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A PAN EUROPEAN MAGAZINE

The Complex World of Embedded Electronics: **A Layered Maze of Independent Ecosystems**

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Nordic Semiconductor accelerates cellular IoT leadership with major new product releases at MWC 2026

Nordic Semiconductor unveils its next-generation portfolio featuring Cat 1 bis, satellite NTN, advanced LTE-M/NB-IoT with edge AI, and a clear path to 5G eRedCap delivering secure and resilient connectivity across billions of IoT devices.

Nordic Semiconductor, a global leader in low-power wireless connectivity solutions, today announces a major expansion of its ultra-low-power cellular IoT products and technologies designed to deliver secure, global connectivity as networks and satellite NTN evolve.

A platform expansion introducing two new product series

Built on the proven foundation of Nordic's industry-leading nRF91 Series, the expansion unveils two new cellular product series – the nRF92 and nRF93 Series – alongside major updates to the nRF91 Series.

nRF92 Series – Next-generation LTE-M/NB-IoT and satellite NTN

The nRF92 Series introduces the smallest, highest-integrated, and most power-efficient cellular solution. It integrates a high-performance application MCU combined with ultra-low-power edge AI through Nordic's Axon NPUs (Neural Processing Units), multi-constellation GNSS receiver, Wi-Fi locationing, and sensor co-processing. This will enable new possibilities for applications like smart meters, trackers, labels, industrial sensors, and wearables with multi-year battery life. Lead customer sampling is underway, with general availability from early 2027.

nRF93 Series – LTE Cat 1 bis cellular IoT

The nRF93M1 modules deliver higher throughput (10 Mbps downlink and 5 Mbps uplink), robust performance, global LTE support, and built-in Wi-Fi location capabilities while maintaining Nordic's hallmark low-power consumption and compact form factor. Optimized for asset tracking, gateways, fleet management systems, security devices, advanced metering, and consumer devices, it offers an easy-to-integrate alternative to LTE Cat 1 bis designs. The nRF93M1 is fully integrated with nRF Cloud, along with FOTA, observability, remote debugging, and location services. Lead customers are currently developing products with the nRF93M1, and general availability starts in mid-2026.

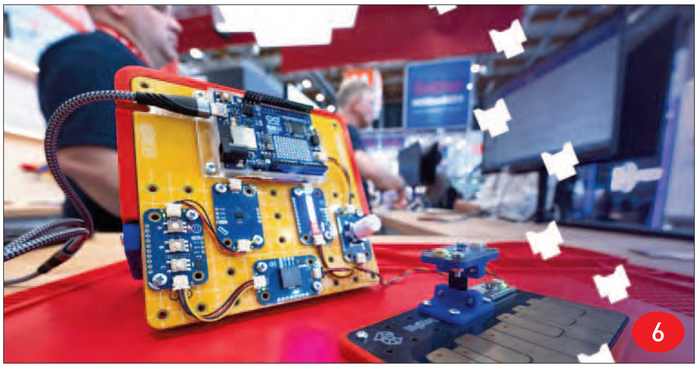
nRF91 Series – Enhanced with new features and modules

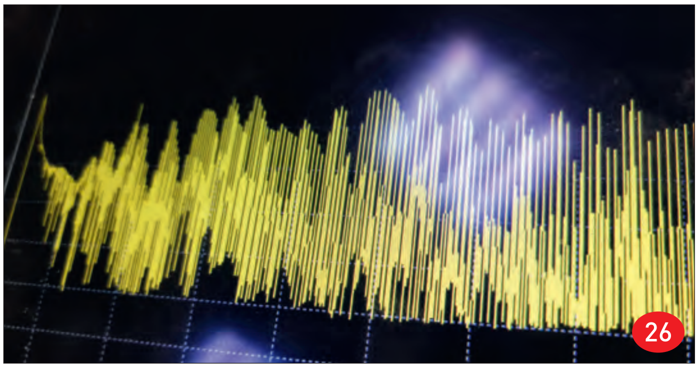
The nRF9151 is the leading LTE-M/NB-IoT module, now including 3GPP-compliant GEO and LEO satellite NTN connectivity – crucial for logistics, smart agriculture, energy, and remote infrastructure. In addition, the nRF9151 will include sub-GHz fallback to maintain connectivity when public networks are unavailable. Nordic is also introducing the nRF91M1 module – a compact, easy-to-use Smart Modem solution for customers seeking a simple and fast way to add cellular connectivity. It offers Nordic's proven low-power modem stack, AT-command interface, and secure cloud integration. It is ideal for the traditional host-modem architecture and for achieving rapid time-to-market.

5G eRedCap – Foundation for Nordic's future ultra-low-power 5G connectivity

Nordic is collaborating with lead customers on next-generation 5G eRedCap technologies that will enable even broader application coverage in the future. These efforts form part of Nordic's long-term strategy to deliver ultra-low-power cellular solutions across the full spectrum of IoT use cases.

■ **Nordic Semiconductor**
www.nordicsemi.com





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5V Operation in Any Condition

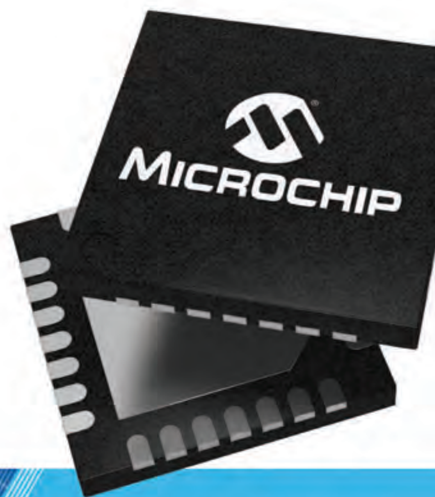
Efficient Performance Without Power Penalties

The PIC32CM PL10 microcontrollers redefines what's possible for engineers seeking an ideal balance between simplicity and performance. Built on the ARM Cortex-M0+ core, these microcontrollers deliver true 5V operation, rare among 32-bit MCUs, ensuring exceptional noise immunity for industrial, appliance and automotive applications. With advanced touch sensing, ultra-low power consumption and seamless support for familiar development tools, the PIC32CM PL10 bridges simplicity and performance with robust capacitive touch capability and reliable 5V support.

Key Features

- True 5V Operation: Robust performance in noisy environments
- Advanced Touch Sensing: Peripheral Touch Controller supports high channel count and resists interference
- Ultra-Low Power Modes: Sleepwalking and low standby current consumption extend battery life
- Easy Migration: Designed for 8-bit users to upgrade with no growing pains
- Familiar Development Tools: Compatible with Microsoft® Visual Studio Code (VS Code®) and MPLAB® Code Configurator, and supported by partner toolchains like IAR Embedded Workbench, Keil and Segger.
- Competitive Price Point: High-end features without premium cost

Upgrade your next design with the PIC32CM PL10 and experience 32-bit performance without the complexity.



MICROCHIP

microchip.com/pic32cm-pl10

Bosch Sensortec validated for use with Snapdragon Wear Elite to elevate wearable experiences

Bosch Sensortec's ultra-low power, high-performance BMP585 barometric pressure sensor has been validated for the Snapdragon Wear Elite Platform and is integrated into the Snapdragon Wear Elite Platform's reference design. This collaboration provides the platform's advanced on-device AI capabilities with exceptionally accurate pressure data, enabling precise altitude tracking and a new layer of contextual awareness for next-generation wearables.

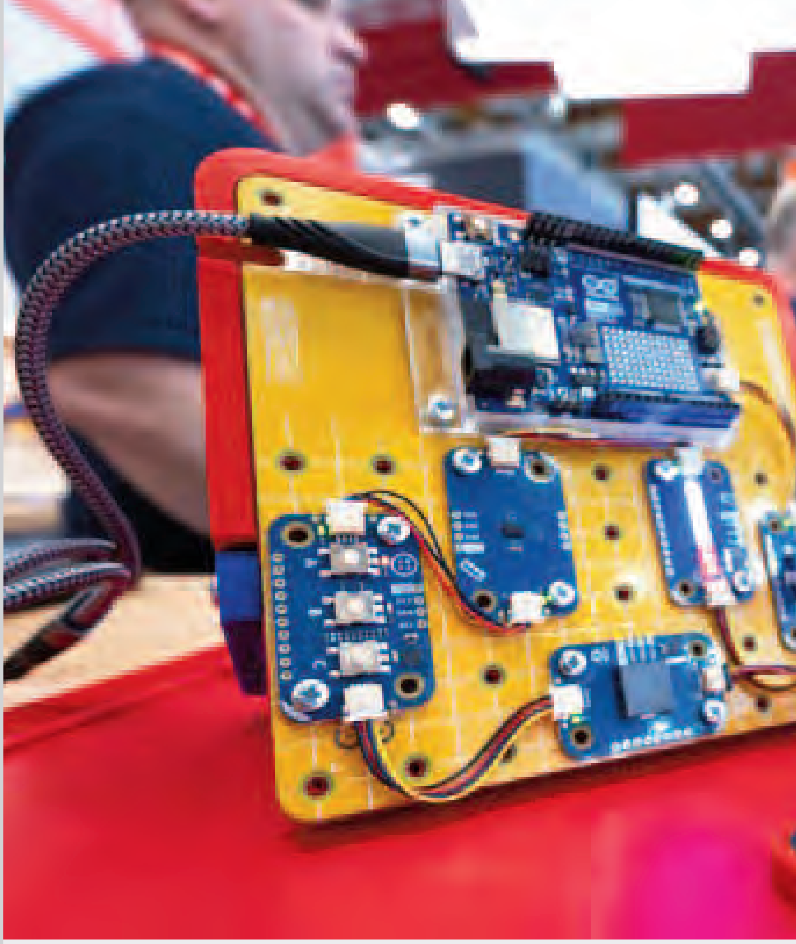
Validation of the BMP585 with the Snapdragon Wear Elite Platform allows for a host of advanced features, including:

- **Enhanced fitness tracking**: Wearables can generate precise elevation profiles for activities like hiking, running, and cycling, and accurately track floors climbed.
- **Emergency services (E911)**: In an emergency, the sensor provides critical vertical location data (z-axis) to supplement GPS, helping first responders pinpoint a user's exact floor within a multi-story building.
- **Smarter user context**: The highly accurate altitude data enriches the on-device AI, allowing wearables to better understand the user's situation, for example, differentiating between walking on a flat surface and climbing stairs.

Adding to its suitability for all-day wear, the BMP585 is a ruggedized barometric pressure sensor. It is designed with a specialized gel-filled cavity, providing robust resistance against common liquids including water, salt water, and chlorinated pool water, ensuring high reliability during fitness and everyday activities.

By fusing data from motion sensors with our family of environmental sensors, Bosch Sensortec delivers a rich, multi-layered data stream. This allows a device to understand the user's complete situation, moving beyond what they are doing to include where they are doing it. With this data, manufacturers can build sophisticated, high-value applications like automatic workout detection, fall detection, personal air quality measurement and seamless indoor navigation, creating the next generation of intelligent personal electronics from wearables and hearables to XR headsets and glasses.

■ **Bosch Sensortec** | www.bosch-sensortec.com



DigiKey Spotlights New Products at Embedded World 2026

DigiKey, the global distribution leader of electronic components and automation products, will feature the latest embedded system products from top suppliers at its booth, 4A-633, during embedded world 2026, March 10-12, in Nuremberg, Germany. The company will also showcase technical capabilities and tools at its popular TechBench and give away exciting prizes at the show.

This year, DigiKey's booth will feature demos from leading supplier partners, including:

- A thread network composed of sensors and actuators from NXP, Microchip, and STMicroelectronics, with Home Assistant as the interface, collects data such as air quality, ambient light and proximity and sends it to a central hub.
- Microchip's LAN865x and LAN867x 10BASE-T1S Single-Pair Ethernet (SPE) network with 17 nodes featuring 19,200 LEDs showing video streaming from a standard camera streaming via an SBC at 60 frames per second.
- Optical heart rate sensing with NXP's MCX N94 microcontroller, a high-performance, low-power microcontroller with intelligent peripherals and accelerators that provide multi-tasking capabilities and efficient performance.
- AI modeling to recognize hand gestures from a camera feed with STMicroelectronics' STM32N6, the first MCU to introduce the Arm Helium vector processing technology, bringing DSP processing capability to a standard MCU.

- Live sensor readings with Arduino's UNO Q 4GB and Arduino's Plug and Make Kit.
- BeagleBoard's PocketBeagle2, which features a small form factor and low power consumption, making it well-suited for embedded development for prototyping or deploying at scale.
- Hands-on Red Pitaya evaluation board experiments with inverting and non-inverting amplifiers, frequency response and gain-bandwidth.
- LabsLand's Prism4, a modular ecosystem for building interactive, real-time, remote hardware systems faster and more efficiently.
- Microchip's veryVerilog mini FPGA kit, an entry-level soldering-and-learning platform for microcontroller and digital design fundamentals developed in collaboration with DigiKey's Academic Program.
- Arduino's Opta PLC training kit, which provides an excellent way to learn PLC programming and the fundamentals of industrial control and automation.

Several of the demos in DigiKey's booth will also feature click boards, like MikroElektronika's, to enable rapid prototyping ecosystems and accelerate innovation at scale.

Visitors to the company's booth can experience electrical engineering in the wild by chatting with technical experts at the DigiKey TechBench and virtual workshop. Attendees can also receive a special giveaway package from our distribution vending machine and claim instant-win prizes at DigiKey's popular slot machines. In addition, the DigiKey Café across from the company's booth will serve free coffee throughout the conference.

For more information about DigiKey's products, tools and resources around embedded systems, please visit the DigiKey website.

■ **DigiKey** | www.digikey.com

EnOcean 5 Click provides fast, bidirectional wireless connectivity communication for EnOcean-based sensors, switches, and actuators

EnOcean 5 Click, a new wireless connectivity Click board™ from MIKROE, the embedded solutions company that dramatically cuts development time by providing innovative hardware and software products based on proven standards, provides a bidirectional communication interface for EnOcean-based sensors, switches, and actuators. Compact Click add-on boards enable developers to rapidly provide proof-of-concept, then prototype and code new embedded projects.

Nebojsa Matic, CEO of MIKROE: *"This new Click board is ideal for developing energy-efficient dimmers, relays, and shutter controllers that rely on self-powered EnOcean switches. It is part of our 260+ strong family of wireless connectivity Click boards and over 850 projects – with working code – featuring the EnOcean 5 Click can be found on MIKROE's embedded projects platform, EmbeddedWiki."*

EnOcean 5 Click is based on the TCM 615 radio transceiver gateway module from EnOcean, which provides an easy to use serial communication interface using EnOcean Serial Protocol version 3 (ESP3). It supports both receiving and transmitting of EnOcean radio telegrams on 868.3MHz using EnOcean Radio Protocol version 1 (ERP1), thanks to its integrated 50Ω RF PCB trace antenna. Combining a sensitivity of -95dBm with an output power of +10dBm enables robust wireless performance in typical indoor and outdoor environments. The TCM 615 also supports the latest security features defined by EnOcean Alliance, providing encryption, decryption, authentication and replay protection functionality directly on-board. It communicates with external devices such as microcontrollers or processors using the industry-standard UART ESP3 interface supporting baud rates of 57,600bps and 460,800bps.

EnOcean 5 Click is a recent addition to MIKROE's 1900-strong mikroBUS™-enabled Click board family. The board also features the ClickID function which enables automatic identification by the host system, simplifying use. Devices can be used on any host system supporting the mikroBUS™ standard, and come with the mikroSDK open-source libraries, offering excellent flexibility for evaluation and customization.

■ **MIKROE** | www.mikroe.com

Melexis drives efficiency in power electronics with a new product line, 'Protective Devices'

Melexis, a global microelectronics engineering company, announces an important expansion of its portfolio with the launch of a new product line: Protective Devices. This strategic move underscores the company's commitment to driving innovation, safety, and extended battery autonomy in the rapidly evolving electric vehicle (EV) and energy management sector.

The new product line will be led by Billy Ye, Product Line Director for Protective Devices. He will focus on delivering highly reliable, specialized solutions that safeguard sensitive electronic components while maximizing the efficiency of high-voltage systems.

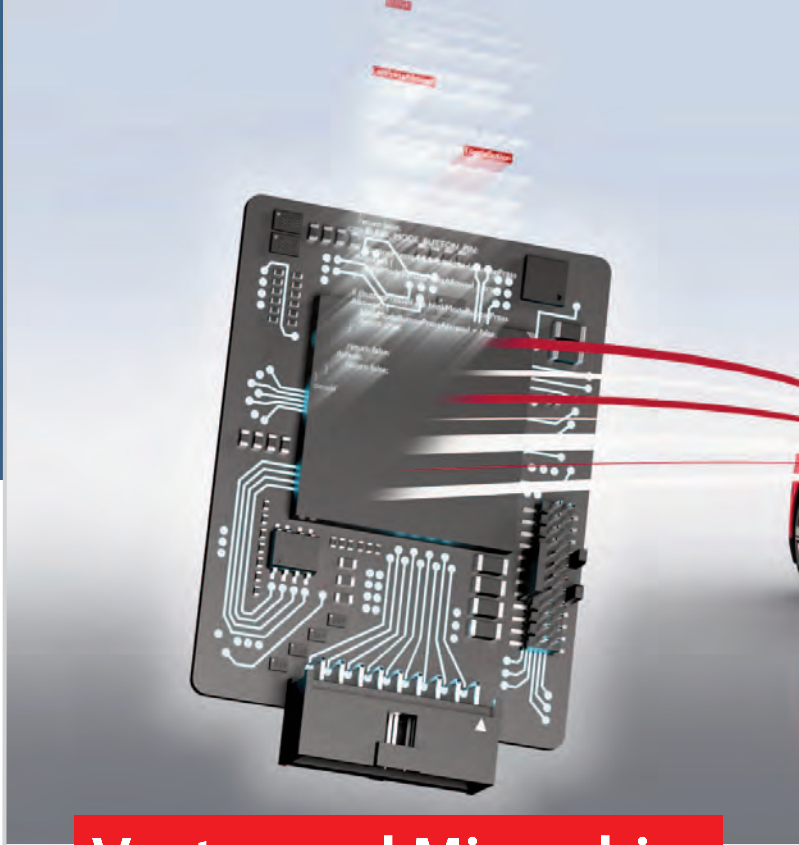
New MLX91299 RC snubber improves protection and efficiency in SiC-based EV power modules

The first product launched in the new line is the MLX91299, a breakthrough solution designed as a game-changer for Silicon Carbide (SiC) power modules. These modules are fundamental to increasing the driving range and improving the efficiency of EVs. The MLX91299 is an integrated silicon-based RC snubber circuit that provides two critical benefits:

1. **Protection**: It mitigates high-frequency oscillations, voltage transients, and parasitic effects that occur during the fast switching of SiC devices, which are major sources of electrical stress and instability.
2. **Power Saving & Range Extension**: By effectively damping these high-speed effects, the snubber can reduce critical switching losses by up to 50% (according to initial measurements). This improved efficiency means less wasted energy as heat and more power delivered from the battery to the wheels, thereby helping to save power and directly extending the driving range of electric vehicles and many other industrial applications.

In January 2026, the company already announced that Leapers, a global manufacturer of advanced power semiconductor modules, will incorporate the Melexis MLX91299 silicon-based RC snubber into its next-generation modules.

■ **Melexis** | www.melexis.com



Vector and Microchip Technology Expand Collaboration on Pre-Integrated Embedded Solutions

Vector and Microchip Technology Inc. are further expanding their collaboration in the field of embedded software and microcontroller platforms. The aim is to offer customers pre-integrated, fully aligned hardware and software solutions specifically designed for small, resource-constrained control units. Initial results are already available: Vector provides ready-to-use support of MICROSAR IO on Microchip dsPIC33A DSCs.

