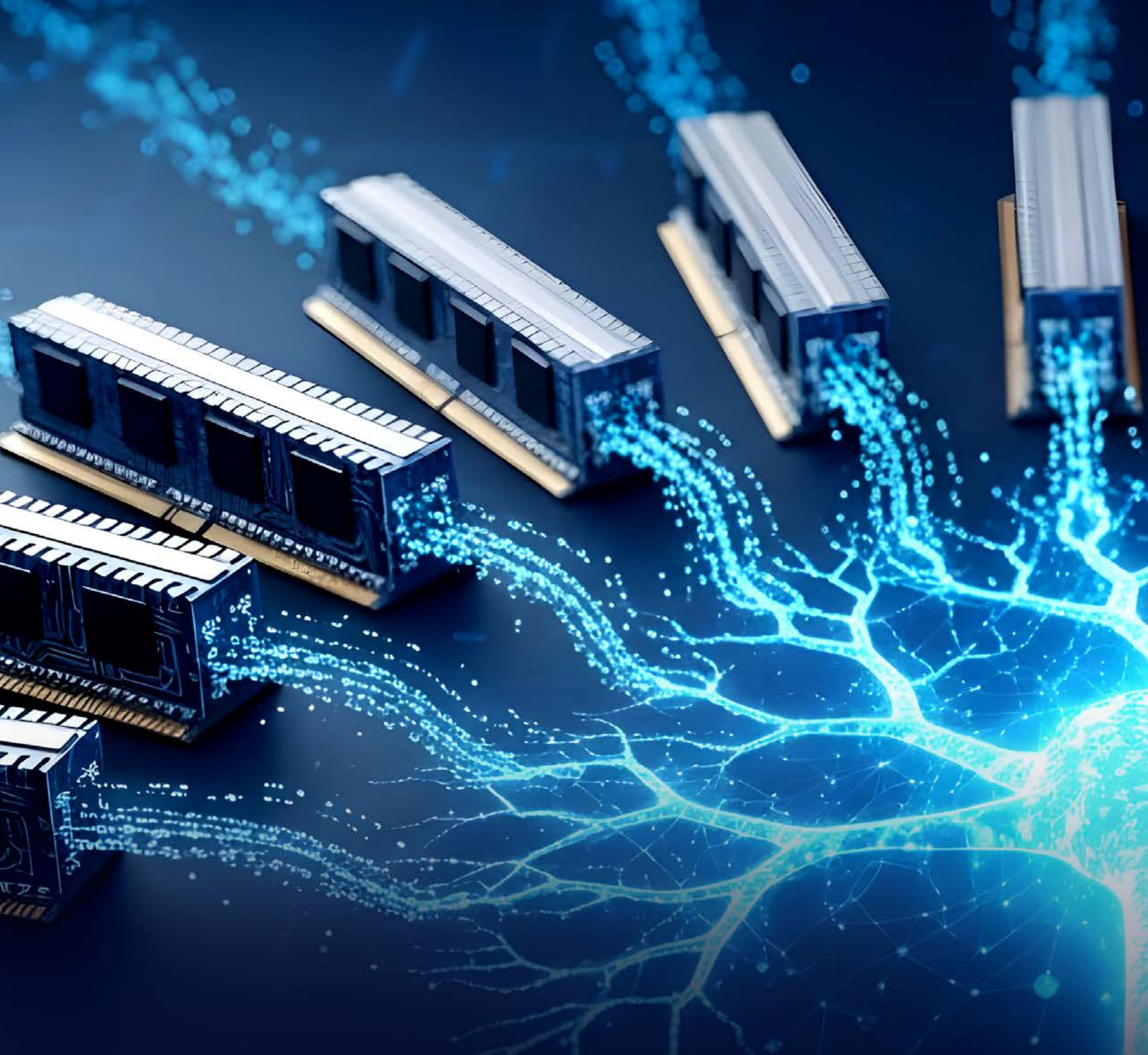
UNO Q SPE SHIELD



Its ease of expandability makes Arduino UNO Q ideal for robotics applications by leveraging the following features:

- **Qwiic connector** for seamless compatibility with Arduino Modulino nodes
- **Traditional UNO headers** allowing you to stack official or custom shields on top of Arduino UNO Q
- **New bottom high-speed connectors** for using carriers to connect MIPI-CSI cameras, MIPI-DSI displays, analog audio, and much more





THREE WAYS ARDUINO UNO Q CAN INSPIRE YOUR NEXT ROBOTICS PROJECT

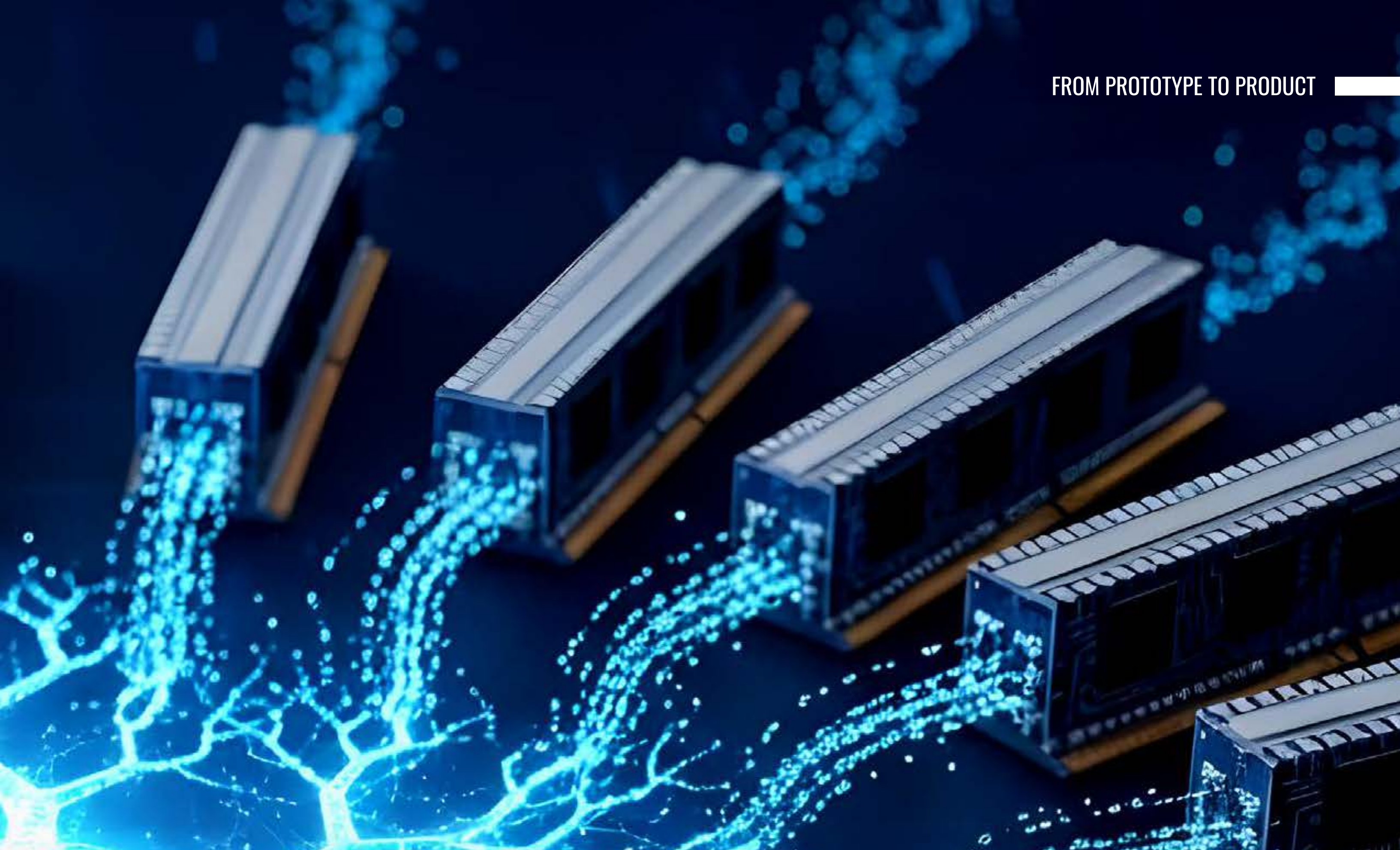
Develop an autonomous delivery bot that can navigate rooms independently, avoiding obstacles and choosing the most efficient routes.