Aligned Integrated Solutions for Faster Development

Vector and Microchip closely align their products to ensure early hardware and software compatibility and to facilitate joint further development. For customers, this approach reduces integration effort, lowers project risks, and enables an earlier start to application development.
MICROSAR IO is a lightweight software base layer specifically developed for sensor and actuator control units with very limited resources and now off-the-shelf supported for Microchips dsPIC33A DSC microcontroller. As a result, project start-up is accelerated, internal ramp-up phases are reduced, and time to implementation is shortened.

Added Value for Customers in the Software-Defined Vehicle

The joint solution is specifically designed for cost-sensitive and compact sensor and actuator control units within Software-Defined Vehicle (SDV) architectures. As part of the functional decomposition in SDV architectures, complex logic is shifted to the HPC and zonal level, while edge nodes are limited to their essential tasks using lean software.

MICROSAR IO now pre-integrated on Microchip dsPIC33A

This enables the use of cost-efficient hardware platforms in high volumes while simultaneously reducing overall system complexity.

The pre-integration of MICROSAR IO on the dsPIC33A hardware platform offers clear benefits to customers.

- Accelerated time-to-market: Ready-to-use, tested platforms enable an immediate start to development
- Reduced integration effort: Hardware and software are already aligned
- Simplified application development: Lean software for sensor and actuator control units facilitates implementation
- Efficient implementation of customer requirements: Close collaboration between the partners enables rapid adaptations

In addition, Vector defines an open, standardized hardware abstraction interface. This allows MICROSAR IO to be easily and quickly ported to additional Microchip hardware platforms in the future – an approach that promotes cross-manufacturer and interoperable software solutions.

Evaluation Bundle Available

To support customers, Vector and Microchip are providing the corresponding MICROSAR IO Evaluation Bundle. It includes sample applications as well as support for Microchip's dsPIC33A platform and will soon be available free of charge via the Vector Download Center.

Joint Presence at embedded world 2026

The ready-to-use embedded solution will be presented for the first time at embedded world in March 2026 in Nuremberg. At Microchip's booth, Vector and Microchip will showcase a joint demo featuring selected MICROSAR IO use cases on dsPIC33A hardware. In addition, Vector will offer a technical deep dive into MICROSAR IO at its own booth. Experts from both companies will be available on site for technical discussions.

■ **Vector** | www.vector.com

IAR accelerates SDV development with Infineon DRIVECORE bundles and AURIX™ RISC-V Debug capabilities

IAR announced expanded automotive ecosystem capabilities to be showcased at Embedded World 2026, highlighting its collaboration with Infineon Technologies AG across Infineon's DRIVECORE software evaluation bundle portfolio and previewing upcoming debug capabilities for Infineon's AURIX™ RISC-V family.

As software-defined vehicles (SDVs) accelerate innovation cycles across the automotive industry, development teams must deliver increasingly complex software across evolving architectures and long product lifecycles. IAR supports this shift through a scalable ecosystem approach that enables consistent workflows, faster onboarding, and cross-architecture continuity.

Strategic DRIVECORE Bundles: Start faster, integrate less

Infineon DRIVECORE is a scalable portfolio of pre-integrated software bundles for TRAVEO™ and PSOC™ platforms designed to accelerate automotive software development. IAR provides professional, pre-certified development tools and workflows as part of DRIVECORE's validated evaluation bundle.

Recent DRIVECORE evaluation bundles include:

- TRAVEO™ T2G DRIVECORE Visualization [Infineon, Qt Group, IAR] - supporting scalable automotive graphics development for digital cockpits, cluster displays, and infotainment systems.
- PSOC™ DRIVECORE Smart End Point [Infineon, Vector, IAR] - targeting compact automotive control systems and small-footprint ECUs.
- PSOC™ DRIVECORE Smart End Point [Infineon, Elektrobit, IAR] - the most recent DRIVECORE expansion, enabling a ready-to-use foundation for compact peripheral ECUs and edge controllers.

Preview at Embedded World 2026: AURIX™ RISC-V Debug capabilities

In parallel with its DRIVECORE collaboration, IAR is expanding automotive support for RISC-V architectures. At Embedded World 2026, IAR will provide a preview of upcoming debug capabilities for Infineon's AURIX™ RISC-V family supported in the IAR platform.

■ **IAR** | www.iar.com

New LX4580 is a Highly Integrated 24 Channel Mixed Signal IC for Aviation and Defense Actuation Systems

Microchip Technology announces the LX4580, a 24-channel mixed-signal IC designed to streamline high-reliability actuation control systems for aviation and defense applications. The LX4580 is highly integrated and replaces multiple discrete components with a single device that supports synchronized data acquisition, fault monitoring and motor control – reducing system size, weight and complexity.

The LX4580 is offered in a compact 144-pin LQFP package and developed for applications including More Electric Aircraft (MEA), guided defense systems, drones and launch platforms. The LX4580 integrates pressure sensing, temperature measurement, PWM motor drive outputs, current sensing, Hall effect sensor inputs, dual LVDT/resolver interfaces and dual high-speed SAR ADCs. This level of integration delivers broad sensor coverage, precise timing alignment and improved reliability compared to multi-device architectures.

The device's redundant architecture is tailored for mission-critical environments that demand fault tolerance and deterministic performance. By consolidating functions commonly spread across MCUs, ADCs, DACs, driver ICs and regulators, the LX4580 reduces board space and wiring complexity, supporting manufacturers' goals to minimize overall system weight while meeting demanding safety and certification requirements.

To accelerate customer development, Microchip offers application documentation demonstrating use with its MCUs. These resources enable standalone evaluation or rapid integration into customer control architectures, simplifying early design phases and helping teams address regulatory documentation requirements efficiently.

For more information on the LX4580 and supporting resources, visit the product web page.

■ **Microchip Technology** | www.microchip.com

Renesas Expands Auto MCU Portfolio with 28nm RH850/U2C for Vehicle Control and Automotive Safety Applications

Renesas Electronics announced the RH850/U2C, a new 32-bit automotive microcontroller (MCU) built on a 28nm process. With rich communication interface support and advanced security, the MCU targets a diverse range of automotive applications, including chassis and safety systems for passenger cars and motorcycles, battery management systems (BMS) and body control functions such as lighting and motor control, and other general-purpose ASIL D applications.

The new device extends Renesas' popular RH850 lineup as a low-end option, complementing the high-end RH850/U2B and mid-range RH850/U2A products. The RH850/U2C combines four RH850 CPU cores operating at up to 320 MHz (including two lockstep cores), with up to 8 MB of on-chip flash memory. Developers currently using RH850/P1x or RH850/F1x devices can smoothly transition to the new MCU to meet the requirements of the latest E/E architectures.

Communication Interfaces for Today's and Next-Generation Systems

The RH850/U2C operates with interfaces designed for modern E/E architectures, such as Ethernet 10base-T1S, Ethernet TSN (1Gbps/100Mbps), CAN-XL, and I3C. It also maintains full compatibility with commonly used interfaces today, such as CAN-FD, LIN, UART, CXPI, I^2C, I^2S, and

PSI5. This comprehensive interface support enables mixed operation with existing ECUs and facilitates a smooth, phased migration across generations. As more vehicle networks transition to domain- and zone-based architectures, the RH850/U2C provides flexible system configuration and scalability, reducing network design complexity.

Robust Functional Safety and Cybersecurity Features

The MCU supports functional safety up to ASIL D, conforming to ISO 26262. To meet modern cybersecurity requirements, the device complies with the latest ISO/SAE 21434 standard and supports cryptographic algorithms ranging from post-quantum cryptography (PQC) to those mandated by current Chinese and other international regulations. Its dedicated hardware accelerators provide high throughput by offloading cryptographic processing and reducing CPU load.

Power-Optimized MCU Architecture

Built on a proven 28 nm manufacturing process, the RH850/U2C consumes significantly lower power in both active and standby modes. A dedicated standby mode further reduces power usage during deep stop and intermittent operation. These low-power modes increase power-design margins and reduce thermal demands so that systems remain compliant as environmental regulations tighten.

Full Development Support

The RH850/U2C is supported by a comprehensive development environment designed to reduce time to market. Developers can use state-of-the-art compilers and IDEs, together with automotive-qualified software packages from Renesas and its ecosystem partners. These solutions meet the highest functional safety requirements and support ISO 26262 up to ASIL D. For fast evaluation and project startup, Renesas offers a dedicated RH850/U2C Starter Kit.

Renesas plans to showcase a demonstration using the RH850/U2C at embedded world 2026, in Nuremberg, Germany, from March 10-12, at the Renesas booth 1-234 (Hall 1, Stand 234).

■ **Renesas Electronics Corporation** | www.renesas.com

Infineon introduces the industry's first highly integrated single-port USB Type-C PD microcontroller with integrated 55V buck-boost controller

Infineon Technologies launched the EZ-PD™ PMG1-B2, the industry's first highly integrated single-port USB Type-C Power Delivery (PD) microcontroller with an integrated 55V buck-boost controller for 2- to 12-cell (2S to 12S) lithium-ion battery charging. The solution complies with the latest USB Type-C and PD specifications and supports a wide input voltage range from 4.5 to 55 V and a programmable switching frequency from 200 to 700 kHz.

The EZ-PD PMG1-B2 is ideal for high-voltage battery charging in embedded systems across consumer, industrial, and communications applications that are powered via USB-C and utilize the available MCU functions. Target applications include cordless power tools and gardening tools, cordless vacuum cleaners, cordless kitchen appliances, e-bikes, e-kick scooters, drones and robots, and more.

At the core of the EZ-PD PMG1-B2 is a 32-bit Arm® Cortex®-M0 processor with a 128 KB flash memory and 8 KB SRAM, providing the processing capability needed for customizable USB PD applications. The device integrates various analog and digital peripherals, including ADCs, PWMs, UART/I²C/SPI interfaces, and timers, reducing the bill of materials as well as the space required on the PCB. Development is simplified through a comprehensive SDK, fully interoperable USB PD stacks, and a proprietary software suite for easy customization. Integration of MCU, USB PD, high-voltage LDO, buck-boost battery charger, and battery protection blocks, including VBAT to GND short protection in PMG1-B2, helps reduce system BOM cost and simplifies the design for USB-C-based battery powered applications. The solution comes in a 68-pin QFN package and supports an ambient temperature range of -40°C to +85°C and a maximum operating junction temperature of 125°C.

Based on the EZ-PD PMG1-B2, Arrow Electronics and Infineon will soon introduce a 240 W USB-C PD 3.2 reference design that combines the new controller with Infineon's PSOC™ C3 and 100 V CoolGaN™ G5 transistors to enable compact, high-efficiency battery-powered motor control systems. Supporting fast charging for 2- to 12-cell Li-ion battery packs and advanced motor drive control, the demo board targets applications such as e-bikes, e-scooters, power tools, home appliances, garden equipment, and robotics.

■ **Infineon Technologies** | www.infineon.com

Analog Devices' 2026 Outlook:

From Edge AI and Micro-Intelligence to Autonomous Robotics

*Analog Devices is looking ahead to 2026: Which technological advancements will create new opportunities and shape our daily lives. We are pleased to share with you the insights and predictions of **Massimiliano "Max" Versace**, VP of Emergent AI, Analog Devices & **Paul Golding**, VP of Edge AI and Robotics, Analog Devices.*

The following predictions are attributable to Massimiliano "Max" Versace, VP of Emergent AI, Analog Devices.

1 Decentralized AI will appear in new-generation humanoid robotics by the end of 2026.

By late 2026, decentralized AI architectures merging sensing with neuromorphic and in-memory compute will transition from pilot programs to early commercial deployment. We'll see humanoid robotics systems getting a bit closer to biological systems, where local circuits in sensory organs and spinal pathways handle reflexes and balance, allowing smoother, more adaptive movement, drastically reduced power consumption, and freeing the central brain to "think and plan."

These technological leaps will start with intelligent sensors that embed novel AI compute, such as neuromorphic and in-memory-compute architectures, directly within the sensor. The combination of decentralized AI and novel AI compute architecture will dramatically reduce latency and power consumption, allowing always-on AI at the edge and freeing larger processors to focus on higher-level reasoning, planning, and learning, rather than micromanaging continuous sensorimotor control loops.

By enabling real-time, low-latency AI processing at the edge, robots will become more efficient, responsive, and capable of near-biological sensory-motor skills. This shift will power a step change in their ability to engage complex, dynamic environments with fluid, reliable coordination and pave the way for practical and pervasive humanoid robotics.

2 In 2026, we'll see the rise of analog AI compute.

Historically sidelined due to scalability and precision limitations, analog compute is reemerging in 2026 as digital architectures face energy, latency, and memory bottlenecks with no solution in sight. This is especially critical in edge environments where real-time responsiveness and power efficiency are a must.

Analog AI compute uses the physics of the sensing and computing substrate to perform computation, transforming energy directly into AI inference. This is a different approach to AI compute vs. conventional digital processors, which separate sensing from computation. Analog AI collapses these layers into a unified framework where intelligence begins at the sensor itself.

By the end of 2026 we'll see initial deployments and adoption of this technology, particularly in robotics, wearables, and autonomous applications, where analog AI enables real-time responsiveness, smoother interactions, longer battery life, and more natural behavior in the devices they power.

The following predictions are attributable to Paul Golding, VP of Edge AI and Robotics, Analog Devices.

1 *In 2026, artificial intelligence will step out of our screens and into the world.*

The next frontier of AI will be Physical Intelligence. The scaling laws that powered the success of large language and vision models will continue through 2026 but will extend into models that learn from vibration, sound, magnetics, and motion (stubborn attributes of the physical world). I predict these physical reasoning models will migrate from the datacenter to the edge, powering a new type of fluid autonomy that thinks and acts locally, sensitive to local physics and without recourse to centralized servers. Such models will dynamically learn from novel situations, exposed to only a few examples of novel circumstance. Think of a mobile factory robot that can reason for itself and determine what to do when faced with an unexpected obstacle. We can expect to see an increase in hybrid "world models" that blend mathematical and physical reasoning with data-driven sensor-fused dynamics, and systems that not only describe the world but participate in it and learn, as Richard Sutton says, from their own "experience."

2 *Audio will become the dominant AI interface in consumer electronics.*

Audio is about to become a reasoning channel, and we'll see this come to life in a big way in 2026. With spatial sound, sensor fusion, and on-device reasoning converging, consumer electronics will evolve into contextual companions.

Augmented Reality glasses and hearables like earbuds and in-vehicle sound systems will quietly interpret our environment, inferring intent, emotion, and presence. These technological leaps will lead to significantly better noise cancellation in our hearable devices, improved battery life, and new form factors that haven't yet been imagined. The always-in-ear hearable experience, already on the rise among Gen Z, will become increasingly prevalent due to the "super-human" hearing of context-aware AI.

3 *Agentic AI will give rise to physically intelligent models, trained via physically accurate simulation environments.*

The next evolution in Edge AI will be agentic. In the future, agentic systems will decide, not just predict, and act autonomously in the world via physically grounded interventions rehearsed in simulated environments. To support this, 2026 will see the mainstream arrival of digital twins to imbue large models with physical-system awareness.

Imagine AI models learning to predict forces instead of text, but within the safety of a scalable simulated environment. Physically intelligent foundation models will merge reasoning with sensor intelligence to orchestrate machines, simulations, and data. Today, many factories have the technology to do predictive maintenance, but you can imagine a future where an agent on the factory floor acts on that prediction. It autonomously reroutes the production line to a healthier machine, adjusts the strained machine to 70% to extend its life, and coordinates with supply chain agents to adjust inventory – all without human intervention.

4 *AI will have its agentic "inception" moment with the emergence of micro-intelligence.*

In 2026, a new class of tiny recursive models will rise – compact systems with remarkable depth of reasoning across a narrow domain but able to run at the edge. Think of them as micro-intelligences rather than just small models: fluid, adaptive, and task-specific, yet still capable of abstraction and reflection.

They will occupy the middle ground between rigid programmed AI seen at the edge today and sprawling foundation models like GPT-5, powering specialized reasoning on chips, in sensors, and inside the smallest of systems, acting as orchestrators of the specialized agents emerging today. These new kinds of models will arise from the race to build fluidly intelligent systems, as encouraged by the ARC Prize and similar initiatives.

I predict the rise of new types of AI benchmarks designed to measure and encourage a new kind of engineering intelligence – multiagent micro-intelligences that can collaborate to solve complex engineering problems, moving from the world of abstract mathematical challenges (like Math Olympiads) to practical problem-solving systems.

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ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Enhance Autonomous Robot Localization Precision

WITH ADVANCED IMUs AND SENSOR FUSION

*This article briefly discusses the unique challenges of AMR localization. It then introduces advanced IMUs from **Analog Devices** and shows how they can be used to address these challenges in indoor, global positioning system (GPS)-denied environments, while drawing lessons from broader cross-domain use.*

Author: **Rolf Horn,** Applications Engineer, **DigiKey**

Inertial measurement units (IMUs) are fundamental to a broad range of mobile systems, including industrial robotics, humanoid robots, unmanned aerial vehicles (UAVs), and immersive mixed-reality systems, among others. Although the specific demands for these systems vary with each application, designers are consistently challenged to provide increasingly accurate, real-time orientation and motion data for the general class of application called autonomous mobile robots (AMRs).

WHY LOCALIZATION IS A CHALLENGE FOR AMR DEVELOPERS

AMRs are central to the productivity of smart factories and warehouses where they help streamline material flow, reduce waste, and improve utilization. Ensuring their accurate localization within the facility is critical to success. In purpose-built facilities, AMR localization challenges can be mitigated through well-placed fiducials (reference markers) or optimized layouts, but most AMRs operate in legacy facilities. In such facilities, the combination of varying lighting, reflective surfaces, and complex geometry makes localization much harder. Furthermore, the lack of consistent infrastructure, such as standardized aisle widths or predictable floor markings, means that robots confront more complex navigation and mapping tasks.

The nature of the navigational environment results in two key operational challenges. [1]

- First, the robot must perform efficient path planning to determine the most optimal route through its environment based on current conditions.
- Second, it must execute precise localization, continuously updating its own position and orientation in real time as it moves.

In GPS-denied indoor environments, these two objectives must be met entirely with on-board sensing capabilities and computational resources.

To meet these challenges, AMRs use a mix of sensor modalities. Visual perception systems, including cameras, light detection and ranging (LiDAR), and radar, provide rich environmental data.

Odometry systems, such as wheel encoders and IMUs, track motion directly from the robot's movement.
Each sensor type offers distinct advantages: Some excel at long-range detection, others at precise detection, but each also has limitations.

By combining them intelligently, AMRs can achieve the redundancy and coverage needed to maintain accuracy in dynamic, unpredictable conditions.

WHAT AN IMU MEASURES AND WHY IT MATTERS

An IMU integrates microelectromechanical systems (MEMS) sensors to measure acceleration and angular velocity in three dimensions. A triaxial accelerometer measures motion along the x, y, and z axes relative to Earth's gravity, capturing both static forces, such as tilt, and dynamic forces, such as acceleration during motion (Figure 1).

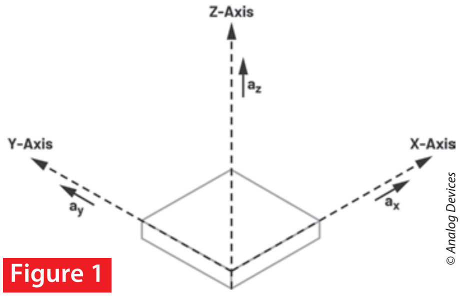


Figure 1

A triaxial accelerometer measures acceleration along the x, y, and z axes, providing both dynamic motion data and a static gravity reference.

A triaxial gyroscope measures angular velocity (ωx, ωy, ωz) about each axis (Figure 2), enabling the robot to track orientation changes.

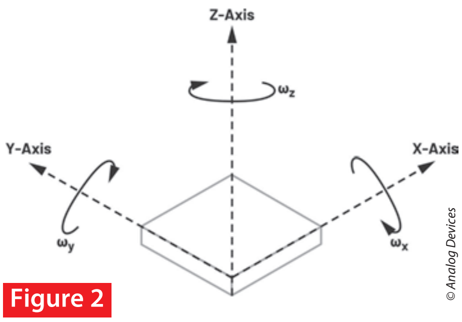


Figure 2

A triaxial gyroscope measures angular velocity about each axis, enabling accurate tracking of orientation changes.

At the core of both accelerometers and gyroscopes in modern IMUs, MEMS structures deflect or vibrate when subjected to acceleration or rotation, and the resulting changes in capacitance or vibration frequency are converted into electrical signals. The advantage of MEMS-based IMUs is their combination of small size, low power consumption, and high measurement rates, making them practical for integration into mobile platforms.

Some IMUs also include additional sensors that expand their capability. A high-performance magnetometer provides magnetic field measurements that aid orientation estimation in challenging environments, although magnetometers are more common in legacy IMUs.

An integrated temperature sensor enables thermal compensation of accelerometer and gyroscope data. A barometer may also be included to measure atmospheric pressure and estimate altitude.

To mitigate the limitations of different sensory systems, a typical AMR relies on a diverse sensor stack that can include vision sensors, time-of-flight (ToF) systems, LiDAR, radar, wheel encoders, and an IMU (Figure 4).

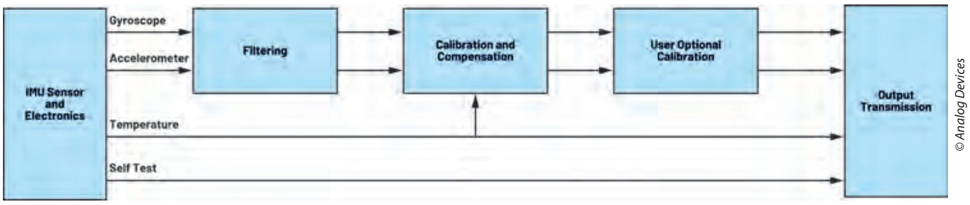


Figure 3

A functional block diagram of an advanced IMU shows an extensive sensor signal chain providing sensing, calibration, compensation, and filtering integrated into a single compact device.

Beyond their sensor array, advanced IMUs also integrate extensive data acquisition signal chains for analog-to-digital conversion, preliminary finite impulse response filtering, and factory calibration to correct sensor biases and axis misalignment (Figure 3).

These devices often allow rotation (dΘ) from the IMU's internal coordinate frame to match the robot's frame before output, reducing the computational load on the main processor.

HOW IMUs STRENGTHEN LOCALIZATION WHEN OTHER SENSORS FALTER

Certain characteristics of different physical environments can impact the effectiveness of individual sensor modalities.

In a feature-sparse corridor, for example (Figure 5), the long stretch of walls lacks the distinctive elements needed for visual simultaneous localization and mapping (SLAM) algorithms to match frames to a stored map. Without unique visual cues, the robot's pose estimate can drift quickly, causing an AMR to lose its position.

In this scenario, the heading and orientation information provided by an IMU can sustain robot navigation despite the loss of visual odometry.

In large open spaces, such as a 50 m × 50 m warehouse, many visual features are beyond the effective range of LiDAR (Figure 6), which typically provides a maximum reach of 10 m to 15 m.

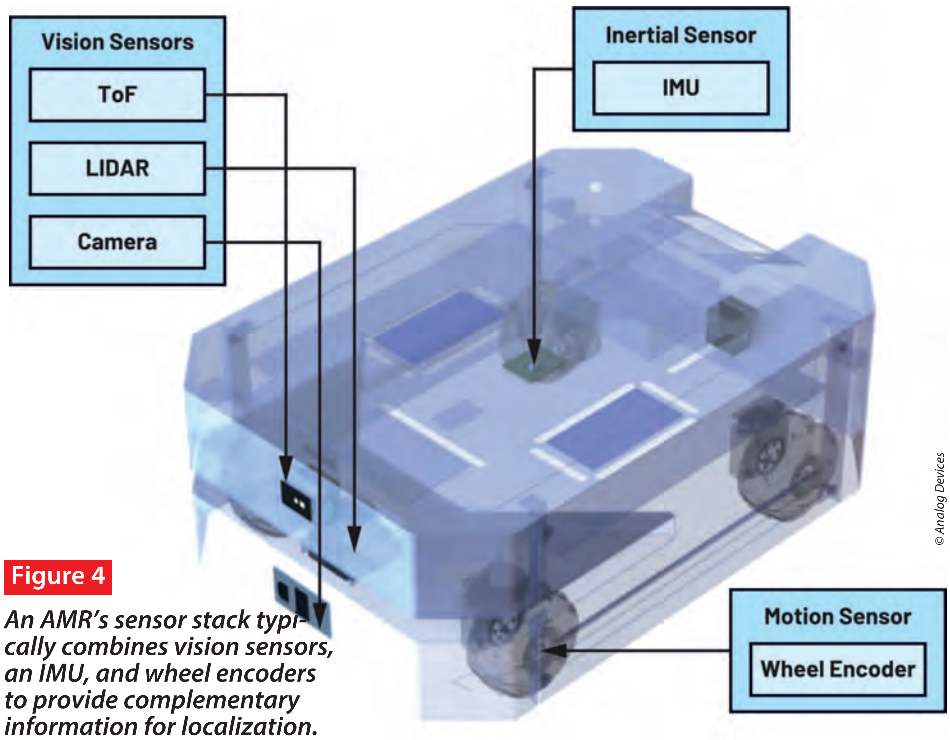


Figure 4

An AMR's sensor stack typically combines vision sensors, an IMU, and wheel encoders to provide complementary information for localization.

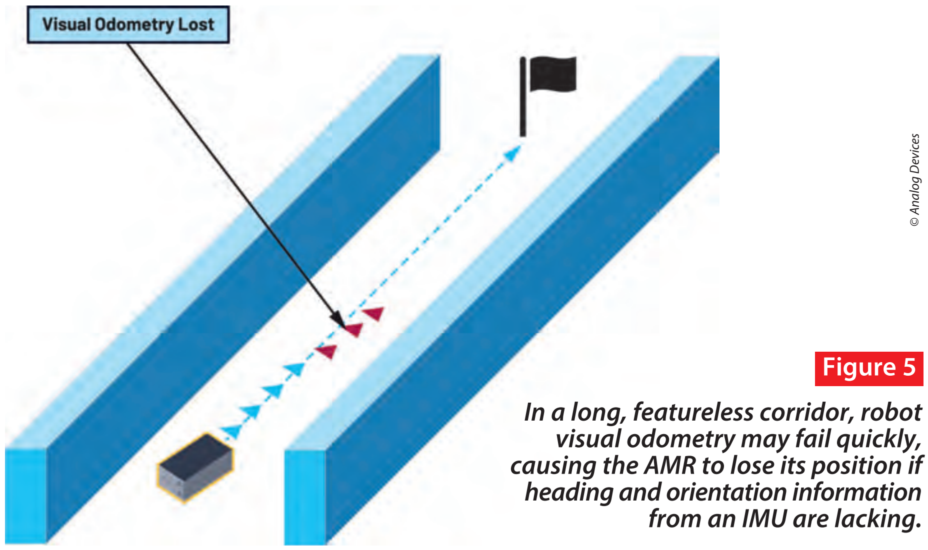


Figure 5

In a long, featureless corridor, robot visual odometry may fail quickly, causing the AMR to lose its position if heading and orientation information from an IMU are lacking.

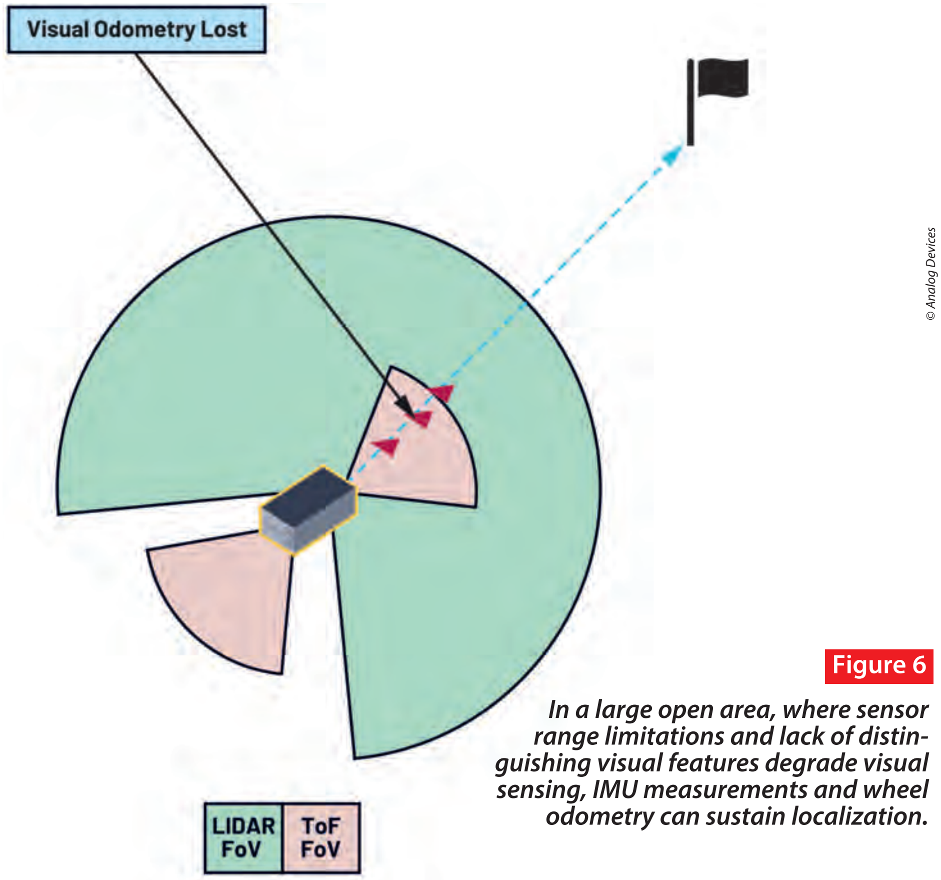
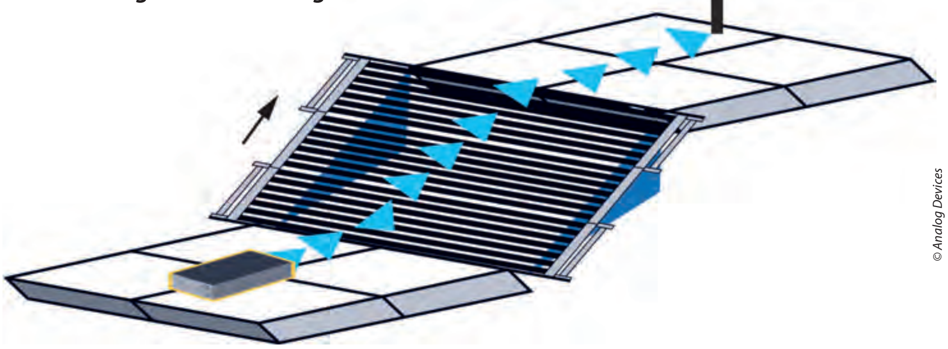


Figure 6

In a large open area, where sensor range limitations and lack of distinguishing visual features degrade visual sensing, IMU measurements and wheel odometry can sustain localization.

Figure 7

IMU pitch and roll readings can reveal the gradient of a slope, correcting 2D SLAM misinterpretations and enabling safe AMR navigation.



Uniform layouts such as evenly spaced shelving or storage racks can confuse visual odometry because of the similar appearance of multiple different locations. In this scenario, the combination of IMU measurements and wheel encoder data allows the robot to maintain local pose estimates.

Sloped surfaces present another challenge (Figure 7). Standard two-dimensional LiDAR captures points in a flat plane; therefore, a slope can appear to be a vertical obstacle. This misinterpretation can disrupt navigation or cause the robot to avoid traversable paths. Here, IMU pitch and roll data can provide gradient information to mitigate this LiDAR misinterpretation, enabling SLAM algorithms to resolve the gradient and distinguish between traversable slopes and true obstacles.

Environmental factors also degrade localization performance of different sensor modalities (Table 1). Factors such as poor lighting, dynamic environments, reflective surfaces, and a need for rich scene geometry can impact most sensory modalities.

HOW IMUs' UNIQUE PERFORMANCE CAPABILITIES BENEFIT AMRs

IMUs update at higher rates than perception sensors, enabling rapid response to dynamic changes in the environment. Unlike perception systems, which typically operate at 10 Hz to 30 Hz, IMUs can provide processed data at 200 Hz and raw data at up to 4 kHz. With its 10x faster update rate, an IMU can enable updated pose estimates during the longer intervals between perception measurements.

This higher update rate ultimately leads to faster reaction times to sudden changes in motion and enhances system reliability in dynamic environments.

IMUs provide the foundation for AMR dead reckoning, where an AMR estimates its current position from a known starting position based on integration of IMU acceleration and angular measurements. By providing data needed to update position, orientation, and speed continually, IMUs enable precise pose estimation for reliable AMR navigation.

Compact size and light weight also favor IMU integration in AMRs. For example, the ADI ADIS16500AMLZ IMU (Figure 8) comes in a BGA package measuring only 15×15×5 mm,

Sensor modality	Affected by poor lighting	Affected by dynamic movers	Affected by reflective surfaces
Standard RGB camera	Yes	Yes	No
Time of flight	No	Yes	Yes
LiDAR	No	Yes	Yes
Radar	No	Yes	Yes
Wheel odometry	No	No	No
IMU	No	No	No

Table 1: Shown is the impact of various environmental factors on sensor effectiveness. *(Table source: Analog Devices)*

yet it integrates a gyroscope, accelerometer, temperature sensor, and a complete signal chain for data acquisition and signal conditioning. This level of integration allows it to deliver comprehensive motion data to the host processor while enabling its use in space-constrained mechanical layouts without compromising the robot's maneuverability.

With its ±2000° per second (°/s) gyroscope dynamic range, the ADIS16500AMLZ captures rapid turns without saturation, which is essential for AMRs navigating tight spaces or performing quick obstacle avoidance. The ±392 m per second squared (m/s^2) accelerometer dynamic range captures both smooth movement and high-impact shocks. Its 8.1° per hour (°/hr) gyroscope bias stability and 125 microns per second squared ($\mu m/s^2$) accelerometer bias stability reduce drift to enhance dead-reckoning accuracy between corrections.

Factory calibration provides built-in correction for sensitivity, bias, and axis alignment, while dynamic offset correction accounts for temperature shifts, supply voltage changes, and magnetic interference, as well as noise reduction. [2] The IMU's mechanical shock tolerance of 19,600 m/s^2 and an operating range of −25 to 85°C enable deployment in demanding environments, while its low-noise, high-bandwidth ADCs ensure continued accurate data capture at the high update rates needed in responsive control systems. IMUs in general are also relatively resistant to electromagnetic interference (EMI) and can operate in varied lighting and environmental conditions. As a result, these devices can serve in a broad array of applications.

MITIGATING THE PERFORMANCE LIMITATIONS OF IMUs

Despite their performance benefits, IMUs present some inherent limitations. [3] Unfiltered noise can affect IMU measurements, which reduces navigation accuracy. Bias in accelerometer and gyroscope sensors accumulates over time, leading to drift in orientation and motion estimates.

Nonlinear sensor behavior distorts measurements, and thermoelectric events can lead to angle random walk (ARW) errors in gyroscopes and velocity random walk (VRW) errors in accelerometers that further degrade long-term performance. Unmitigated, these issues reduce localization reliability over time.

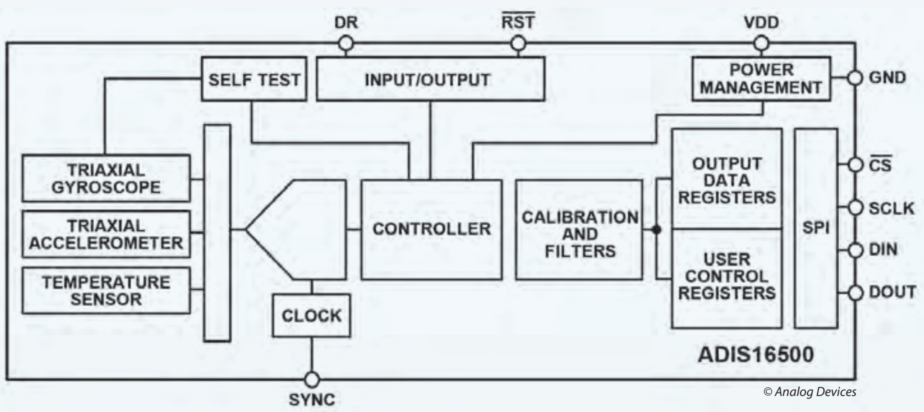


Figure 8 *The ADIS16500AMLZ IMU integrates a gyroscope, accelerometer, temperature sensor, and a complete signal chain for data acquisition and signal conditioning.*

Sensor fusion can overcome IMU limitations by integrating IMU data with other sensor inputs to increase the quality and reliability of the data, improve estimation of unmeasured states, and increase coverage to enhance safety.

State estimation techniques such as extended Kalman filtering (EKF) (Figure 9) can correct for noise, random walk, and bias instability during normal AMR operation.

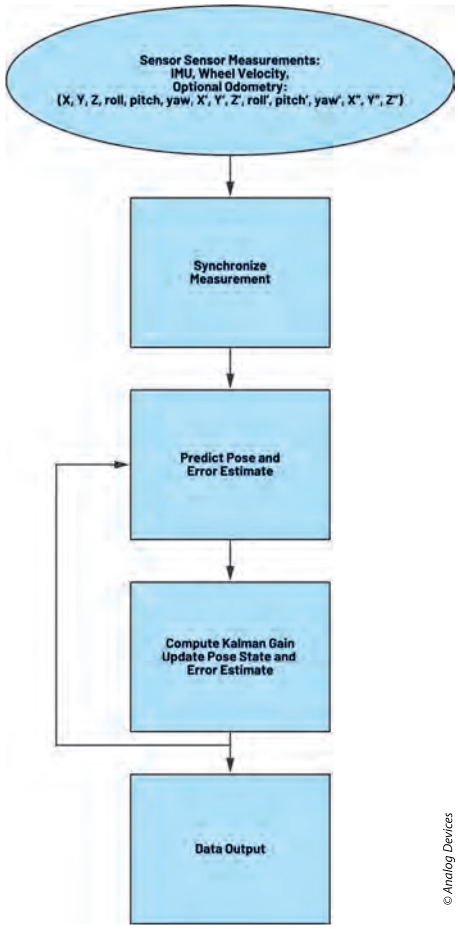


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Figure 9

A simplified EKF algorithm processes noisy sensor measurements over time to produce a corrected, continuous estimate of robot pose and motion.

By measuring acceleration due to Earth's gravity, pitch and roll gyroscope errors can be eliminated. Finally, bias drift can be tracked and corrected. In operation, EKF effectively enables estimation of past, present, and future states despite lack of complete knowledge about the nature of the modeled system.

EKF has gained widespread use because it can model system dynamics and measurement uncertainties, then update the state estimate when new data arrives.