Thanks to the Arduino UNO Q powerful image processing and graphics capabilities, the bot quickly understands its environment, while versatile connectivity options let you easily add extra sensors for enhanced precision.

Bring to life a small robot that responds to your hand and body movements, creating fun and interactive experiences.

The Arduino UNO Q fast dual cameras and powerful processor allow it to easily recognize gestures in real time, while the onboard microcontroller handles motors and sensors smoothly. Wireless connectivity lets you program and control your creation without hassle.

Create a robot arm that adjusts its grip or movements by "seeing" the object with Arduino UNO Q cameras. The fast processor handles image analysis while the microcontroller controls precise arm movements. This combination makes building smart and responsive robotic arms accessible to anyone – just like the SmartFixure use case by IDT.



WHY ARDUINO UNO Q?

Open Source + Open Industry = Cost-effective Robotics

For IDT it is not just new hardware, it's a new way to bring open innovation to the factory floor faster and with fewer compromises, all supported by Arduino.

Today, they are a team of 30 people, focussed on providing end-to-end solutions with a vendor-neutral, open-standards approach. Not being tied to anyone's platform allows IDT to build solutions that are more agile, cost-effective and customer centric. IDT's relationship with Arduino goes back years. In 2016, IDT started out using Arduino products for small industrial applications like poka-yoke systems when open-source hardware was still untested for the industry – that first Arduino-based automation solution still runs 24/7 in an automotive plant to this day.

What IDT were missing in this type of fixture that they designed (apart from having a lightweight stackable application powered by a piece of hardware that could be both reduced in size and costs) was the option to have a simple HMI for the operator that could run on the same system, without integrating additional hardware for traceability purposes. An added requirement was the possibility of using different vision systems and different cameras for the quality checks. Thus, they needed an operating system!

This is when Arduino® UNO Q came in.

CONCLUSION

How IDT's SmartFixture Achieved All-in-One Automation

The robot with a camera on the wrist checks the presence and correct positioning of the plastic clips on the component placed and fixed onto the jig. All the sensors and actuators are controlled by Arduino UNO Q, which has both the controls program running and the user interface running with also the machine vision software integration. All of this on the same board.

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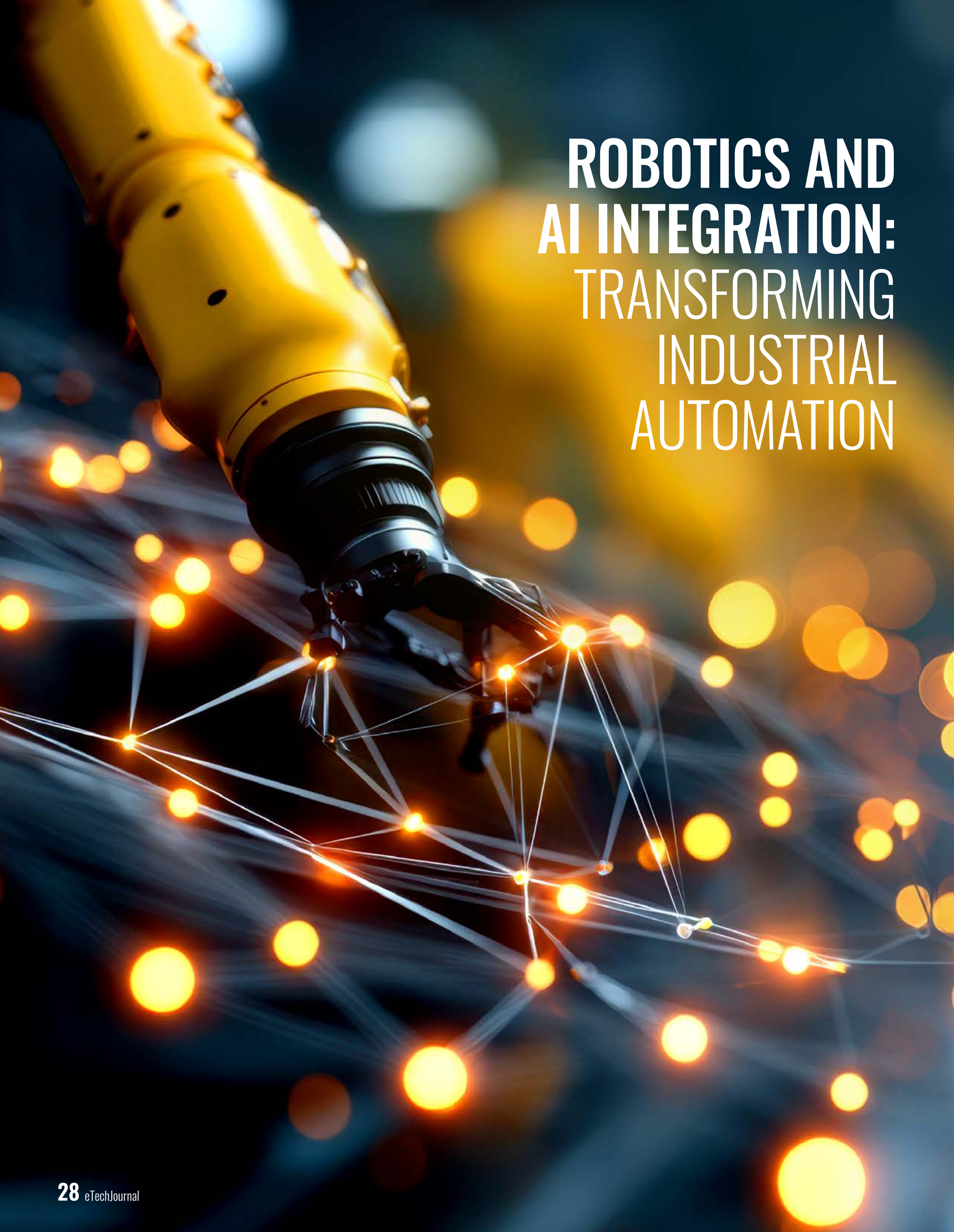


ROBOTICS AND AI INTEGRATION: TRANSFORMING INDUSTRIAL AUTOMATION

Automation, a technology that uses mechanization and computation to perform tasks with minimal human intervention, has revolutionized various sectors like manufacturing, agriculture, healthcare, and logistics. However, the current landscape is marked by a shift towards the integration of robotics and artificial intelligence (AI).