Measurements that may contain Gaussian white noise or other inaccuracies are observed over time and used for correction. The filter estimates the true value of measurements by synchronizing measurements between sensors, predicting pose and error estimates, and estimating and updating the uncertainty of the predicted value.

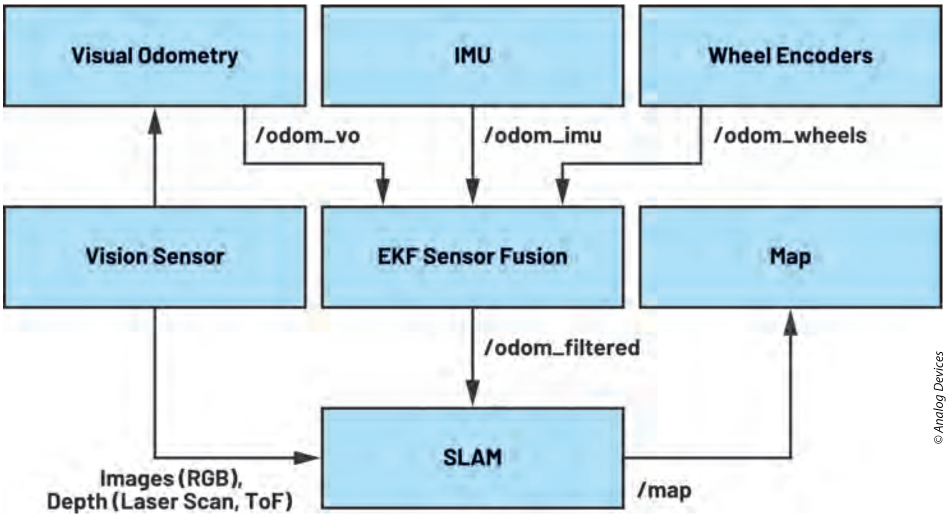

Figure 10 ***A typical ROS-based sensor fusion software architecture combines multiple sensor inputs through the robot_localization package to produce a robust, continuous pose estimate.***

Using these inputs, robot_localization generates an estimated pose state expressed as a vector of actual and derived measurements:

Pose State = $(X, Y, Z, roll, pitch, yaw, \dot{X}, \dot{Y}, \dot{Z}, \dot{roll}, \dot{pitch}, \dot{yaw}, \ddot{X}, \ddot{Y}, \ddot{Z})$

The evaluation system allows real-time sampling of the IMU at full sample rate and is powered via its USB port. All required software is downloadable from the resource page.

CONCLUSION

IMUs are essential for maintaining precise localization in AMRs, providing orientation estimates and motion tracking at high update rates even when other sensory modalities fail due to environmental conditions.

By using sensor fusion to compensate for limitations across different sensor types, AMRs can perform precise navigation even in dynamic environments that normally confuse AMR localization.

With the availability of highly integrated IMUs and associated breakout boards and evaluation systems, developers can quickly design AMRs able to achieve the accurate, reliable localization required for precise navigation.

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Figure 11 ***The ADIS16500/PCBZ breakout board (left) and the EVAL-ADIS-FX3Z evaluation kit (right) enable the rapid development of applications based on the ADIS16500 IMU.***

Sensor fusion algorithms are embedded in the Robot Operating System (ROS) open-source robot_localization package,[4] which implements EKF-based fusion and utilizes the EKF algorithm at its core (Figure 10).

This ROS package enables the fusion of an unrestricted number of sensors and can accept a variety of input types, including IMU data, wheel velocity, and odometry. The fused output includes full 3D position and orientation, linear and angular velocities, and acceleration, which feed directly into navigation and SLAM algorithms.

ACCELERATE DEVELOPMENT OF PRECISE AMR LOCATIONING

The ADIS16500AMLZ IMU demonstrates how precision sensing and integrated processing can improve AMR localization performance. To help developers accelerate application development, Analog Devices provides the **ADIS16500/PCBZ** breakout board (Figure 11, left) and accompanying **EVAL-ADIS-FX3Z** evaluation system (Figure 11, right). The breakout board comprises the IMU and a 16-pin header that mates to 2 mm ribbon cables to connect to the evaluation system.

References

1) Shoudong Huang and Gamini Dissanayake, Robot Localization: An Introduction, John Wiley & Sons, August 2016.
2) Randy Carver and Mark Looney, “MEMS Accelerometer Calibration Optimizes Accuracy for Industrial Applications,” EE Times, October 2007.
3) Oliver J. Woodman, “An Introduction to Inertial Navigation,” University of Cambridge, August 2007.
4) robot_localization Documentation, v2.6.12, Tom Moore, 2016.

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The Complex World of Embedded Electronics

A LAYERED MAZE OF INDEPENDENT ECOSYSTEMS

From the outside, an electronic system may appear to be a single unified discipline or device that works as a seamless, efficient, and precise unit. Yet anyone who has worked in the field knows that beneath the surface lies a fragmented, multilayered reality. Each layer of embedded electronics is so independently complex and expansive that it has given rise to its own ecosystem of tools, experts, workflows, and even philosophies.

Author:
DK Singh, Vice President of Digitalization, **Renesas Electronics**

And therein lies both beauty and challenge: it's an orchestra without a conductor. Each section plays with remarkable mastery and impeccable rhythm, but rarely in harmony.

Every layer advances at its own pace, following its own innovation curve. This independence has driven extraordinary breakthroughs, but it has also created silos that slow progress, complicate design cycles, and often leave engineers struggling to see the whole picture. It's rare to find an engineer, or even a company, that fully grasps all layers end-to-end.

This is not for lack of effort, but because each layer is a universe unto itself, and visibility diminishes as one looks across them.

Consider semiconductors. We've pushed boundaries to the brink of physics, etching features at the 1nm scale, leveraging EUV lithography, and packing billions of transistors into a fingernail-sized die.

Meanwhile, in PCB design, the very layer that connects these marvels, progress has been incremental. We still wrestle with trace widths, impedance control, and manufacturability limits that have hardly kept pace.

The depth and speed of innovation within each layer is staggering, yet coordination across them remains minimal. This asymmetry is not a matter of effort but of necessity. It is a symptom of deep specialization, and deep specialization often leads to silos.

Over the past two decades, from my early days of system debugging in Japan, to managing the silicon design work in the U.S., and now at the intersection of AI and embedded systems, I've had the rare opportunity to walk through these layers and experience their complexity firsthand.

Each has its own brilliance, and each is often blind to the realities of its neighbors. The analog designer rarely interacts with the embedded software engineer. The PCB layout specialist seldom has full context on application-level behavior. And system-level decisions are often made without end-to-end visibility. Let's take a closer look.

THE LAYERS OF EMBEDDED ELECTRONICS

1. Semiconductor Devices (The Foundational Layer)

At the heart of every embedded system lie the devices: microcontrollers, SoCs, memory, sensors, power ICs, and specialty chips. Designing them requires nanometer-scale precision, intricate tradeoffs, and deep process know-how. Each chip is its own universe, having passed through layout constraints, fabrication, packaging, validation, and years of accumulated expertise.

2. Architecture & Circuit Design (The Invisible Art)

Even with the best silicon, performance hinges on how parts interact; power trees, clocking strategies, and trade-offs between performance, cost, and manufacturability introduce a multitude of variables that affect the outcome. This layer manages signal integrity, noise isolation, thermal behavior, and long-term reliability. Decisions made here ripple throughout the system.

3. Simulation, Verification & Validation (Predicting Reality)

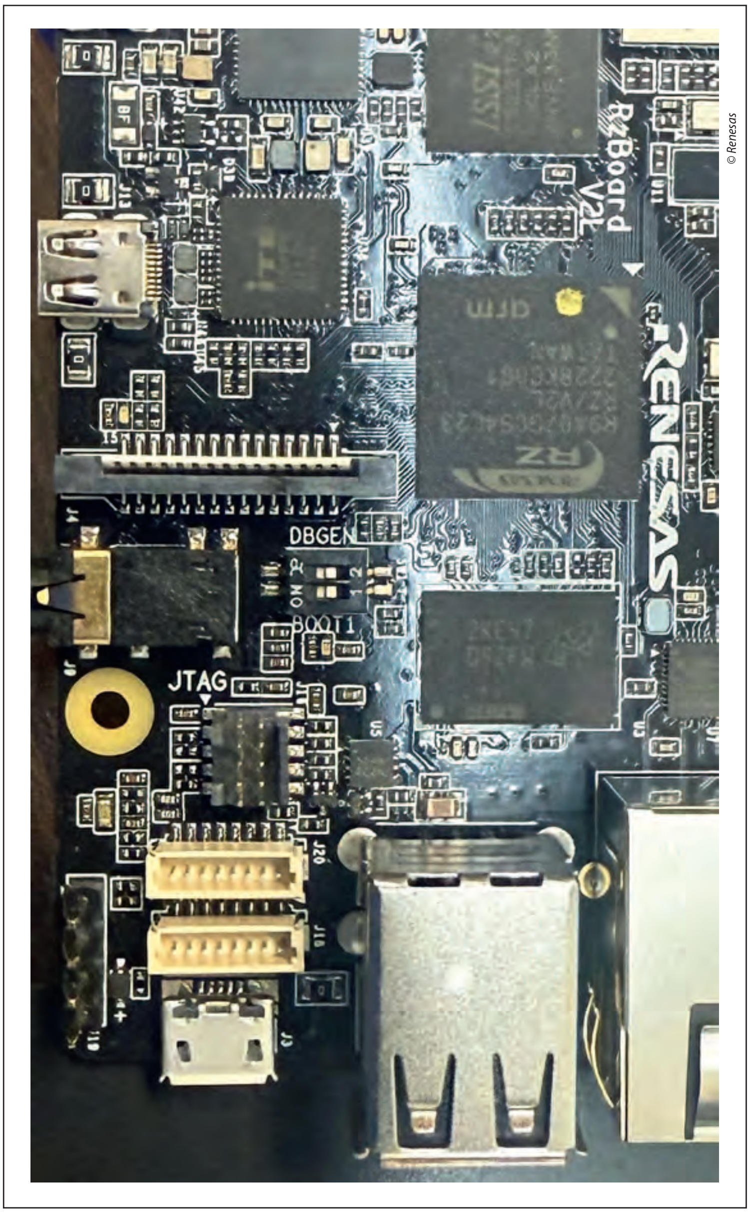
Simulation is where theory meets approximation. Before a PCB is fabricated, designs must be verified and validated. Tools like SPICE, MATLAB, or Ansys SIwave are invaluable, but are only as good as their models. Individual circuits and devices are simulated to ensure fitness before higher-level system checks. Yet the lab remains the ultimate truth-teller.

4. PCB Design & Physical Integration (Where Physics Bites Back)

Implementation happens on the PCB – the skeleton and nervous system of embedded design. Here, electrical, mechanical, and thermal realities collide. High-speed routing, minimizing crosstalk, optimizing layer stack-ups, and manufacturability are constant challenges. The board is where elegant theory meets the hard constraints of physics.

5. Embedded Firmware & Real-Time Software (The Silent Brain)

Hardware is powerless without firmware. This invisible layer brings the system to life, handling boot-up sequences, drivers, real-time control, and communication.
But it also exposes weaknesses: many "hardware bugs" are firmware timing issues, and many "software bugs" trace back to silicon errata.



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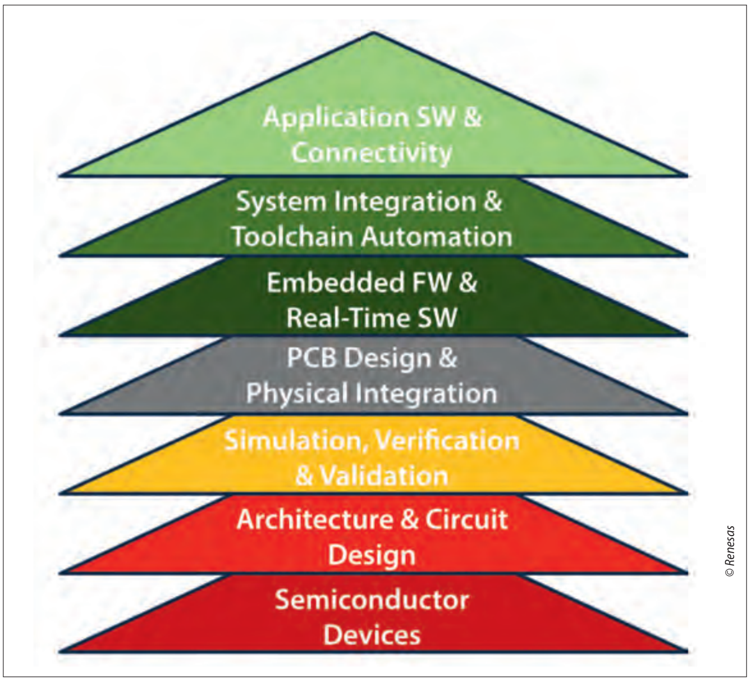

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6. System Integration & Toolchain Automation (Where the Glue Matters)

Integration is the true test. Unit-tested blocks meet and often clash. Mismatched compilers, inconsistent toolchains, or missing automation can stall progress. A 10-minute joint debug session between hardware and firmware engineers often saves weeks of finger-pointing.

7. Application Software & Connectivity (The User's Reality)

This layer translates raw data into usable insights, provides control interfaces, and connects to broader ecosystems such as IoT, robotics, or industrial automation. Timing, protocols, latency, and cloud synchronization all matter here. Ultimately, users never see a schematic or firmware code – they see the app, the dashboard, the experience.

FRAGMENTATION BY DESIGN

Each of these layers is a world of its own, with distinct tools, rules, experts, and challenges. This separation is not accidental – it is structural. Success in embedded systems is not only about mastering a single layer but about bridging the gaps between them.

Because each domain has grown so deep, cross-layer mastery is nearly impossible. The consequences are clear:

- Toolchains remain isolated, creating inefficiencies in debug and integration
- Expertise stays domain-locked, limiting collaboration
- Design cycles stretch, as insights are lost in translation across layers

The embedded industry is immensely capable – but fractured in execution.

A CALL FOR BRIDGING THE LAYERS

The next leap in embedded systems will come not from flattening complexity, but from orchestrating it. True system-level co-design, rapid prototyping, and AI-assisted development can connect these independent ecosystems. The future lies in creating shared abstractions, interoperable tools, and frameworks that enable experts to work in harmony without needing to master every detail.

A BOLD, FUTURE – READY MOVE BY RENESAS

Renesas has been steadily advancing toward a more orchestrated, end-to-end approach to electronics system development, one focused on reducing friction across disciplines while expanding access to modern, software-defined design workflows. A major milestone in that direction was Renesas' acquisition of Altium, followed by the announcement of **Renesas 365 (Powered by Altium) in 2025**.

Renesas 365 is an industry-first cloud-based open electronic system development and lifecycle management platform designed to connect historically fragmented layers of system architecture, hardware implementation, embedded software, and lifecycle governance.

Renesas 365 threads together the complete design flow into one platform, including device exploration, system modeling, simulation, system development and lifecycle management.
Built on Altium's cloud-based collaboration and digital continuity platform, the environment provides a single, secure, collaborative experience that maintains shared system context across domains while enabling real-time, multidisciplinary collaboration and end-to-end digital traceability.

As demonstrated publicly at embedded world 2025, Renesas 365 addresses long-standing inefficiencies caused by manual component discovery, fragmented documentation, and siloed execution between hardware and software teams.

By unifying silicon context, hardware realization, embedded software, and lifecycle workflows into a single continuous digital environment, the platform enables faster convergence from concept through implementation while aligning with the governance, traceability, and agility requirements of modern software-defined products.

Renesas has indicated commercial availability beginning in early 2026 and plans to showcase the integrated Renesas 365 experience in greater depth at **embedded world 2026.** This will offer attendees a practical, hands-on view of how this approach operates within real engineering teams.

Renesas 365 is intended to bridge these layers by unifying silicon, hardware implementation, embedded software, and lifecycle governance in a secure, cloud-based development environment.

Renesas plans to share an early glimpse of this integrated workflow at the Renesas 365 booth (4-305) at embedded world 2026.

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Sustaining Legacy Systems in a Rapidly Evolving Market

Rochester's proven approach to obsolescence and critical component continuity

Rochester Electronics

When maintaining legacy systems, one of the most common questions we hear from customers is: "Can you rebuild this?" In most cases, the answer is a confident "Yes", backed by our proven processes and deep technical expertise.

Rochester Electronics consistently invests in and develops proactive strategies for the components and raw materials used in original product designs to ensure ongoing support for legacy systems. The processes, tooling, storage conditions, and supplier relationships are vital for maintaining part viability. We aim to minimize customer risk by treating obsolescence as a strategic discipline that includes component lifecycle management, tooling preservation, inventory storage, and customer communication.

Component obsolescence is a top priority for our customers, and rightfully so. However, even a strategic Last-Time-Buy (LTB) can fail if parts are stored improperly or if manufacturing tooling is no longer available during a production lull. An effective obsolescence strategy must include proper material storage and maintenance of tooling continuity.

THE SILENT OBSOLESCENCE RISK: Manufacturing Tooling That Vanishes

Manufacturing tooling is usually owned by the customer and managed by the supplier. When a package hasn't been ordered in 24 to 36 months, suppliers may scrap or repurpose tooling without notice, leading to significant unexpected rebuild costs, delays, and potentially a broken customer contract.

Rochester Electronics has implemented a structured, cross-functional process for managing component and tooling lifecycles, encompassing procurement, engineering, and operations. We monitor component history, identify parts lacking a second source, and routinely review PCNs and EOL notifications. Furthermore, if a tool remains unused for 24-36 months, we evaluate whether to place a maintenance order to prevent potential loss.

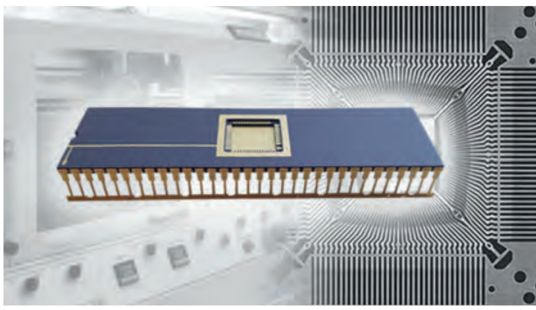
For legacy semiconductor packages like CERDIP, PDIP, QFP, Ceramic Flat Pack, CQFP, Side-brazed DIPs, CPGA, and custom ceramic hybrids, specialized tooling is essential for maintaining continuity.

However, these tools are often overlooked until it is too late.

When it comes to tooling and obsolescence risk, hermetic and plastic packages present different challenges. Hermetic packages often depend on expensive specialized tooling, which carries a higher risk of being scrapped during production lulls to free up space or reduce overhead costs for suppliers. The lead times and costs can become very significant.

In contrast, plastic packages like PBGA, QFP, or QFN use more standardized, high-throughput tooling.

Progressive stamping dies can be used for high-volume programs, but most tooling for plastic packages involves chemical etching masks. These support lower volume programs and only require design and mask sets for tooling to stay active, with less impact on cost and lead time.



Rochester's strategy is to maintain the tooling's viability.

We monitor tooling health through a structured review cycle.

For critical packages, we:

- Place low-volume "maintenance orders" to ensure tool viability.
- Negotiate storage and retention agreements with our key suppliers.
- Maintain a tooling registry tied to part numbers.

STORAGE ISN'T LOGISTICS. IT'S RISK MANAGEMENT.

Strategic inventory is another crucial aspect of obsolescence management. Rochester intentionally stores components for long-term demand in critical programs, using:

- Nitrogen or dry cabinet storage for moisture-sensitive components and gold brazed ceramic packages.
- Strict FIFO inventory rotation and shelf-life monitoring.
- Reinspection protocols for stock over 12 months old.
- Controlled repackaging with updated desiccants and humidity indicators when needed.

When storing high-value legacy components such as gold preforms, hermetic lids, specialty passives, and brazed packages, controlling the environment is essential.

Poor storage can turn a proactive Last-Time-Buy (LTB) into scrap or, worse, cause materials to degrade, which can affect performance in high-reliability applications.

Regular inspections of long-term stock and digitized storage data make risk reviews quicker and easier.

CUSTOMER ALIGNMENT:

Share the Risk, Share the Strategy

In legacy programs such as aerospace and defense, customer collaboration is critical. Programs can falter when end users assume parts will always be available or don't realize their build relies on tooling from a supplier that is exiting the market. At Rochester, it is standard practice to communicate and engage with our customers to help provide reliable long-term forecasts by:

- Communicating risks to our customers through PCNs and obsolescence status during customer reviews.
- Offering alternate storage or "vaulted inventory" solutions based on forecasted needs.
- Involving customers in last-time buy planning, considering real lead-time and tooling constraints.

THE KEY TAKEAWAY:

Foresight is a Competitive Advantage

In high-reliability sectors, simply "having the part" is not sufficient. Customers need the tooling, testing, storage conditions, and organizational discipline to keep parts viable long-term.

Legacy systems can only be as resilient as the supply chain that supports them. By integrating proactive storage practices, tooling retention plans, and transparent customer communication, Rochester not only extends part availability but also extends program life and preserves performance, reliability, and trust.

As a licensed semiconductor manufacturer, Rochester has manufactured over 20,000 device types. With over 12 billion die in stock, Rochester has the capability to manufacture over 70,000 device types.

For over 40 years, in partnership with over 70 leading semiconductor manufacturers, Rochester has provided our valued customers with a continuous source of critical semiconductors.

ROCHESTER OFFERS A FULL RANGE OF MANUFACTURING SERVICES

- **Design Services**

We can replicate the original device, avoiding lengthy, expensive system requalification, recertification, or redesign. The end-product is a form, fit, and functional replacement guaranteed to the original data sheet performance.

- **Wafer Storage**

Our next-generation capabilities include an ISO-7/10K certified, nitrogen-controlled environment, secure room, and individual cabinets, Stainless steel dry boxes incorporating microprocessor humidity control.

- **Wafer processing**

Includes Back-side Grind (BSG), dicing, dice inspection, and sorting using state-of-the-art equipment in our Newburyport, MA, facilities.

- **Assembly Services**

We provide a full range of including Quick Turn IC package assembly, Hermetic assembly, Plastic assembly, component lead finishing, BGA Re-balling, package, substrate, and leadframe replication with a variety of lead finishes including Sn, SnPb, and RoHS.

- **Test Services**

We provide a range of high-quality test services, including Analog, Digital, Mixed Signal, Memory, and Power, with a range of legacy platforms through to advanced test solutions.

- **Analytical Services & Reliability Testing**

We have significant expertise that enables our customers to accelerate potential failure mechanisms, help identify root cause, and take actions to prevent failure modes. Our range of Analytical Services includes Electrical, Materials, and Polymer Analysis.

■ **Rochester Electronics**
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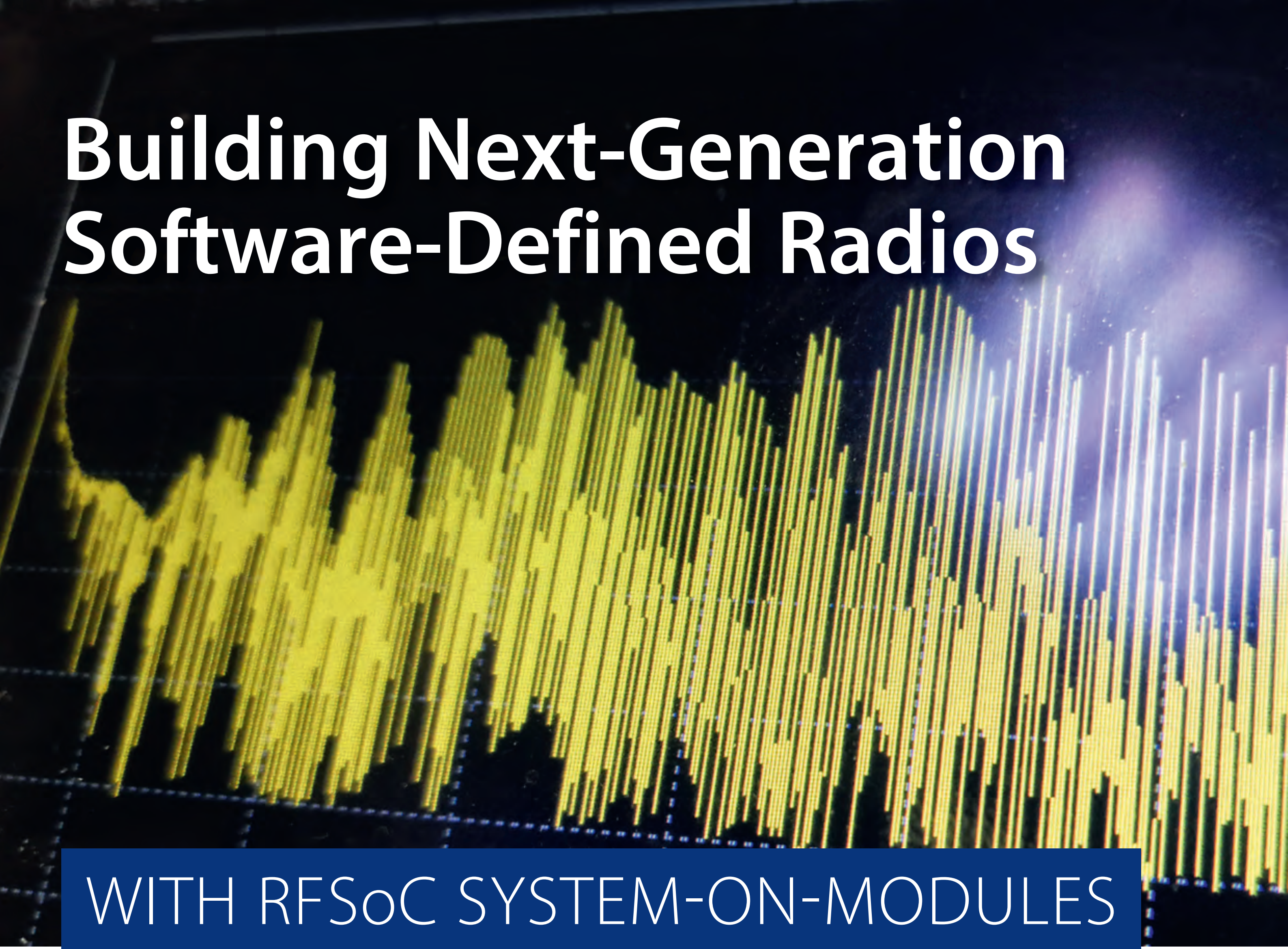


Building Next-Generation Software-Defined Radios

WITH RFSoC SYSTEM-ON-MODULES

***Software-defined radio (SDR)** represents one of the most significant transformations in the field of wireless communication. Unlike conventional radios that rely on fixed analog circuitry for filtering, mixing, and modulation, SDRs shift much of the processing to the digital domain. By replacing hardware-centric functions with software-driven algorithms, SDRs gain an unmatched level of flexibility allowing designers to upgrade features, adapt to new protocols, and extend system lifecycles without redesigning the hardware.*

Author: **Rolf Horn,** Applications Engineer, **DigiKey**

This ability to reconfigure on the fly makes SDRs indispensable in a broad spectrum of applications, from defense systems and aerospace to 5G infrastructure, satellite communications, and electronic test equipment.

HOW SDR DIFFERS FROM TRADITIONAL RADIO SYSTEMS

In a traditional RF receiver, analog components handle most of the workload: mixers down-convert incoming signals, filters shape the spectrum, and modulators or demodulators recover information. This analog chain can be inflexible and susceptible to noise, requiring redesign for each new frequency band or standard. By contrast, an SDR reduces the analog front end to the bare minimum – typically just the antenna and a basic RF front-end circuit (Figure 1).

Once the incoming waveform is digitized by an analog-to-digital converter (ADC), the heavy lifting is performed in software.

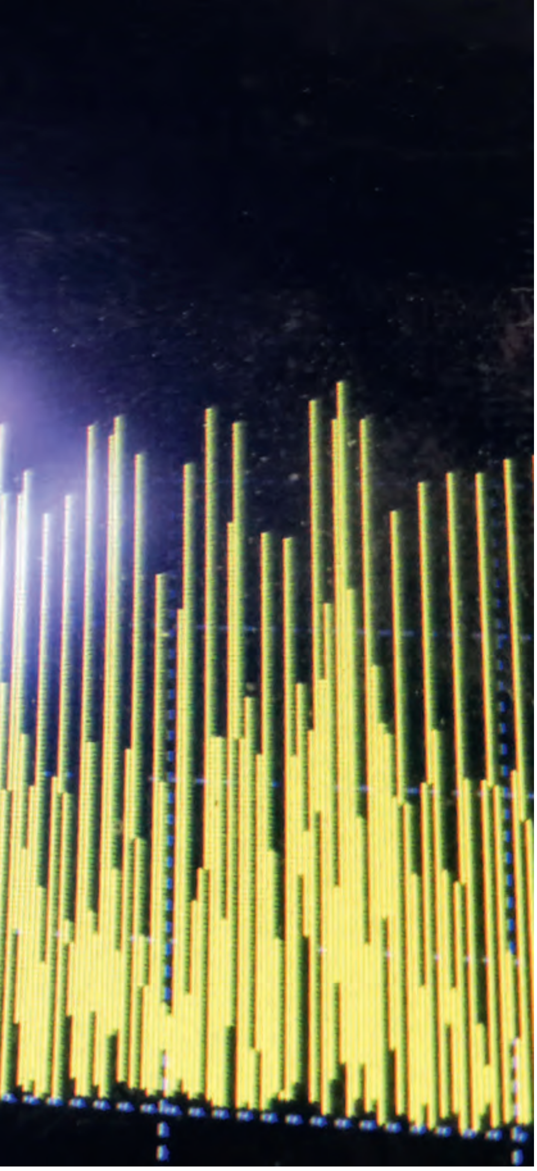
Modulation, demodulation, channel filtering, error correction, and decoding all happen digitally. Similarly, for transmission, a digital-to-analog converter (DAC) transforms processed data back into RF signals, again controlled by software routines.

This shift unlocks tremendous agility: the same radio hardware can support Wi-Fi today, a 5G band tomorrow, and secure tactical communications the next – all with a software update.

RFSoC: AN IDEAL PLATFORM FOR SDR

Building a high-performance SDR requires ultra-fast converters, a powerful processing fabric, and low-latency data paths. AMD's Zynq™ UltraScale+™ RFSoC family addresses these needs by integrating:

- Multi-gigasample RF-ADCs and RF-DACs
- FPGA programmable logic for real-time DSP



- Embedded Arm® processors for software control
- High-speed memory and transceiver interfaces

By consolidating what previously required multiple discrete chips into a single device, RFSoC dramatically simplifies board design. This integration lowers power consumption, reduces latency, and improves signal integrity. For real-time RF applications where timing precision and performance are non-negotiable, RFSoC delivers a monolithic solution with ultra-low latency and tight synchronization.

THE POWER OF DIRECT RF SAMPLING

One of RFSoC's defining advantages is its ability to support sampling rates in the multi-GSPS range. Its RF-ADCs can capture signals directly at RF frequencies, while its RF-DACs can generate extremely wide-band outputs – both without relying on intermediate down-conversion stages.

This enables an "almost all-digital" radio architecture, where standards like Wi-Fi at 2.4 GHz, 5G New Radio around 3.5 GHz, and cellular bands from 800 MHz to 1.8 GHz can be directly digitized and processed.

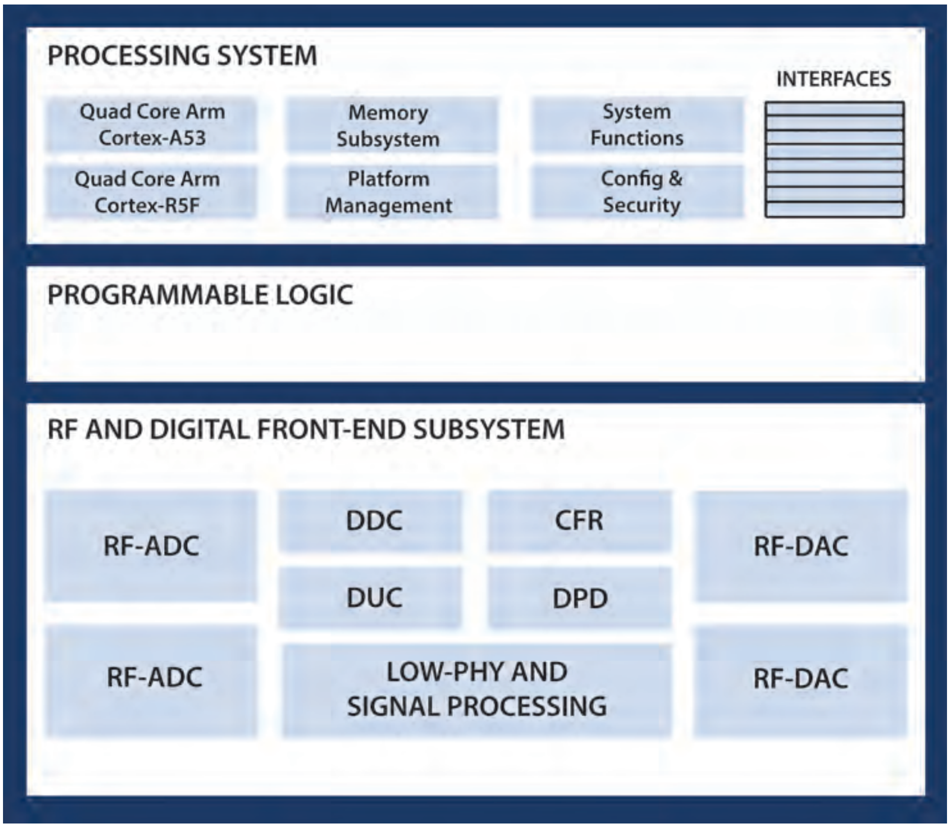


Figure 1 *The basic SDR processes.*

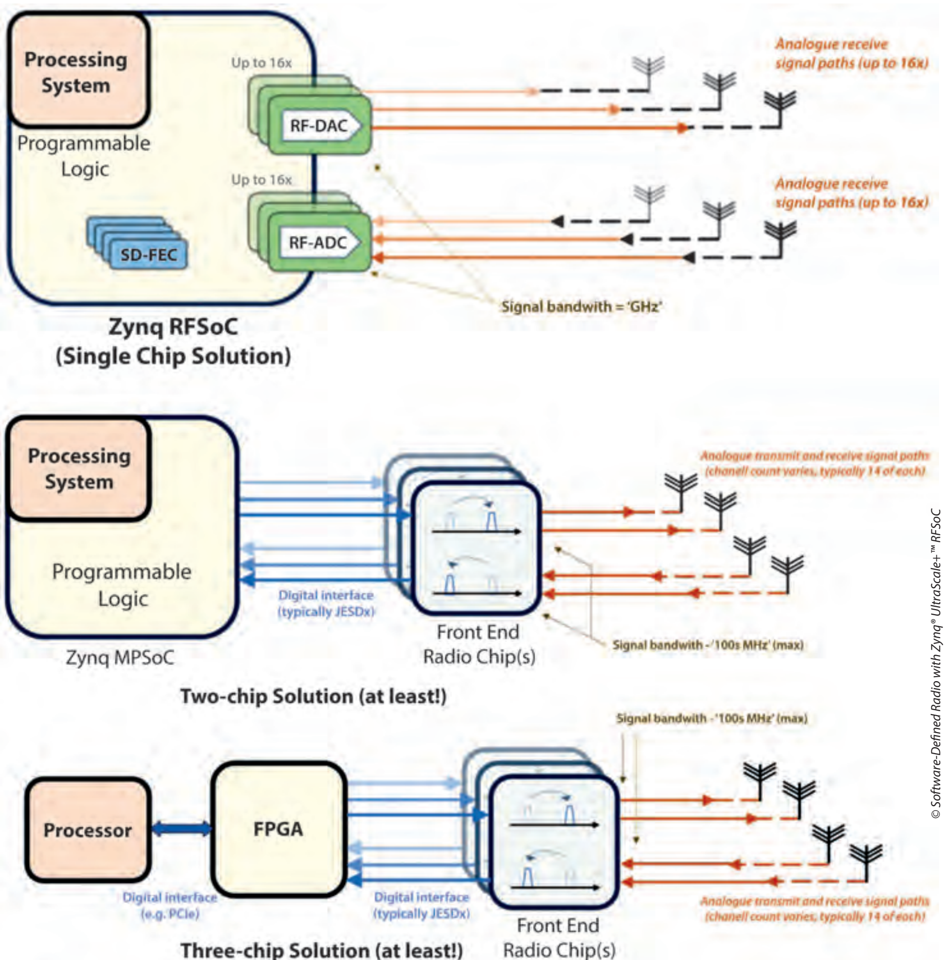
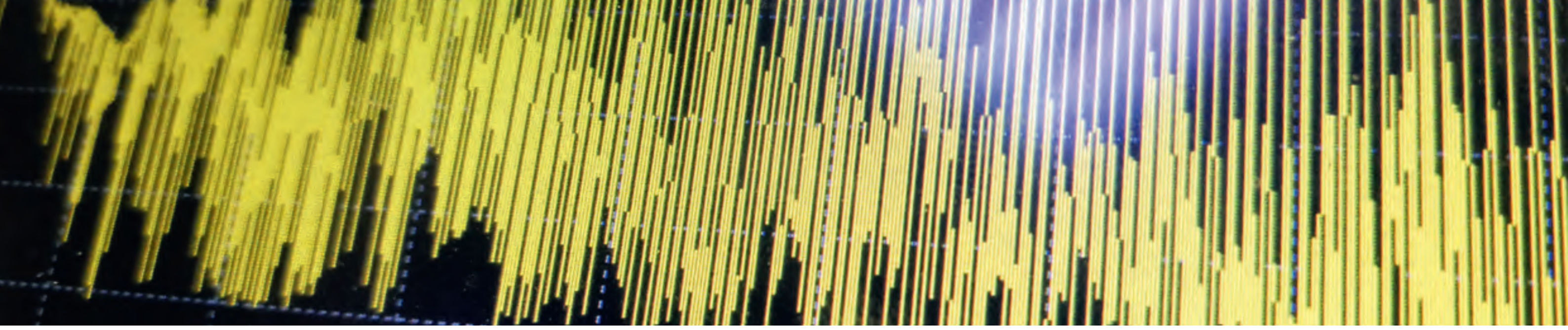


Figure 2
Comparison of a single-chip RFSoC SDR solution, with multi-chip alternatives.