This symbiotic integration has led to a seismic transformation in automated systems, enabling more versatility, efficiency, and adaptability. Robotics, with their precise mechanical appendages, enable tasks once impossible for machines to execute, while AI systems, equipped with machine learning algorithms and neural networks, enable machines to learn, adapt, and make context-aware decisions.

This fusion is not only redefining the technical landscape but also the socioeconomic and cultural fabric of society, disrupting traditional business models, redefining workforce dynamics, and challenging efficiency and productivity. Understanding how robotics and AI are propelling the future of automation is crucial.

THE RISE OF ROBOTICS IN INDUSTRIAL AUTOMATION

Industrial automation is transforming with the integration of Industry 4.0 and IIoT concepts, advanced technologies like AI, TSN, 5G communication, collaborative robots, cloud computing, digital twin, and high-performance edge computing. This convergence leads to enhanced productivity and reduced downtime.

Smart factories of the future are characterized by the integration of IIoT technology, robotics, and AI, enhancing operational efficiency and productivity. Robotic automation offers benefits like enhanced productivity, superior quality, and decreased costs. However, it presents challenges such as significant initial investment costs, the need for a skilled workforce, and effective change management.

The rise in robot production has led to an abundance of affordable robots and advanced automation technologies, influencing the manufacturing process and presenting new opportunities for businesses and workers. Advancements in robotics technology include AI integration, enhanced sensory capabilities, and collaborative robots. AI algorithms enable machines to learn and adapt, while sensory systems like vision and proximity detectors improve robot interaction.

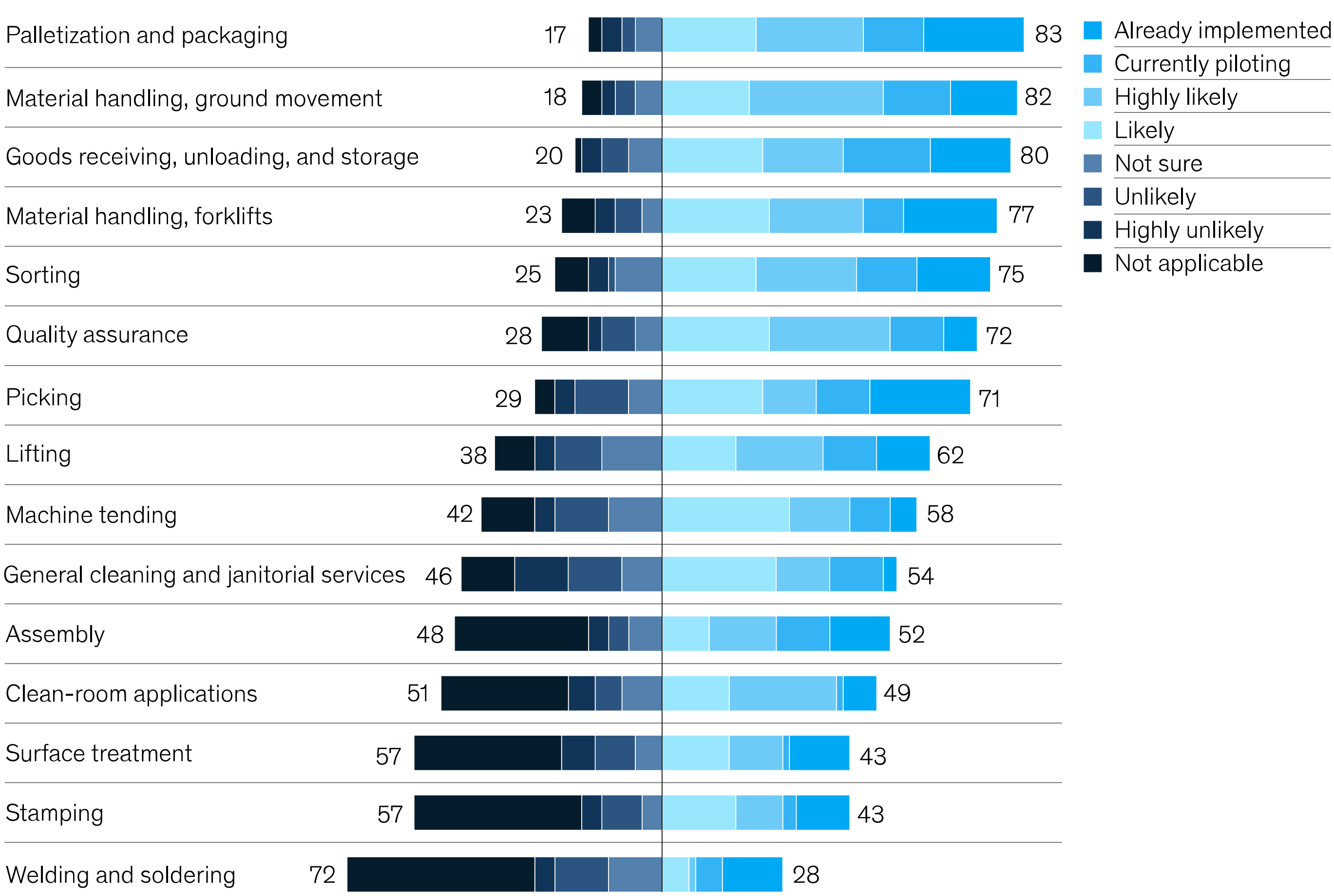
Difference Between Industrial Automation and Robotics

Aspect	Industrial Automation	Robotics
Core Functionality	Orchestrating physical machines and processes	Performing a wide range of physical tasks
Human Involvement	Typically minimal human interaction	Can work alongside or collaborate with humans
Intelligence	Focus on efficient operation and monitoring	Capable of adapting, leaming, and problem-solving
Sensors	Often relies on IoT sensors for monitoring	Utilizes various sensors for perception and interaction
Types	Industrial Automation, Business Process Automation (BPA), Intelligent Process Automation (IPA)	Versatile problem-solving robots with various applications
Use Cases	Ensuring smooth machine operation, production optimization	Handling diverse tasks in manufacturing, logistics, healthcare, etc.
Goal	Streamlining processes, reducing errors, increasing efficiency	Enhancing flexibility, productivity, and adaptability
Integration with AI	May incorporate AI for data analysis and decision-making	May use AI for advanced perception and cognition
Examples	Automated manufacturing lines, quality control systems	Autonomous guided vehicles, product picker robots

Case studies of robotics in industrial automation

The key use cases for automation in industrial companies include material handling, palletization, and sorting.

Likelihood of automation adoption, by use case, % of respondents



Source: McKinsey Global Industrial Robotics Survey, 65 senior leaders and executives in automotive; food and beverage; life sciences, healthcare, and pharmaceuticals; logistics and fulfillment; and retail and consumer goods sectors, August 2022

McKinsey & Company

Certainly, integrating artificial intelligence (AI) with robotics in industrial automation offers additional advantages that further enhance operational efficiency and capabilities.

1. Enhanced decision-making:

AI-enabled robotics can adapt and make decisions based on real-time data and changing conditions. Machine learning algorithms empower robots to continuously learn and improve their performance, leading to more efficient and adaptive manufacturing processes. This adaptability allows for better decision-making in dynamic environments.

2. Predictive maintenance:

AI algorithms can analyse data from sensors and equipment to predict maintenance needs before breakdowns occur. This proactive approach helps prevent costly downtime by scheduling maintenance when it's most convenient, thereby optimising equipment utilisation and minimising disruptions in production.

3. Increased flexibility:

AI-driven robotics can be programmed and reconfigured swiftly to handle various tasks and production requirements. This flexibility enables manufacturing facilities to adapt quickly to changes in product design or demand without significant retooling or reprogramming efforts.

4. Quality control and assurance:

AI-powered vision systems and machine learning algorithms enable robots to conduct intricate quality inspections and identify defects more accurately than human eyes. This ensures higher product quality and consistency throughout the manufacturing process, reducing waste and rework.

5. Collaborative robotics (cobots):

AI advancements facilitate the development of collaborative robots that can work alongside human operators safely. These cobots can assist workers in tasks that require dexterity, precision, or strength, fostering a more efficient and collaborative work environment.

The integration of AI with robotics in industrial automation amplifies the benefits by introducing intelligence, adaptability, and predictive capabilities, ultimately driving higher efficiency, productivity, and quality in manufacturing processes.

Robotics in industrial automation has numerous real-time applications, and both Avnet and Farnell are distributors that offer components and solutions for these industries. Here are some use cases:

1. **Automated assembly lines:** Robots are employed to handle repetitive tasks such as assembling components, tightening bolts, or placing parts on a production line. Avnet and Farnell can supply various sensors, actuators, and controllers needed for such systems.

2. **Material handling:** Robots are used to transport materials within a warehouse or factory floor. They can pick and place items, load/unload trucks, or manage inventory. Avnet and Farnell might provide robotic arms, conveyor systems, and sensors for efficient material handling.

3. **Quality inspection:** Robotics equipped with vision systems can perform quality checks on products, identifying defects or inconsistencies in real time. Avnet and Farnell may offer cameras, machine vision systems, and AI-powered algorithms for this purpose.

4. **Packaging and palletizing:** Robots assist in packaging products and palletizing them for shipping. They can pack items in boxes, seal them, and arrange them on pallets. Avnet and Farnell might supply robotic grippers, controllers, and sorting systems.

5. **Welding and fabrication:** Industrial robots are employed for welding and fabricating metal parts in automotive, aerospace, and construction industries. Avnet and Farnell could provide welding robots, welding equipment, and safety systems.

6. **Collaborative robots (cobots):** These are robots designed to work alongside humans. They are used in tasks where human-robot interaction is crucial, like in small-scale manufacturing or intricate assembly processes. Avnet and Farnell might offer sensors and safety equipment tailored for collaborative robotics.

7. **Predictive maintenance:** Robotics in industrial settings can utilize sensors to monitor equipment health, predicting when maintenance is required to prevent breakdowns. Avnet and Farnell could supply various sensors and IoT components for predictive maintenance systems.

Avnet and Farnell are distributors of electronic components, sensors, controllers, and other hardware necessary for building and maintaining these robotic systems in industrial automation. They provide access to a wide range of products that can be integrated into robotic solutions for different industries and applications.

The growth of robotics in industrial automation has been significant in recent years, driven by technological advancements, cost-effectiveness, and increasing demand for efficiency in manufacturing processes. Here's an overview of the growth supported by statistics and real-world information up until my last update in January 2022.

1. MARKET SIZE AND GROWTH

- The global industrial robotics market has been experiencing substantial growth. According to data from Statista, the global market size for industrial robots was estimated at around 50 billion U.S. dollars in 2021. It's projected to grow to around 75 billion U.S. dollars by 2025.
- The International Federation of Robotics (IFR) reported that in 2020, despite the challenges posed by the COVID-19 pandemic, worldwide shipments of industrial robots increased by 12%. The automotive industry has historically been the largest user of industrial robots, but other sectors such as electronics, healthcare, and logistics are increasingly adopting robotics for automation.

2. TECHNOLOGICAL ADVANCEMENTS

- Robotics technology has advanced significantly, enabling robots to become more versatile, adaptable, and easier to integrate into various industrial processes. Innovations in sensors, machine learning, AI, and collaborative robotics (cobots) have expanded the capabilities of industrial robots.
- Collaborative robots have gained popularity due to their ability to work alongside humans safely. These robots are designed to perform tasks collaboratively with human workers, enhancing productivity and flexibility in industrial settings.

3. INCREASED EFFICIENCY AND COST SAVINGS

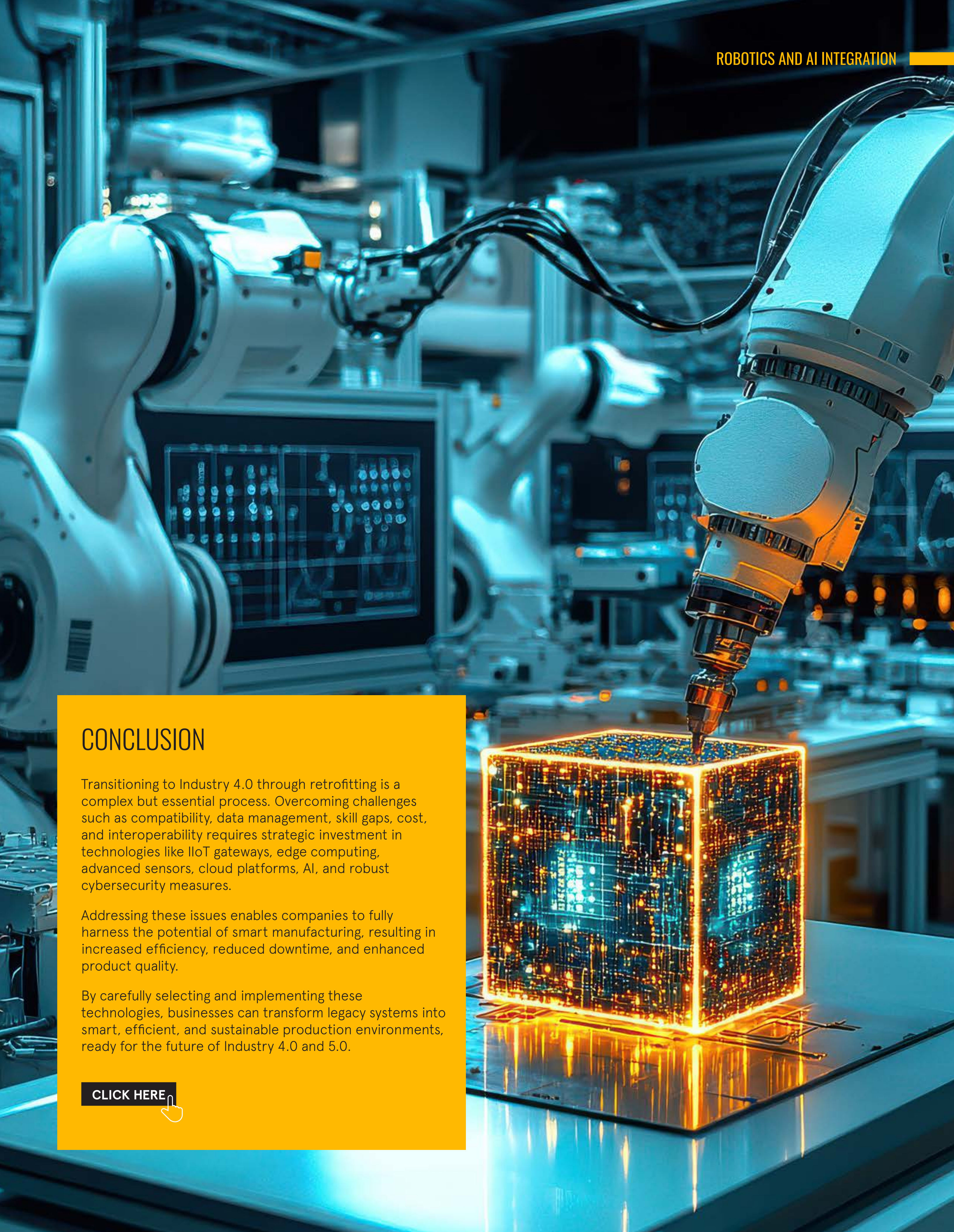
- Industries are adopting robotics to improve efficiency, accuracy, and speed in manufacturing and logistics. Robots can work continuously without fatigue, leading to consistent production output and reducing errors.
- By automating repetitive and dangerous tasks, industries can enhance workplace safety while reducing operational costs in the long run.