Metric	Single-chip Zynq RFSoC solution	Two-chip solution	Three-chip solution
Cost	Lowest (integrated platform reduces BOM)	~25% to 30% higher than single-chip	Highest (due to multiple high-speed devices)
Development time	Fastest (fewer integration steps)	Moderate (complex signal chain and routing)	Longest (requires full custom integration)
RF signal integrity	High (minimal signal path loss)	Medium (signal degradation through links)	Lower (increased risk of crosstalk, jitter)
Latency	Ultra-low (<1 µs typical)	Medium (~1 µs to 5 µs depending on design)	High (interconnect adds cumulative latency)
Performance	High (tightly coupled ADC/DAC + PL)	Medium (dependent on interconnect and sync)	Variable (limited by clocking & PCB layout)

Table 1: **Comparison of RFSoC to conventional SDR solutions.**

By contrast, many off-the-shelf SDR platforms are limited to sampling rates of a few tens or hundreds of MHz, making them dependent on analog mixers to shift signals down to an intermediate frequency. By eliminating those analog stages, RFSoC-based SDRs achieve higher fidelity, lower latency, and a more compact design (Figure 2).

COMPARING SDR ARCHITECTURES: SINGLE-CHIP VS MULTI-CHIP

With ADCs, DACs, FPGA logic, and processors all inside one package, RFSoC avoids the pitfalls of inter-chip communication. For developers, this translates to shorter design cycles, reduced cost, and superior end performance.

WHY CHOOSE A SYSTEM-ON-MODULE FOR RFSoC SDRs?

While RFSoC itself is highly integrated, designing a custom board around it can still be daunting. Power sequencing, clock distribution, and multi-gigabit layout require advanced expertise. A system-on-module (SoM) provides a practical solution.

By delivering a compact, pre-validated module that houses the RFSoC, memory, power management, and high-speed interfaces, SoMs let engineers:

- Accelerate prototyping and minimize design risk
- Focus on application-specific innovation rather than baseboard integration
- Achieve compact, SWaP-optimized (size, weight, and power) designs suited for aerospace and defense
- Rely on long-term availability and production-grade quality

Carrier boards can be tailored to each use case while the SoM remains constant, allowing teams to reuse intellectual property (IP) and reduce total development cost.

iWAVE'S RFSoC SYSTEM-ON-MODULE PORTFOLIO

iWave offers a comprehensive set of RFSoC SoMs and evaluation platforms, each tuned for high-performance SDR and RF applications:

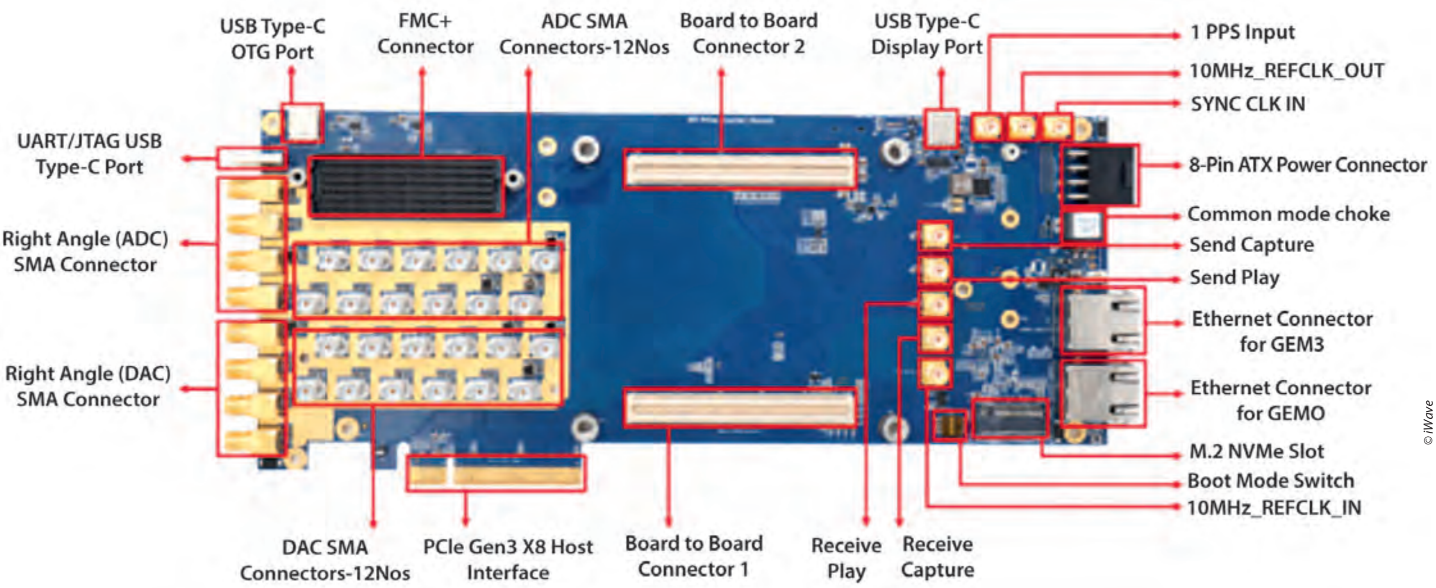


Figure 3 *iWave carrier board for RFSoC SDRs.*

- **iG-G42M**
  ZU49/ZU39/ZU29DR RFSoC SoM
  - Features 16 ADCs (2.5 GSPS) and 16 DACs (10 GSPS).
- **iG-G42P**
  RFSoC PCIe Card (ZU49/ZU39/ZU29DR)
  - PCIe Gen3 connectivity, NVMe storage, SMA I/O, and FMC+ expansion.
- **iG-G60M**
  ZU48/47/43/28/27/25DR RFSoC SoM
  - Up to 8-channel ADC/DAC (5 GSPS / 9.85 GSPS).
- **iG-G60V** ***(Coming Soon)***
  RFSoC ADC/DAC 3U VPX Plug-in Module
  - Ruggedized form factor for aerospace and defense.

These modules are backed by robust software stacks including Linux BSPs, JESD204B/C support, GStreamer pipelines, and reference applications, ensuring a seamless path from prototyping to production.

REAL-WORLD IMPACT OF RFSoC SDRs

The combination of direct RF sampling, integrated digital processing, and module -level deployment results in SDR systems that are:

- **Highly flexible** – configurable for multiple wireless standards
- **Compact and efficient** – optimized for SWaP-sensitive platforms
- **High fidelity** – with minimal signal degradation
- **Scalable** – from lab prototypes to deployed defense and telecom infrastructure

Whether in unmanned aerial systems conducting real-time surveillance, 5G base stations supporting dynamic spectrum allocation, or portable test equipment analyzing wideband signals, RFSoC SDRs enable solutions that were once impractical with discrete designs.

CONCLUSION

Software-defined Radio is reshaping wireless communication by making radios more flexible, upgradeable, and future-ready. AMD's Zynq UltraScale+ RFSoC brings this concept to life by collapsing converters, FPGA fabric, and processors into one silicon die.

Pairing RFSoC with a System-on-Module unlocks faster time-to-market, reduced risk, and production-grade reliability.

With over 25 years of expertise in FPGAs and embedded systems, iWave delivers RFSoC SoMs and ODM services that balance performance, cost, and long-term support.

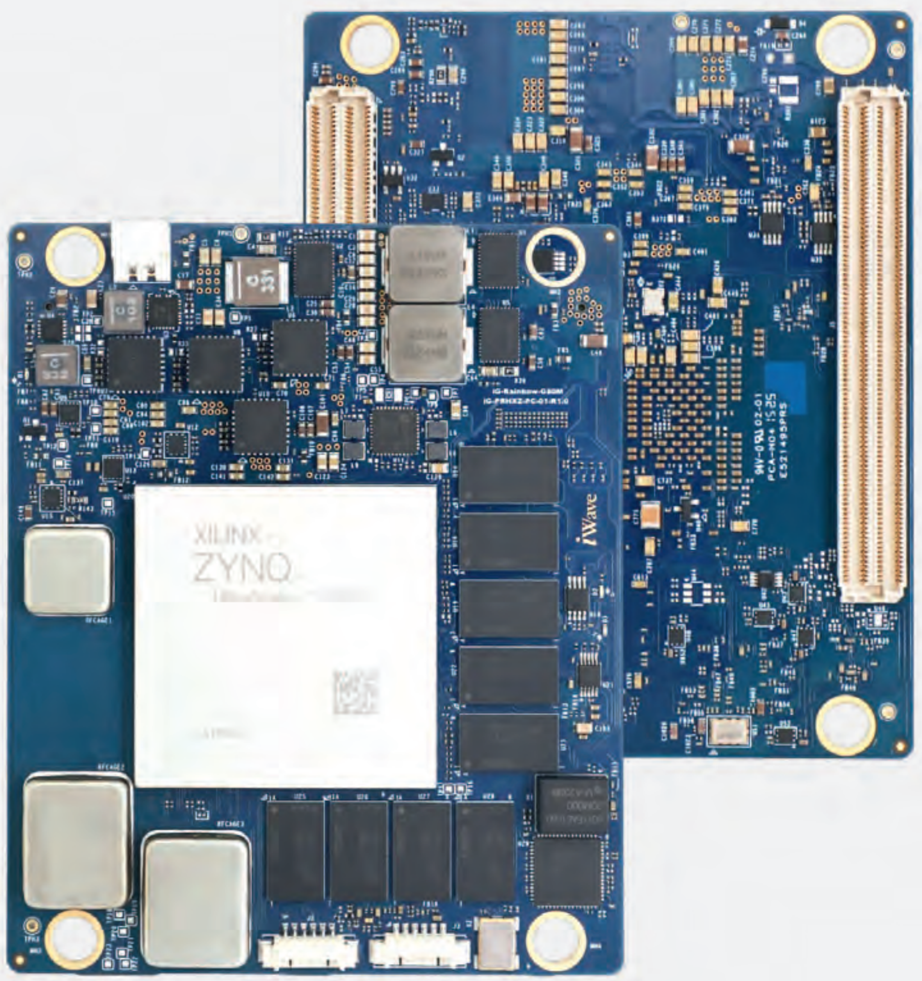


Figure 4 *iWave RFSoC SoMs.*

About the author

Rolf Horn, applications engineer at DigiKey, has been in the European Technical Support group since 2014 with primary responsibility for answering any development and engineering related questions from customers in EMEA, as well as writing and proof-reading German articles and blogs on DigiKey's TechForum and maker.io platforms. Prior to DigiKey, he worked at several manufacturers in the semiconductor area with focus on embedded FPGA, microcontroller and processor systems for industrial and automotive applications. Rolf holds a degree in electrical and electronics engineering from the University of Applied Sciences in Munich, Bavaria and he started his professional career at a local electronics products distributor as system-solutions architect to share his steadily growing knowledge and expertise as trusted advisor.

To explore how iWave's RFSoC portfolio can accelerate your SDR projects, contact us at mktg@iwave-global.com.

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Next-Generation IGBT7 Technology: Versatile and Simplified Power Management

IGBTs have been a mainstay in the industry, combining the advantages of high power with simple driving mechanisms. The new IGBT7 technology has succinct differentiation in device characteristics such as lower forward voltage, higher current ratings, 175°C over-load capacity, improved dv/dt control and enhanced freewheeling diode. When paired with innovative low-inductance packaging, IGBT7 technology offers ease of use, enhanced ruggedness, higher power densities, and improved efficiency, all while reducing system costs. Essential for motor drive applications, the versatile IGBT7 devices will empower a wide range of industries, including aerospace, renewable energy, energy storage systems (ESS), data centers, and commercial and agricultural vehicles.

Author:
Amit Gole, Product Marketing Manager, **Microchip Technology**

An Insulated-Gate Bipolar Transistor (IGBT) is a power semiconductor device with a collector, emitter and gate. It is called a bipolar transistor as the conduction happens because of the movement of electrons and holes.
IGBTs are power horses for a plethora of power electronics applications, including power converters, inverters and choppers. IGBTs are widely used in mains-powered systems and equipment with medium or high switching performance from a few kWs to MWs. IGBT power modules are essential components in contemporary power electronics.

These modules control and convert electrical power in various applications, including industrial motor drives, renewable energy systems, Electric Vehicles (EVs) and power grids.

NEXT GENERATION IGBT7

The seventh generation of IGBT power modules are now available in seven packages across multiple parts.
These devices feature lower VCE (sat) and VF, overload capacity at TJ of 175°C, 50% higher current capability, enhanced controllability of dv/dt, improved FWD softness and simpler driving compared to previous legacy generations.

These features offer a differentiated value proposition of high-power density, durability, reduced system costs, higher efficiency, ease of use and faster time to market.

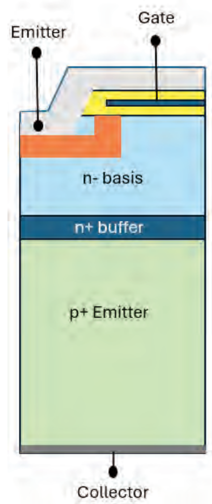
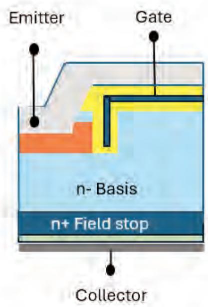
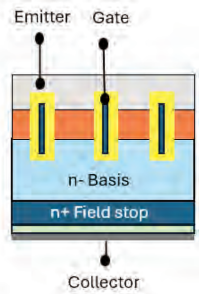
Punch Through (PT) IGBTs	IGBT Tench 4 Field Stop	IGBT Trench 7 Micro Pattern Trenches
		
• Higher VCE (sat) • Higher Switching losses • Rugged	• Lower Switching Losses • Enhanced Ruggedness	• Lower VCE(Sat) and VF • Improved Softness • Higher Ruggedness • Precision in driving • Better Short Circuit performance

Figure 1 *IGBT technology progression.*

IGBT7 TRECH TECHNOLOGY

The IGBT Trench7 uses Micro-Pattern Trench (MPT) technology, which consists of parallel trench cells separated by sub-micron mesas as compared to the square trench cells used in previous generation.
Figure 1 shows the cross section of the different technologies from punch through to the IGBT7. The carrier storage close to the emitter electrode increases for the IGBT7 trench cells due to smaller cell pitches and narrow mesas between the gates. This results in improvement in electrical conductivity in drift zone, which in turn reduces the forward voltage drastically, resulting in lower conduction losses for the IGBT7 technology.

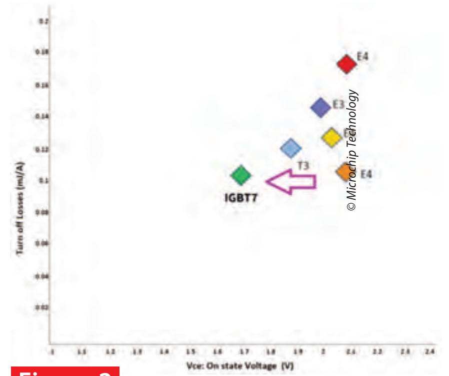


Figure 2

Comparison of IGBT technologies (IGBT3 (T3/E3) at TVJ (op): 125°C while IGBT4 and IGBT7 at TVJ (op): 150°C.

Figure 2 shows the relative comparison of different IGBT generations including 2, 3,4 and the latest IGBT7. IGBT7 has the lowest on-state voltage, around 15 to 20% reduction compared to previous generation of IGBT4. This low on-state loss results in low conduction losses and, in turn, increases the efficiency for low-to-mid switching frequency applications. Additionally, the IGBT7 comes with a soft antiparallel diode that has better reserve recovery characteristics and low forward voltage (Vf), reducing the losses further to provide higher power density.

IGBT7 PORTFOLIO

IGBT7 power modules are available in the industry-standard 62 mm packages for phase leg or half bridge configuration in D3 package and for single-switch configuration in D4 packages.
Microchip offers low-inductance/low-profile packages in 62 mm, such as SP6C, SP6P and SP6LI, offer reduced profile height and lower package inductance and enable high-power density with high reliability.

Lower power levels can be served with smaller packages such as SP1F and SP3F, which are also low-profile packages available in various configurations.

The ratings extend up to 900A with 1200V and 1700V.

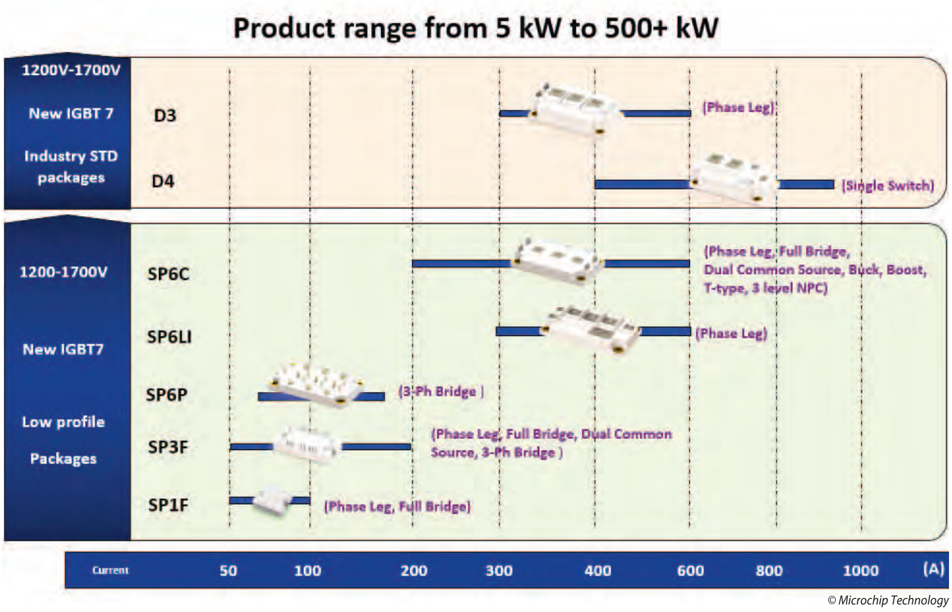


Figure 3 *IGBT7 Portfolio.*

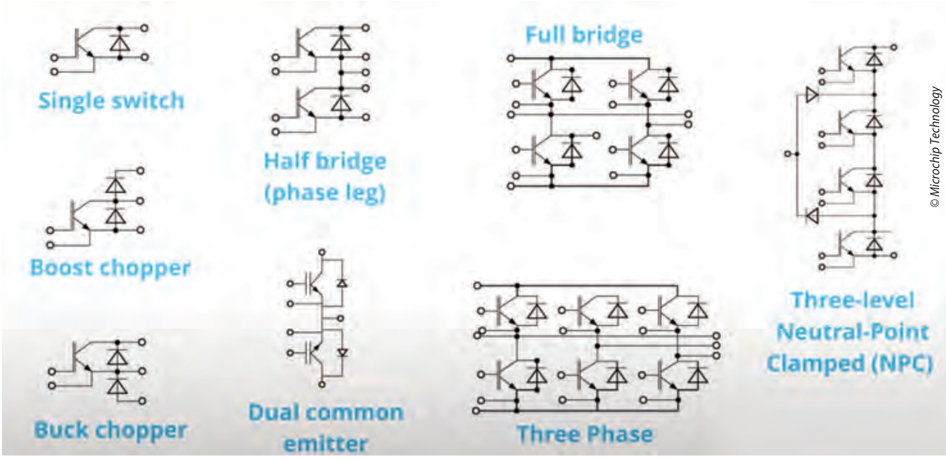


Figure 4 *IGBT7 topologies.*

SN	IGBT7 portfolio Features	Application Benefits	User Benefits
1	Lower on-state voltage VCE (sat) and Vf with improved FWD	15% Lower Power Losses Vs IGBT4	High Efficiency
2	Overload capability at TVJ (op) is 175°C	Design flexibility, avoids overdesign	Reliability, High performance to cost ratio
3	Enhanced controllability of dv/dt	Precise control, reduced EMI issues	Reliability, Ease of use
4	Optimized for simple driving	Simplified driver design	Ease of use
5	Higher Current capability	Reduced need for paralleling, Frame size jump	High Power Density, Faster time to Market
6	Lower Inductance /Low profile packages	Avoids overdesign	Reliability, reduced cost

Table 1: **IGBT7 Portfolio Features, application benefits and end user benefits**

LOWER ON-STATE VOLTAGE VCE (SAT) AND LOWER VF WITH IMPROVED FWD

With 15 to 20% lower on-state voltage, there is significant loss reduction up to mid switching frequency applications, while the conduction losses at the given dv/dt limitation are decreased and there is a reduction in antiparallel diode loss. Conduction losses of the IGBTs are directly proportional to the VCE (sat) of the IGBT technology. IGBT7 has around 1.77V of typical VCE (sat) at TJ 175°C that is far lower than the VCE (sat) of IGBT4, which is 2.1V at TVJ 150°C. This reduction of VCE (sat) by 15% reduces the conduction losses significantly.