4. REAL-WORLD APPLICATIONS

- Automotive Manufacturing: Companies like Tesla, Toyota, and Volkswagen heavily rely on robots for assembly, welding, painting, and quality control in car manufacturing.
- Electronics Industry: Robotics is extensively used for precision assembly and testing in electronics manufacturing plants by companies such as Samsung, Apple, and Sony.
- E-commerce and Logistics: Warehouses and distribution centers of companies like Amazon and DHL employ robots for tasks such as picking, packing, and sorting items to expedite order fulfillment.

5. FUTURE TRENDS

- The integration of AI and machine learning algorithms into robotics will further enhance their capabilities, allowing for more autonomous decision-making and adaptability in dynamic environments.
- The expansion of robotics beyond traditional manufacturing into sectors like healthcare (surgical robots), agriculture (agribots), and construction is expected to continue.
- The growth of robotics in industrial automation is poised to continue due to ongoing technological advancements and the increasing demand for efficiency and productivity in various industries. However, specific statistics and developments beyond January 2022 may have evolved, so consulting more recent industry reports or news articles would provide the most up-to-date information on this topic.



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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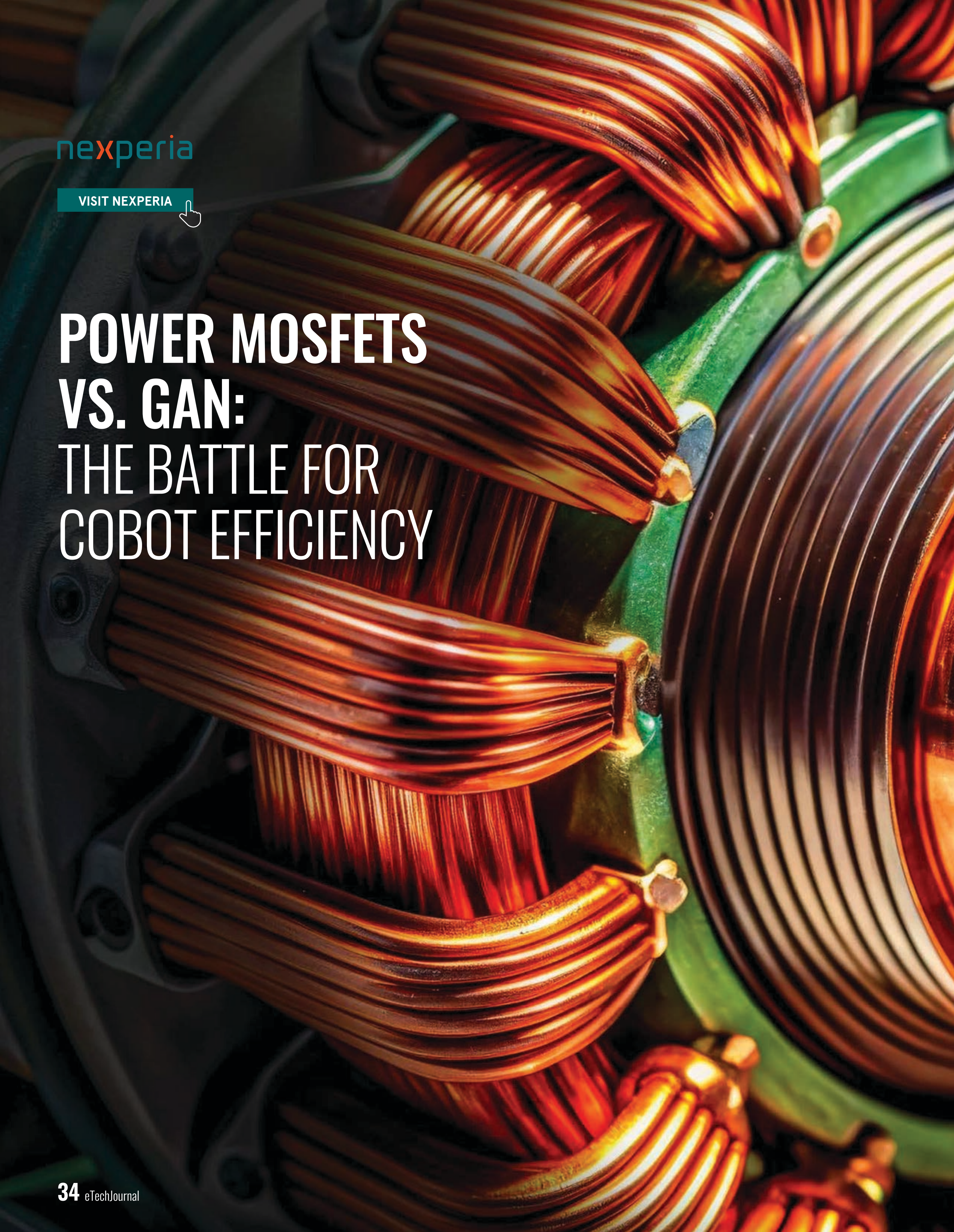


nexperia

VISIT NEXPERIA

POWER MOSFETS VS. GAN: THE BATTLE FOR COBOT EFFICIENCY

While articulated robots still dominate in industrial automation, the adoption of Collaborative Robots (Cobots) is growing rapidly, enabling safe, precise interaction between humans and machines.

A key requirement in Cobot applications is accurate movement and torque sensing, which is why they typically employ brushless DC motors for their high efficiency and control precision.

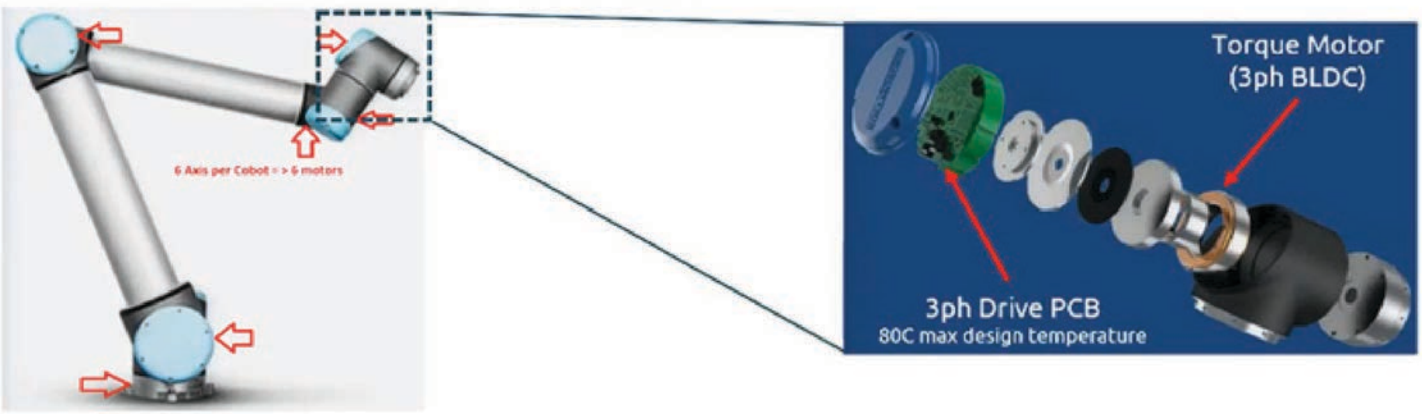
To support evolving industrial needs, Cobots are increasingly designed with modular and decentralized architectures, enhancing system flexibility and simplifying maintenance.