Also, reduced forward voltage of the antiparallel diode helps in reducing the diode losses, so the improved diode reduces the forward voltage by 100 mV compared to IGBT4, which reduces the conduction further.

- Total conduction loss = IGBT conduction loss + diode conduction loss
- Total switching loss = IGBT switching loss + diode switching loss
- Total power loss = total switching loss + total power loss
- Efficiency = output power/input power = input power + total power loss/input power

OVERLOAD CAPABILITY AT TVJ (OP) IS 175°C

Maximum junction temperature of 175°C compared to 150°C (IGBT4), which is key for motor drives for repetitive, short term overload operation. The IGBT7 power modules are built for challenging applications as they can withstand junction temperature of 175°C during overload condition as opposed to 150°C for IGBT4.

This 25°C improvement not only has tremendous advantages in the reliability and durability of the drive power inverter, but also can result in cost-saving benefits with the high-performance-to-cost ratio of the IGBT7 over any other technology.

Inverter motor drivers used in multiple applications such as Commercial and Agricultural Vehicles (CAV), industrial plants and railways where it is important to withstand the short-term overload while working at the normal operating temperature for not less than 1 minute/60 seconds.

The same is true to applications such as UPSs where short term overload are critical for the power specifications where the typical overload durations could vary greatly, for example 110% for 10 min+ 125% for 120 sec+ 150% for 15 sec.

During these overall intervals, the inverter and, in turn, the switches carry more current that result in higher junction temperatures. The power switch must be capable of inherently withstanding such overload and the wear and tear caused by the repetitive nature, during its lifetime.

Repeated overloads are a part of industrial motor applications and need to be factored into the design of the inverter and the selection of proper power semiconductor switches.

It is important to preserve the durability of the switch when dealing with these overload intervals for prolonged and successful operations.

Momentary Overload /Base Current	Time Interval between overload (minutes)
110%	>= 9
125%	>= 28
150%	>=60

Table 3: **Example of overload durations for Inverter-Fed Polyphase Motors (per ANSI/NEMA MG 1-2016 (Revised 2018))**

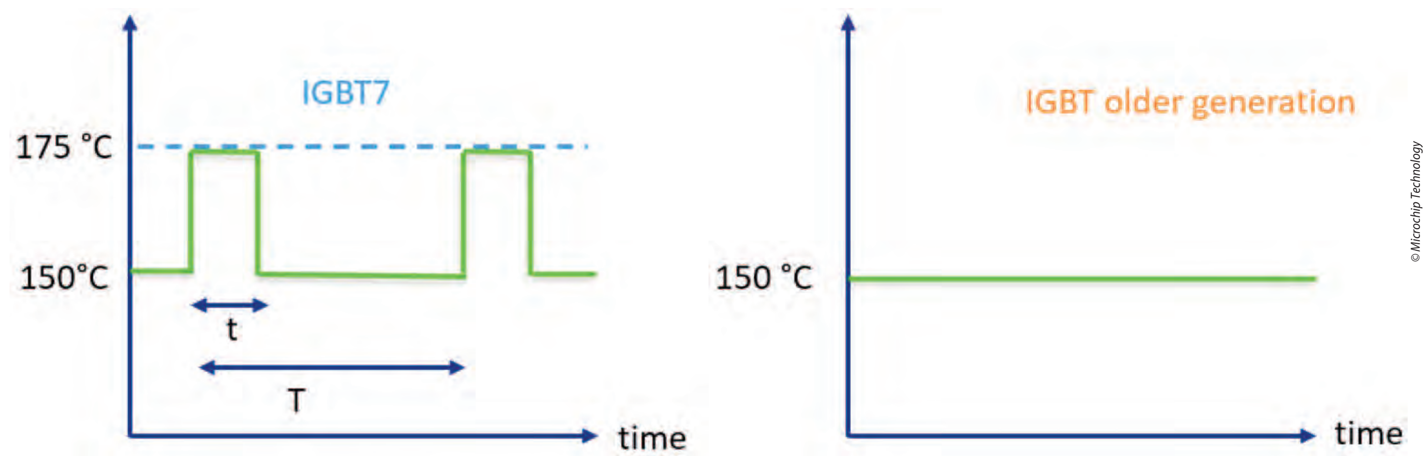


Figure 5 *Maximum operation junction temperature comparison between the IGBT7 and older IGBT generations.*

Technology	IGBT4	IGBT7	Difference	% reduction
Part	APTGL325A120D3G	APTGX300A120D3G		
Package	D3 62mm standard			
VCE (sat)Typical at TJ = 125 °C VGE = 15V IC = 300A	2.2V	1.7V	0.5V	22.72%

Table 2: **An example comparison between IGBT4 and IGBT7 specs VCE (sat)**

ENHANCED CONTROLLABILITY OF DV/DT

High level of controllability (ability to vary the dv/dt by adjusting the value of the gate resistor (Rg)) to match the motor insulation requirements or EMI limitations. Inverters are used to drive the motor use Pulse-Width Modulation (PWM) signals do not produce sinusoidal output voltage waveforms. In addition to lower-order harmonics, these waveforms also have superimposed on them steep-fronted, single-amplitude voltage spikes.

Turn-to-turn, phase-to-phase and ground insulation of stator windings are subjected to the resulting dielectric stresses. High switching frequency implies higher and steeper pulse rise times. This higher pulse rise time of the switches results in high dv/dt, which is further exacerbated by the long cables used in the motor drive application from the inverter to the motor, resulting in higher peak voltages right at the motor terminals.

The rise time could also damage the bearings due to parasitic currents flowing from the rotor to the motor frame. These dangerously high voltage spikes due to rise time can result in arching and eventually insulation failure. Longer motor cables even result in higher voltage overshoot with peak values as high as five times the system operating voltage (> 2000V for 415V systems).

High voltage spikes can lead to insulation breakdown, resulting in phase-to-phase or turn-to-turn short circuits, with subsequent over-current trips by the drive sensor.
This is why motor manufacturers strongly recommend not exceeding the dv/dt of 5 kV/µs at the inverter terminal in the worst-case scenario for 3-phase motors of typical 380/415/440 VAC.

The higher the length of connection between the motor and inverter, the higher the possibility of peak dv/dt and sharpness of dv/ dt that could increase the voltage at motor terminal to dangerous levels. It is important to optimize the voltage gradient dv/dt as per the motor insulation requirement while carefully designing the general-purpose industrial drive. To achieve this optimization, IGBT7 demonstrates the highest level of perfection in controlling the inverter's ability to change the dv/dt through adjustment of gate resistor (Rg).

When Rg in increased, both turn-on and turn-off dv/dt decrease, while turn-on dv/dt decreases significantly with Rgon in the optimum range, Rg value needs to be optimized to achieve the desired dv/dt < 5 kV/µs.

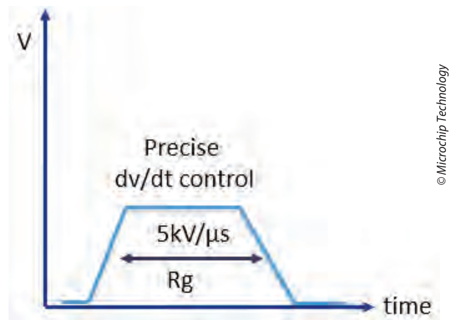


Figure 7 *Optimization of dv/dt with Rg using IGBT7.*

Microchip can provide the graph of Rg and relative dv/dt on special request for optimization of dv/dt which alleviates major design concerns for design and application engineers of Industrial motor drive.

SIMPLE AND HASSLE-FREE GATE DRIVING

CGE (Gate Emitter Capacitance) and CGC (Gate Collector capacitance) are balanced to give the IGBT7 full control over the dv/dt, and to optimize the switching waveform and CGE is designed to avoid parasitic turn-on effects, so zero voltage supply for turn-off is feasible (unipolar gate driver power supply).

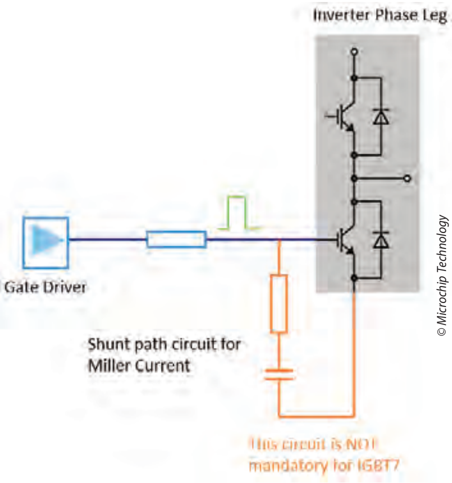


Figure 8 *IGBT7 Driver Circuit.*

HIGHER CURRENT CAPABILITY

The IGBT7 chip inherently has more current capability than the previous generation IGBT4. This results in higher output power for the given footprints, resulting in frame size jump, which implies a lower frame size can be used in lieu of bigger ones.

This also increases the overall power density as more power can be compressed in a given area, avoids paralleling of number of switches, reduces the complexity and improves reliability and durability. Higher power density reduces the power system Bill of Material (BoM) costs and offers faster time to market.

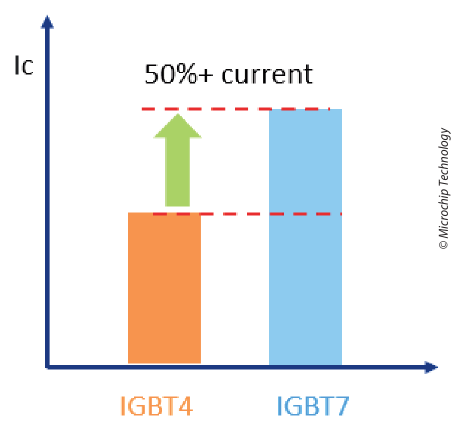


Figure 9

Frame Size jump with 50% higher current in same package.

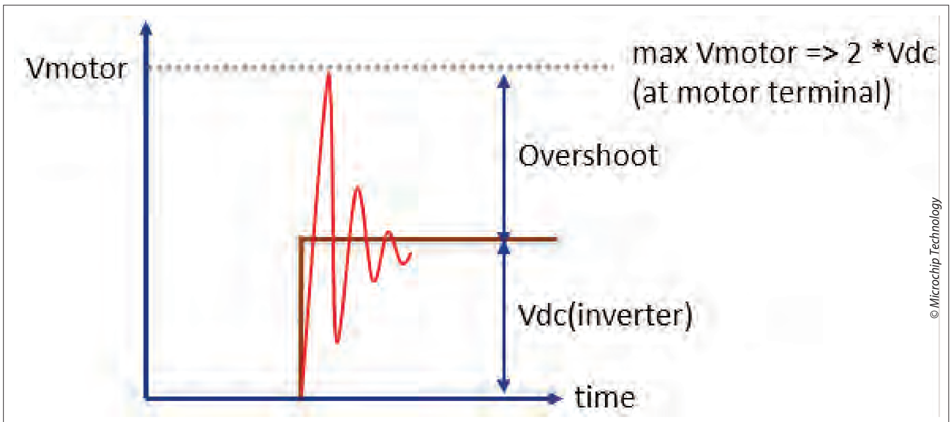


Figure 6 *Motor voltages at the motor terminal.*

LOWER INDUCTANCE AND LOWER PROFILE PACKAGES

Microchip's low parasitic inductance packages reduce the voltage overshoot enhancing the durability and reliability. Lower profile enables packing more power in less volume improving the power density when used with IGBT7 technology.

With lower overshoot voltage, it becomes relatively easier for the user to use 1200V modules for DC link up to 700 to 800V instead of 1700V provided overall inverter lay out is low inductive with sandwiched busbar. This saves considerable cost for not only modules but also gate driver board resulting in low-cost power system design. The IGBT7 features and its end user benefits makes these power modules versatile for multiple applications and megatrends from low to Mid switching frequency applications. The ease of use without complexity in gate drive mechanism makes the design hassle free and obviates the resources in designing new drivers. The multiple topologies can be readily used as a building blocks for converter of multiple applications providing design flexibility and faster time to market. IGBT7 power modules enable multiple applications such as solar, wind, motor drive, Energy Storage System (ESS), Commercial and Agricultural Vehicles (CAVs), data center, railways, E-mobility, transmission and distribution, and aviation with their versatility and provide great benefits to customers with power, precision and performance.

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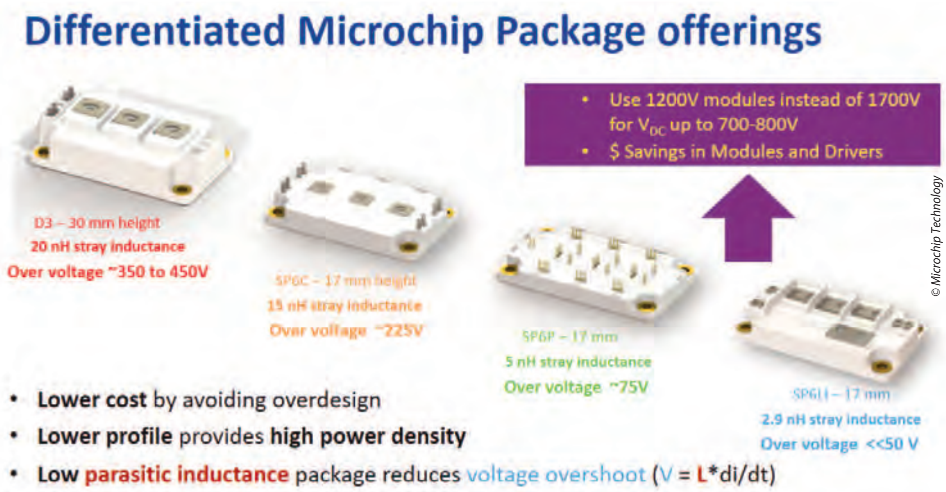

Figure 10 *Differentiated Microchip Packaging.*

Package	D3	SP6	SP6P	SP6LI
Height:	30mm	17mm	17mm	17mm
Stray inductance:	30nH	15nH	5nH	2.9nH
Voltage overshoot	~350 to 450V	~225V	~75V	~< 50V

Table 4

References
• https://www.fluke.com/en-us/learn/blog/power-quality/cable-length-vfd-motors
• https://www.nema.org/docs/default-source/standards-document-library/mg-1-part-31-watermark.pdf?sfvrsn=649fb42f_1
• Application Manual Power Semiconductors (Semikron)
• TRENCHSTOP™ 1200 V IGBT7 T7 Application Note (Infineon) (AN2018-14)
• Amit's Tech Corner, Microchip Aviation and Defense Newsletter Edition 23 Dec 2024

Figure 11 *Key IGBT7 applications.*

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How to secure tomorrow's data today

CYBERSECURITY IN THE QUANTUM AGE

From prevention to digital defense: Quantum computers are challenging today's encryption – and our digital security with it. Why Europol calls for action, how German semiconductor suppliers fit in and what your data has to do with my grandmother's wisdom.

Author:
Bernd Hantsche, Vice President Technology Competence Center, **Rutronik**

Doomsayers never rest. But what does it mean when even the advice of my conservative grandmother, who was shaped by the post-war era, to "make hay while the sun shines" now feels like a call for digital prevention. Because defense today is not about tanks – it is about protecting our data. The threat is real: Europol warns that organized networks are already collecting encrypted data today to decrypt it later with quantum computers for their own purposes [1]. The scenario is called "Store now, decrypt later".

Quantum computers are fundamentally rewriting the rules of cryptography. Algorithms like RSA (Rivest-Shamir-Adleman), upon which much of our digital communication is based, could soon be cracked by quantum computers. Post-quantum cryptography (PQC) offers the solution: Put simply, new cryptographic methods that will remain effective even against quantum computers.

IT IS TIME TO ACT: THE QUANTUM THREAT LOOMS

Quantum computing is advancing rapidly. From tech giants and universities to start-ups, everyone is striving to outshine with achievements. Meanwhile, security research is stepping up: The US National Institute of Standards and Technology (NIST) has already designated three algorithms as post-quantum standards: The Federal Information Processing Standards (FIPS) FIPS-203 (ML-KEM), 204 and 205 offer robust key exchange and digital signature mechanisms designed to resist attacks from quantum computers.
The Federal Office for Information Security (BSI) has also weighed in on "Q-Day" – the day quantum computers will be able to break conventional encryption for the first time. The BSI anticipates this to happen around 2030, coinciding with the full-scale production of today's electronic developments. Those who fail to prepare now risk deploying outdated security technology later on.
The Quantum Safe Financial Forum (QSFF), initiated by Europol, also pushes the financial sector, in particular, to use today's tools to defend against tomorrow's technology.

CHALLENGES OF TRANSITIONING TO POST-QUANTUM CRYPTOGRAPHY

Clear though the goal may be, the road to it is anything but easy. Bigger keys and more complex algorithms demand greater processing power – a particular strain on legacy systems.

Moreover, since standardization has not yet been fully completed, the algorithms in use may yet change.

And from an organizational standpoint, the transition is far from easy – it requires investment, new mindsets and technical expertise. The key to success therefore lies in what is known as crypto-agility: From the start, systems need to be designed for flexibility, enabling rapid response to emerging findings or threats.

THE FIRST STEPS TOWARD A SECURE IT INFRASTRUCTURE IN THE QUANTUM AGE

Despite these challenges, initial practical implementations show that the transition to post-quantum cryptography is already underway: Infineon, Rutronik's largest franchise partner, established itself early on as a PQC pioneer. Quantum-resistant key exchange was first implemented on a contactless chip back in 2017 [2].

At the beginning of 2025, the BSI awarded the world's first EAL6 certification to a security controller featuring ML-KEM technology [3]. Infineon, therefore, focuses particularly on smart card applications.

Other German semiconductor suppliers are also driving development forward. Elmos Semiconductor, together with ID Quantique, is introducing a key PQC component: a miniaturized quantum random number generator (QRNG).

All encryption methods start with a random number to generate the key. However, a discrete, logical device struggles to generate genuinely random numbers.

HRNGs, or hardware random number generators, have existed for a long time and are available in various technical designs.

Conventional generators (TRNGs/PRNGs) are susceptible to manipulation – through physical factors such as light, pressure, temperature, electromagnetic fields or supply voltage, as well as through targeted interventions using artificial intelligence.

QRNGs use genuine quantum effects, like photon emission, to generate truly random numbers. This method is more secure and provides additional hardening for FIPS 203, 204, and 205 compared to keys with conventionally generated numbers.
At present, such QRNGs are best known as server expansion cards. Elmos has now miniaturized the technology into a compact 2×2 mm DFN package (Figure 1).