This shift allows for easier upgrades and better fault isolation, making Cobots more adaptable to dynamic production environments.

Most Cobot systems operate within a power range of 300 watts to 1.5 kilowatts, and are rated for continuous operation at temperatures up to 80°C. This ensures reliable performance across a wide range of tasks, from delicate assembly to more demanding operations.

These technical requirements guide the selection of motor control, power electronics, and sensing technologies in modern Cobot platforms.

Cobots: Main Challenges and Requirements



Precisie movements and Torque sensing required	Brushless DC Motor typically used
Enhance flexibility, modularity and simplify maintinance	Moving from a centralized to a de-centralized architecture
Typical Power Range 300 W-1500 W at 80 °C Tmax.	High Performance MOSFETs required
6 Axis Architecture with Voltage range 24-48 VDC	At least 36 FET per Cobot + 6 FET per Protection

RELIABLE AND EFFICIENT BLDC MOTOR CONTROL FOR COLLABORATIVE ROBOTICS

Copper Clip Technology: A Game-Changer for Reliability

In collaborative robot (Cobot) applications, BLDC motors must operate reliably under demanding conditions - high thermal loads, mechanical stress, and continuous motion in compact, vibration-prone environments. These challenges place significant pressure on the motor control electronics, especially the power switching components.

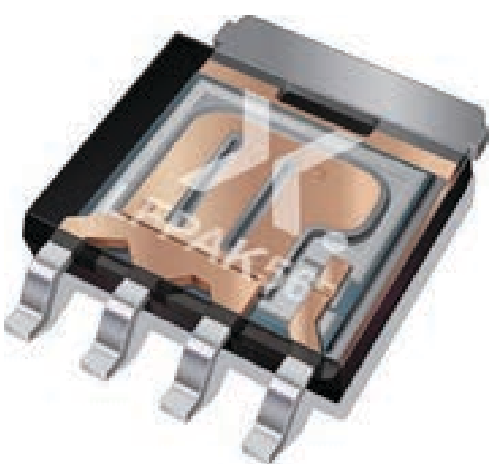
Nexperia's LFPAK and CCPAK packaging technologies address these challenges with a robust copper clip frame that replaces traditional wire bonding.

This design significantly enhances both thermal resistance and mechanical durability, ensuring long-term reliability in dynamic robotic systems.

The copper clip's geometry reduces package inductance and resistance, which improves switching efficiency and minimizes energy losses.

Additionally, the clip extends into gull-wing pins, which help absorb mechanical and thermal stress - critical for Cobots performing repetitive, multi-axis movements. These pins also improve board-level reliability, especially under thermal cycling and vibration.

Another key advantage is the exposed lead design, which simplifies optical inspection during manufacturing. This feature supports automated quality assurance processes, helping ensure consistent, defect-free assembly of motor control electronics - essential in high-volume production environments where Cobots are deployed at scale.



NextPower 80/100V MOSFETs: Designed for 48V Motor Control

Cobots increasingly rely on 48V DC systems to power BLDC motors, striking a balance between safety, energy efficiency, and performance. Nexperia's NextPower 80/100V MOSFET series is engineered specifically for this voltage class, offering a combination of electrical performance and thermal robustness that meets the demands of collaborative robotics.

The series features low reverse recovery charge (Qrr), optimized body diodes, and high thermal performance - all critical for precise and efficient motor control. These characteristics enable smoother torque delivery, faster switching, and reduced power losses, even in compact robotic systems.

Available in compact formats - 5x6 mm, 8x8 mm, and 12x12 mm - the MOSFETs support up to 100V inductive loads and span a broad RDS(on) range from 1 mΩ to 15 mΩ, making them suitable for both low and medium power Cobots. Their split-gate trench architecture ensures fast switching and minimal conduction losses, ideal for the frequent, fine-tuned actuation required in robotic joints, grippers, and end-effectors.

Performance Advantages for BLDC Motor Control in Cobots

The NextPower MOSFETs deliver several performance advantages that directly benefit BLDC motor control in Cobots:

- The low body diode voltage (1V) reduces reverse conduction losses by up to 20%, improving efficiency during dead time - a frequent condition in motor control switching cycles.
- Low Qrr enables high-frequency switching, which is increasingly common in Cobots using advanced PWM control schemes. This also reduces current ripple, allowing designers to use compact ceramic capacitors instead of bulkier electrolytic ones.
- Smaller capacitors and reduced filtering requirements contribute to smaller inverter designs, lowering system cost and freeing up space in compact robotic housings.
- Lower Qrr also helps suppress voltage spikes and EMI emissions, improving system stability and compliance with electromagnetic standards - especially important in environments where Cobots operate alongside sensitive equipment or humans.
- Improved thermal performance ensures reliable operation even in enclosed robotic arms or mobile platforms with limited cooling options.

These combined benefits result in smoother motion, lower energy consumption, and greater reliability, all of which are essential for Cobots performing precision tasks in industrial, medical, or service environments.

MLPAK for Precision Robotics: Compact Solutions for Controlled Environments

For existing designs based on DFN footprints, Nexperia's MOSFETs in MLPAK package offer a compact and efficient solution for BLDC motor control in robotics—especially in environments that are not subject to harsh vibration or extreme temperatures.

These devices are ideal for precision applications where mechanical ruggedness is not the primary concern. MLPAK combines space-saving packaging with reliable electrical performance, making it a practical choice for Cobots operating in controlled settings.

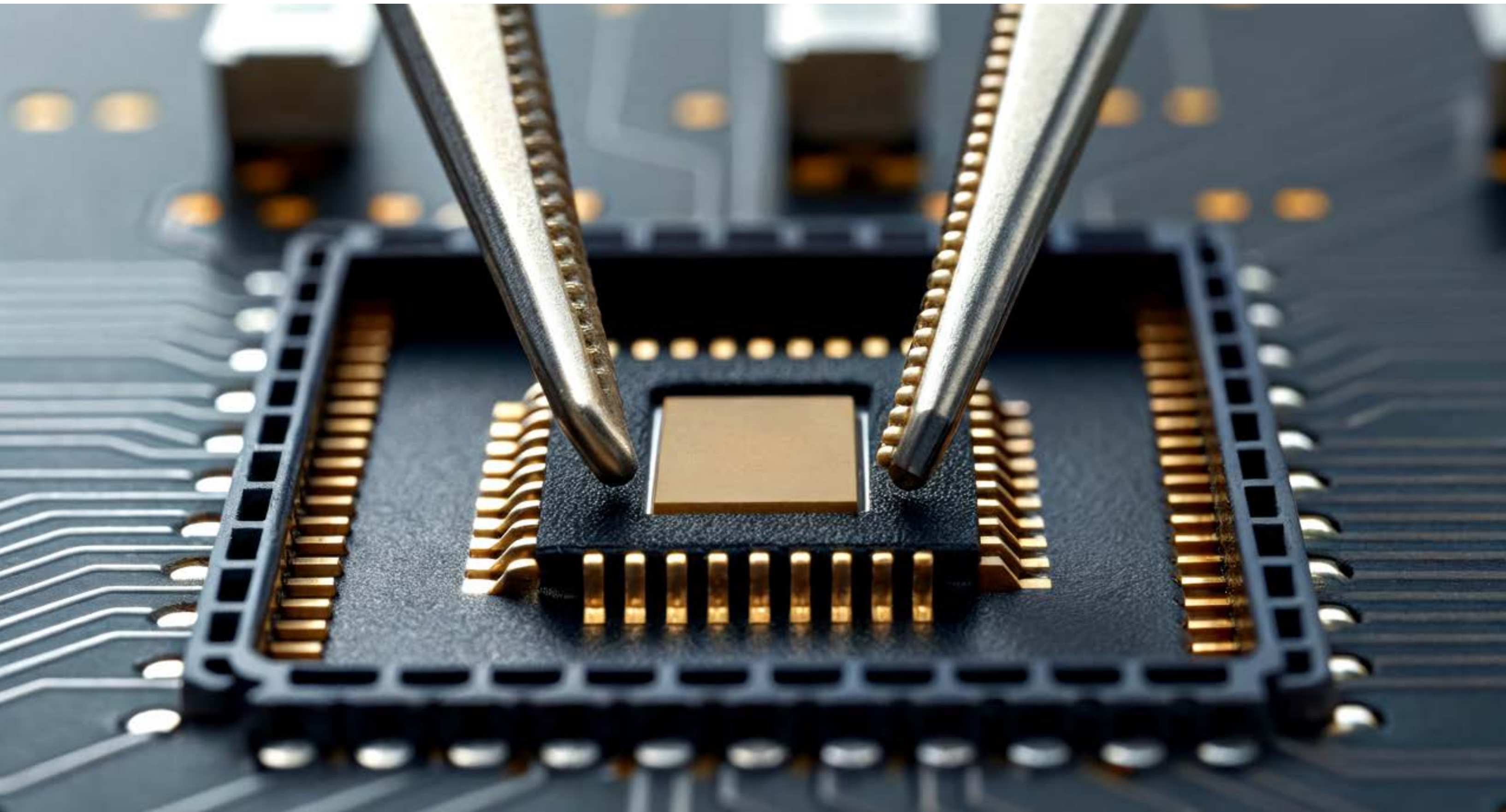
This allows for high control accuracy and system efficiency while benefiting from simplified integration into existing layouts.

Precision Control with NGD4300 Gate Driver

To fully leverage the capabilities of the NextPower MOSFETs, Nexperia offers the NGD4300 gate driver, designed for ultra-fast and accurate switching control. The NGD4300 is capable of handling input pulses as short as 10 nanoseconds, enabling rapid response times in motor control loops.

This responsiveness supports high-speed control algorithms and real-time adjustments, allowing Cobots to execute delicate tasks - such as assembly, inspection, or interaction with humans - with high precision and repeatability. In collaborative environments, where safety and accuracy are paramount, the NGD4300 ensures that motor control remains stable, responsive, and efficient.

Together, NextPower MOSFETs, and NGD4300 gate drivers forms a comprehensive solution for BLDC motor control in Cobots. It addresses the key challenges of thermal management, switching efficiency, mechanical reliability, and control precision - empowering the next generation of collaborative robotics.



SMARTER, SMALLER, SMOOTHER: GAN TECHNOLOGY FOR COBOT MOTOR SYSTEMS

Gallium Nitride: Unlocking New Potential for BLDC Motor Control in Cobots

As collaborative robots (Cobots) evolve to become more compact, efficient, and responsive, the demand for advanced motor control solutions continues to grow. These systems must deliver precise torque control, operate quietly, and maintain high efficiency - all within tight mechanical and thermal constraints.

To meet these demands, Nexperia identifies Gallium Nitride (GaN) in enhancement-mode (E-mode) as a transformative technology for next-generation BLDC motor control in Cobots.

GaN's unique material properties make it exceptionally well-suited for high-performance systems requiring higher switching applications. With a critical field strength of 3.5 MV/cm, GaN devices can achieve the same breakdown voltage as silicon with a thinner die, resulting in smaller and more efficient switching device. Additionally, GaN offers higher electron mobility and saturation velocity, enabling faster switching speeds and lower conduction losses.

These characteristics are particularly valuable in Cobots, where motor control systems must respond rapidly to changing loads and movement patterns. Whether in robotic arms, mobile platforms, or precision grippers, GaN's ability to support high-speed and high-frequency switching translates into smoother motion, better energy efficiency, and more compact designs.

New Levels of Efficiency and Compactness

To understand the impact of GaN-based inverters on motor control drives, two aspects are worth mentioning: higher switching frequency operation and dead band reduction. They result in improved motor current control responsiveness and efficiency.

Impact of higher switching frequency

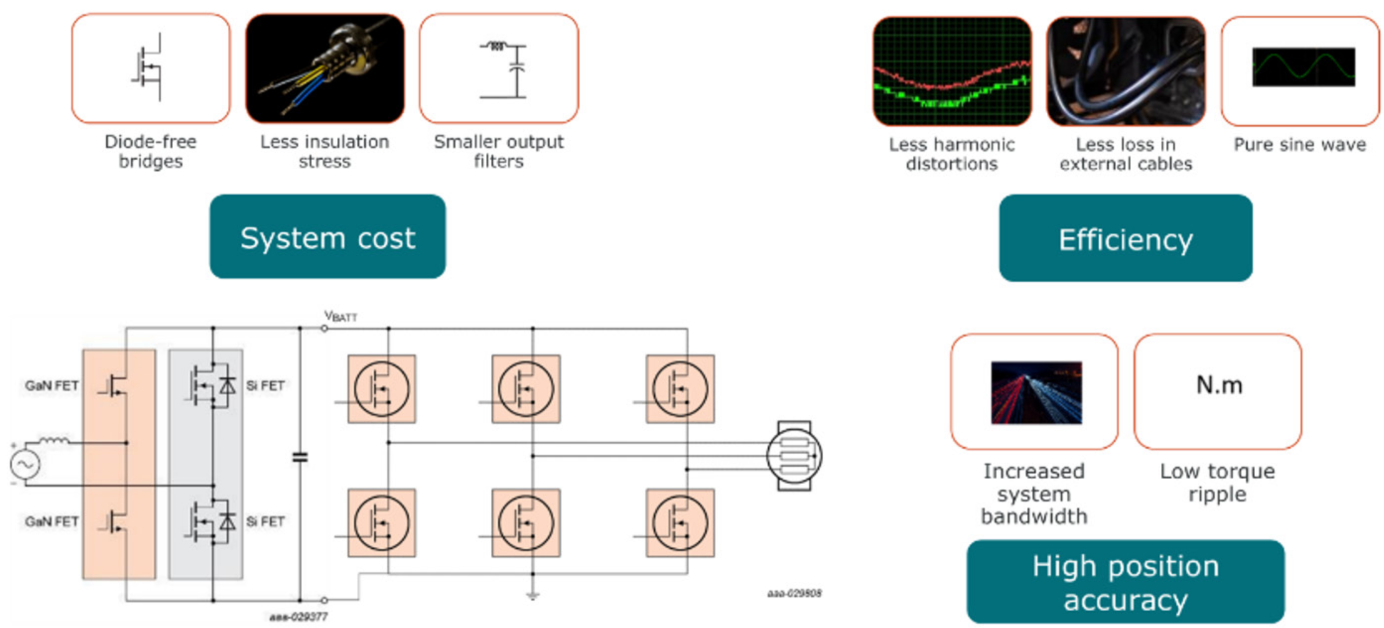
One of GaN's most impactful advantages is its ability to operate at higher switching frequencies (e.g., 100 kHz or more), which directly improves total harmonic distortion (THD). This results in cleaner sine wave generation and smoother torque ripple - critical for Cobots performing delicate tasks or operating in environments where noise and vibration must be minimized.

Higher switching frequencies also enable Cobots to operate above the audible range (e.g., >20 kHz), thereby reducing acoustic noise and improving user comfort in human-centric settings, such as healthcare, retail, or collaborative manufacturing.

GaN also contributes to smaller and more cost-effective inverter designs. Its low current ripple enables the use of ceramic capacitors instead of bulkier electrolytic ones for the DC bus link. Ceramic capacitors offer better thermal stability, lower cost, and a smaller footprint - ideal for space-constrained robotic systems.

Additionally, the filtering stage can be minimized due to reduced harmonic distortion and ripple, further shrinking the overall system size. This is especially beneficial for Cobots using high-speed BLDC motors (e.g., >20,000 RPM) or low-inductance motors, which demand fast and precise control. Even in lower-speed applications, GaN improves efficiency, reduces THD, and enhances thermal management - making it a versatile solution across a wide range of Cobot platforms.

Motion Control & Servo Drive



The impact of reduced dead-time

The faster transition between ON to OFF (and vice versa) allows the control system to minimize dead time safely. As a result, dead-time can be reduced to just a few nanoseconds (e.g., ~10 ns), improving timing precision. GaN devices have lower gate and output capacitance, leading to less stored energy and faster turn-on/turn-off. This translates into less risk of overlap (shoot-through), allowing tighter control over dead-time margins.

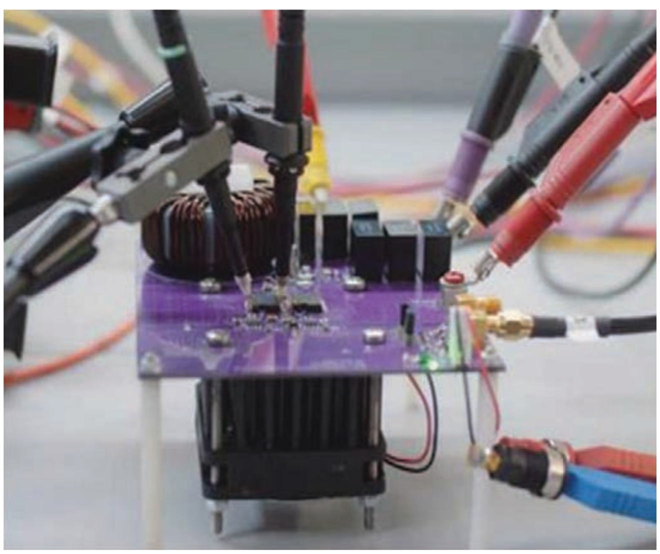
GaN FETs are majority carrier devices and do not suffer from reverse recovery losses (unlike silicon MOSFETs or IGBTs). This eliminates reverse recovery current during dead-time, which is a major contributor to: voltage overshoot, EMI, and motor torque ripple. The system gives better waveform integrity and less need for long dead-time.

In a nutshell, lower dead band time means less phase current distortion in PWM-controlled motors, reduced total Harmonic Distortion (THD), and smoother torque production. This is especially important in Field Oriented Control (FOC) and sensorless motor drives, where timing precision is critical.

While GaN offers compelling advantages, it also introduces specific design challenges that must be addressed to fully realize its potential in Cobot motor control systems.

Implementing GaN-based motor control also requires versatile, microcontrollers and more precise control algorithms and a perfect PCB layout. The fast switching speeds and sensitivity to timing demand accurate gate drive and system-level coordination to avoid performance degradation or EMI issues.

By following these design recommendations provided by Nexperia application notes, engineers can unlock the full potential of GaN in BLDC motor control for Cobots – achieving quieter, more efficient, and more compact robotic systems that are better suited for collaborative environments.



CONCLUSION

MOSFET vs. GaN: A Strategic Design Decision

In the pursuit of Cobot efficiency, the choice between power MOSFETs and GaN is more than technical – it's strategic. Both power MOSFETs and GaN technologies offer distinct advantages. MOSFETs in LFPAK, CCPAK and MLPAK packages offer proven reliability, thermal resilience, and cost-effective integration for 48V BLDC systems.

MLPAK, in particular, offers a compact solution for precision robotics in controlled environments. GaN, with its high switching frequency, reduced dead-time, and compact inverter potential, enables smoother torque control and lower harmonic distortion. However, its design complexity and sensitivity to layout demand advanced engineering.

The challenge is not about replacing one with the other – it's about choosing the right toolset for the application. In collaborative robotics, efficiency is won through smart, context-driven design.

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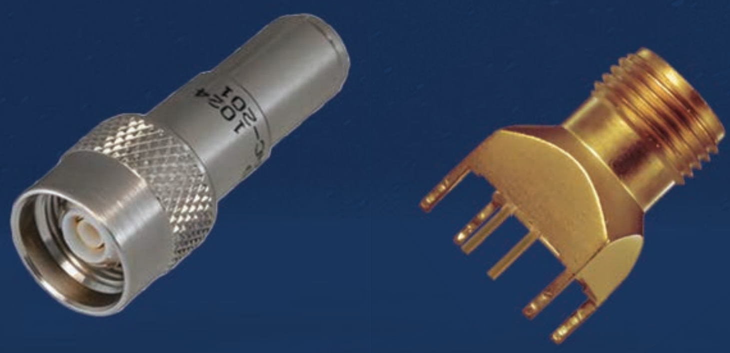
Trompeter Space Rated Connectors



Cinch Connectivity Solutions Trompeter™ space grade TRB and TRT miniature series connectors and TRS and TTM subminiature series meet NASA outgassing and MIL-STD-1553B standards. Benefits such as robust signal transmission, minimized signal loss, and strong EMI/RFI protection make this product suitable for demanding military, aerospace, and space environments. Subminiature TRS and TTM series offer higher density spacing and lighter weight applications.

Features

- Meet or exceed NASA outgassing requirements:
- 1% total mass loss (TML) and 0.1% collected volatile condensable materials (CVCM)
- All connectors meet MIL-STD-1553B data bus specifications
- Stringent visual and mechanical testing specifically developed by Trompeter
- Made in the USA

Applications

- Military & Commercial Space
- Launch Vehicles
- Navigation (GPS) Satellites
- Human Spacecraft
- Cargo Spacecraft
- Deep Space Probes

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