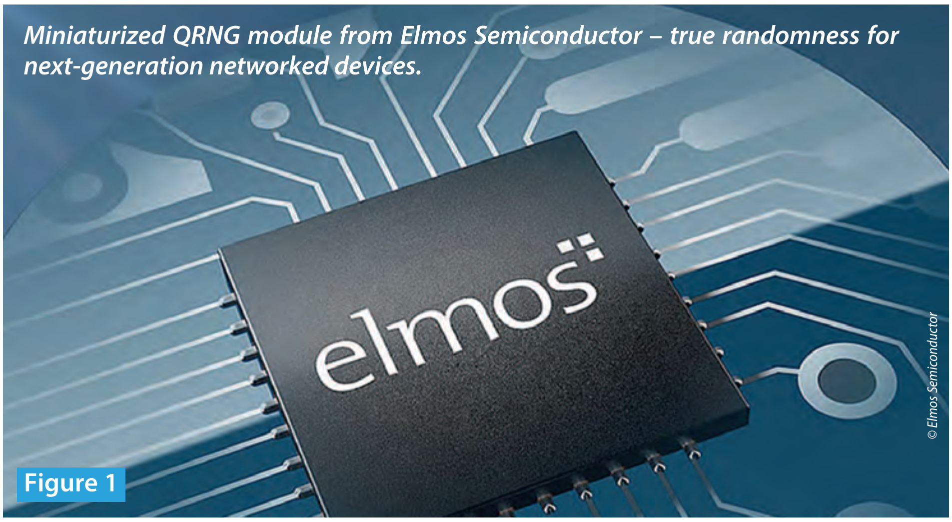
As a result, Rutronik makes the patented technology available to customers worldwide. Not only the financial sector but also the industrial, medical and automotive sectors are gaining benefits.

SAFETY IS A DUTY, NOT A LUXURY

Since: It is no longer just about banks. Whether industrial plants, medical devices or vehicles with assistance systems – our world is digital, networked and therefore at risk.

What if vehicle assistance systems suddenly misinterpret traffic signs, or if cars can be unlocked via ultra-wideband technology and rolling key methods because the key was predictable? Or if medical data is intercepted because the random number generator was not genuine?

The quantum revolution is coming. Perhaps not tomorrow, but certainly sooner than most expect. Those who do not invest today will pay tomorrow.



Miniaturized QRNG module from Elmos Semiconductor – true randomness for next-generation networked devices.

Figure 1

As my late grandmother would have wisely said: "Encrypt your data sensibly today, and you will be safe from tomorrow's quantum cyberattacks."

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Digression: Random is not always random

TRNG, PRNG, QRNG – these acronyms denote different methods for generating cryptographically essential random numbers. PRNGs (pseudo random number generators) generate numbers through deterministic processes that can be reproduced with sufficient knowledge. TRNGs (true random number generators) use physical processes but are not fully tamper proof. Only QRNGs (quantum random number generators) deliver truly unpredictable random numbers, as they are based on quantum physical effects like single-photon emission – a key security advantage for tomorrow's cryptography.

The terms at a glance

***Q-day** – The point in time when quantum computers can crack current encryption systems. The BSI expects this to happen around 2030.*

***QRNG vs. TRNG** – Quantum random number generators produce genuine, non-manipulable random numbers based on quantum physical processes. TRNGs use physical effects but are potentially susceptible to interference.*

***FIPS-203/204/205** – Security standards for quantum-secure algorithms (key exchange and digital signatures) published by NIST as the foundation for post-quantum cryptography.*

***ML-KEM** (Module Lattice Key Encapsulation Mechanism) is a key encapsulation mechanism (KEM) standardized by NIST under FIPS 203. It enables two parties to establish a shared secret key that is resistant to conventional and quantum computer attacks.*

Sources

1) www.europol.europa.eu/media-press/newsroom/news/call-for-action-urgent-plan-needed-to-transition-to-post-quantum-cryptography-together
2) www.infineon.com/cms/en/product/promopages/post-quantum-cryptography
3) www.infineon.com/cms/de/about-infineon/press/press-releases/2025/INFCSS202501-043.html#_ftnref1

Toward Smarter Digital Predistortion Engines:

A NEURAL NETWORK-BASED APPROACH

This article addresses the challenges of signal distortion and energy inefficiency in power amplifiers (PAs) for next-generation wireless communication by introducing an AI-driven digital predistortion (DPD) framework. Traditional polynomial-based DPD methods struggle with computational complexity and limited adaptability to nonlinearities and memory effects. Leveraging advanced neural network architectures, the proposed system dynamically optimizes predistortion, outperforming traditional approaches in efficiency, adaptability, and real-time correction. Despite challenges such as model interpretability and energy consumption, the framework offers scalable and energy-efficient solutions, marking a significant advancement in RF transmitter design for modern communication networks.

Author:
Hamed M. Sanogo, Principal Engineer and End Market Specialist, **Analog Devices**

INTRODUCTION

Launched by OpenAI in November 2022, ChatGPT became one of the fastest-adopted software products, showcasing the potential of artificial intelligence (AI). Machine learning (ML), a subset of AI, is transforming industries by enabling tasks such as decision-making and data analysis.

In communications, AI and ML are advancing digital predistortion (DPD), a technique critical for reducing signal distortion and improving power amplifier (PA) efficiency. Traditional DPD models may struggle with nonlinearities and memory effects in modern communication systems like 5G. They assume that the PA's behavior is static and memoryless, relying on polynomial models that only account for instantaneous input-output relationships. AI and ML, however, excel at learning complex patterns, offering more precise solutions.

This article introduces an artificial neural network-based DPD framework that leverages PA data to reduce gain/phase errors, enhance efficiency, and improve spectral performance, surpassing traditional methods.

ENHANCING PA EFFICIENCY: DIGITAL PREDISTORTION MEETS AI INNOVATION

Digital predistortion is a critical technique enabling power amplifiers to operate efficiently near the saturation region without compromising linearity. By extending the PA's linear operating range, DPD allows radio frequency (RF) designers to leverage the efficiency of a nonlinear PA while maintaining the transmit signal linearity required for complex modulation schemes like orthogonal frequency division multiplexing (OFDM).

At its core, DPD works by introducing predistorter coefficients derived from modeling the inverse amplitude-to-amplitude (AM-to-AM) and amplitude-to-phase (AM-to-PM) characteristics of the PA.
This process effectively compensates for the PA's nonlinearities by introducing precise antidistortion into the input waveform. Consequently, DPD improves signal quality while allowing the PA to operate at peak efficiency.
A detailed discussion about DPD algorithms and how ADI's ADRV9040 RF transceiver provides a streamlined hardware platform for designing and implementing it is presented in the article "Simplifying Your 5G Base Transceiver Station Transmitter Line-Up, Design, and Evaluation." Figure 1 illustrates the DPD concept for linearizing a PA response.
Power amplifiers exhibit nonlinearities near saturation, causing signal distortion, spectral regrowth, and reduced efficiency, especially in high bandwidth systems with impairments like I/Q imbalance and memory effects. AI and ML, particularly neural networks (NNs), offer a transformative solution by modeling PA distortions and dynamically optimizing predistortion. This AI-driven approach improves efficiency and adaptability, surpassing traditional methods while balancing performance and computational complexity.

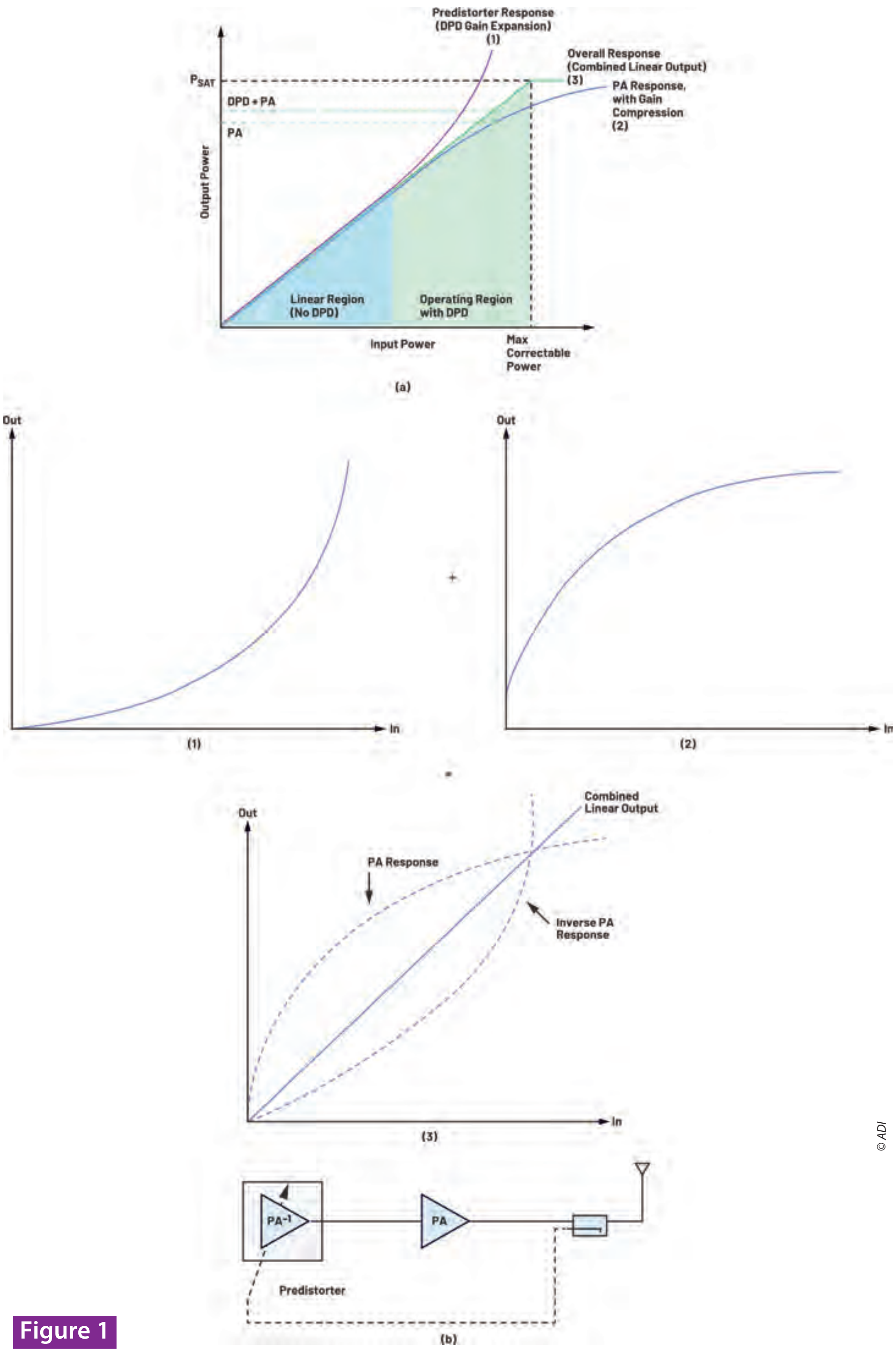


Figure 1

Generic concept of DPD for linearizing the PA response: (a) typical AM-to-AM curve showing the overall linear region is in green; (b) basic concept of DPD and how it improves power amplifier efficiency.

OPTIMIZING DPD ENGINES WITH NEURAL NETWORK MODELS: A PROPOSED GAME-CHANGER FRAMEWORK

Artificial NNs are a cornerstone of artificial intelligence, particularly in deep learning, designed to overcome the limitations of traditional machine learning algorithms. Inspired by the human brain's ability to process information, NNs excel at identifying patterns, learning, and making decisions, making them ideal for addressing complex, nonlinear problems.
For example, in 5G LTE systems, challenges such as I/Q imbalance, phase shifts, DC offsets, crosstalk, and PA nonlinearity can be addressed effectively using an NN-based DPD approach.

Unlike polynomial-based DPD solutions, which require extensive knowledge of system mechanics and struggle with scalability, NN models excel at handling complex nonlinear behaviors with fewer constraints. This section introduces a proposed NN DPD framework to mitigate nonlinearities and transmitter impairments. The process involves three key steps: characterizing the PA and collecting extensive data, training a post-distorter neural network model, and deploying the model with performance monitoring and adjustments.

By leveraging machine learning, this approach transforms large datasets into actionable insights, enabling robust, scalable solutions for modern communication challenges.

Step 1: PA Characterization Data Collection

To design and implement AI/ML models for optimizing wireless power amplifiers, it is crucial to collect comprehensive, high quality characterization data that accurately reflects the PA's real-world performance under diverse conditions. Figure 2 shows an example setup that one might use for a PA characterization data collection effort.

The bench configuration presented in Figure 2 allows for complete characterization by extracting parameters like S-parameters, delivered power, power-added efficiency (PAE), input impedance, input return loss, power gain, AM-to-PM conversion, and others. Table 1 presents a comprehensive list of data points for input into the model. However, it is important to note that the model's dimensionality impacts its response time.

Additionally, the captured data must be digitized before it can be utilized in the training process. This rigorous and systematic approach to data collection forms the foundation for developing AI/ML models capable of accurately predicting and optimizing PA performance.

By leveraging this comprehensive dataset, designers can achieve reliable and efficient wireless communication systems.

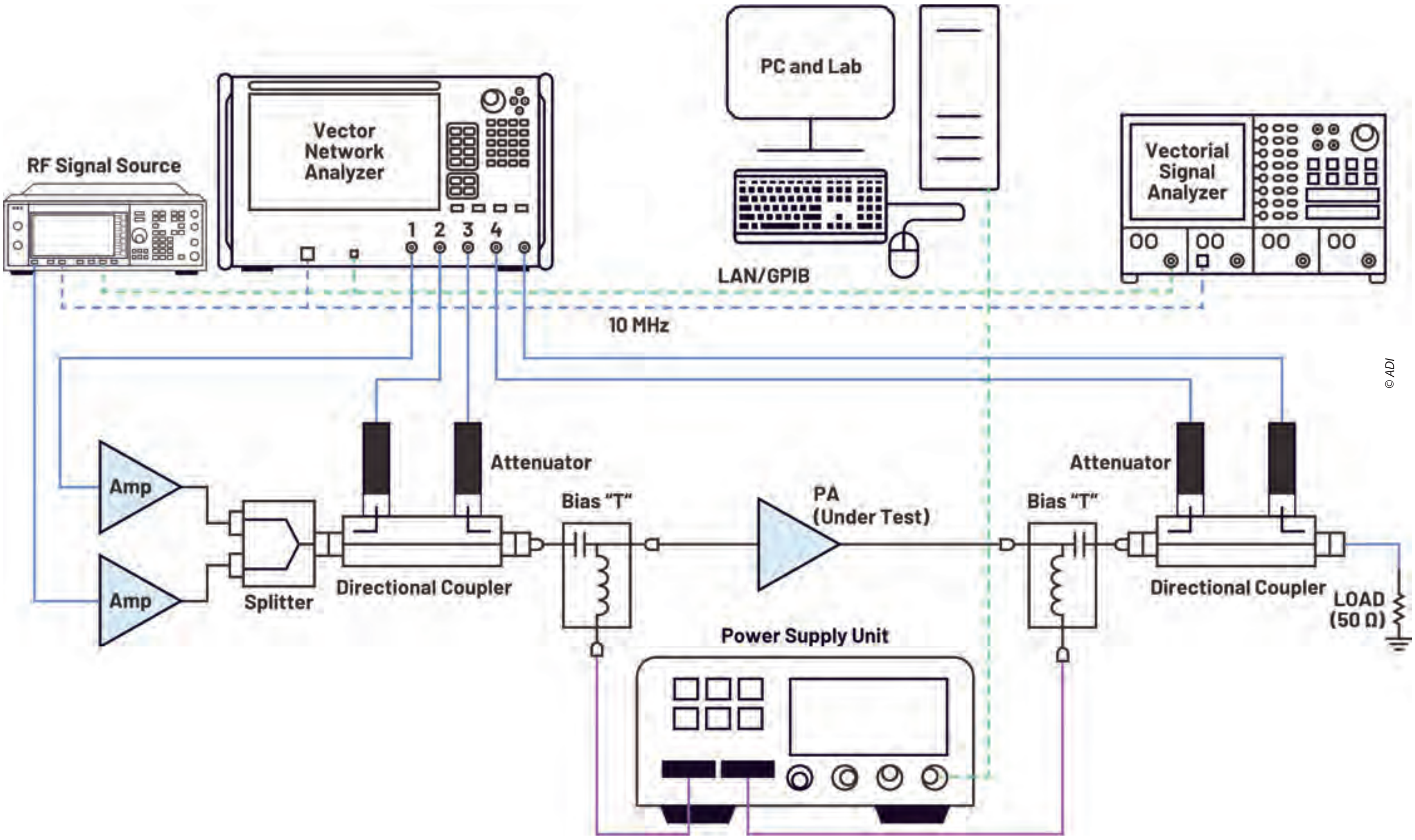


Figure 2 *Measurement setup for wideband PA characterization.*

Areas	Description and Details
Small Signal Characterization	Collect small signal characterization using S-parameters measured with a vector network analyzer across the desired frequency range and under varying biasing conditions. These parameters offer insights into input/output matching and the frequency response of the PA.
Nonlinear Behavior and Large Signal Data	Collect measurement of nonlinear characteristics under large signal operation. This includes collecting data on input-output power relationships (PIN vs. POUT), power-added efficiency, and gain compression points (for example, P1dB). Capturing AM-to-AM and AM-to-PM distortion data is particularly valuable for understanding the PA's behavior under high power levels.
Efficiency Metrics	Collect efficiency data (including drain and overall efficiency, measured across various load conditions, input power levels, and frequencies) and operating temperatures.
Linearity and Signal Integrity	Collect linearity metrics, such as adjacent channel power ratio (ACPR), error vector magnitude (EVM), and intermodulation distortion (IMD).
Thermal Performance	Collect thermal performance data obtained using thermal sensors. This provides insights into heat dissipation and PA reliability under varying power levels and ambient conditions.
Environmental and Aging Data	Collect data on environmental conditions (such as temperature and humidity variations) and accelerated aging tests help predict long-term performance and reliability.
Noise Characteristics	Noise performance, characterized by metrics like noise figure and phase noise spectrum, adds critical information on signal integrity.

Table 1: **List of Measurement Areas and Descriptions**

Core Components	Description and Details
Input Layer	The input I/Q components, denoted as $I_{IN}(n)$ and $Q_{IN}(n)$, form the minimum requirements for the model. Additional independent variables, such as P_{IN}/P_{OUT} data and AM-to-AM/AM-to-PM measurements, are outlined in Table 1. Although the neural network DPD model can be trained using all the input variables listed in Table 1, incorporating a larger number of dependent variables increases the model's dimensionality and computational demands. This added complexity results in more weights and biases to train, leading to longer training and inference times, as well as greater memory requirements for storing the model and processing intermediate computations.
Hidden Layers	The layer(s) that exists between the input layer and the output layer. Each neuron takes inputs from the previous layer, applies a weighted sum, adds a bias term, and passes the result through an activation function. ML engineers can experiment with different activation functions and select the most suitable based on their environment and results.
Output Layer	The final layer that provides the network's predictions. This layer translates the high-level features learned by the hidden layers into meaningful predictions. Figure 2 shows a multiclass scenario with two nodes consisting of two neurons with a linear activation function, which maps the outputs to weights and coefficients to be used by the DPD actuator block shown in Figure 4. These outputs are either directly interpreted or further processed.
Weights	Weights represent the strength or importance of the connection between two neurons in adjacent layers. A weight determines how much influence the output of a neuron in one layer has on the input to a neuron in the next layer.
Bias	A bias is an additional parameter added to the weighted sum of inputs to a neuron. It allows the activation function to shift, enabling the network to model more complex relationships.
Activation Function	This function introduces nonlinearity to the model, allowing it to learn and represent complex patterns and relationships in the data. Common activation functions include ReLU (rectified linear unit), sigmoid, tanh, and softmax.

Table 2: **Neural Network Core Components and Descriptions**

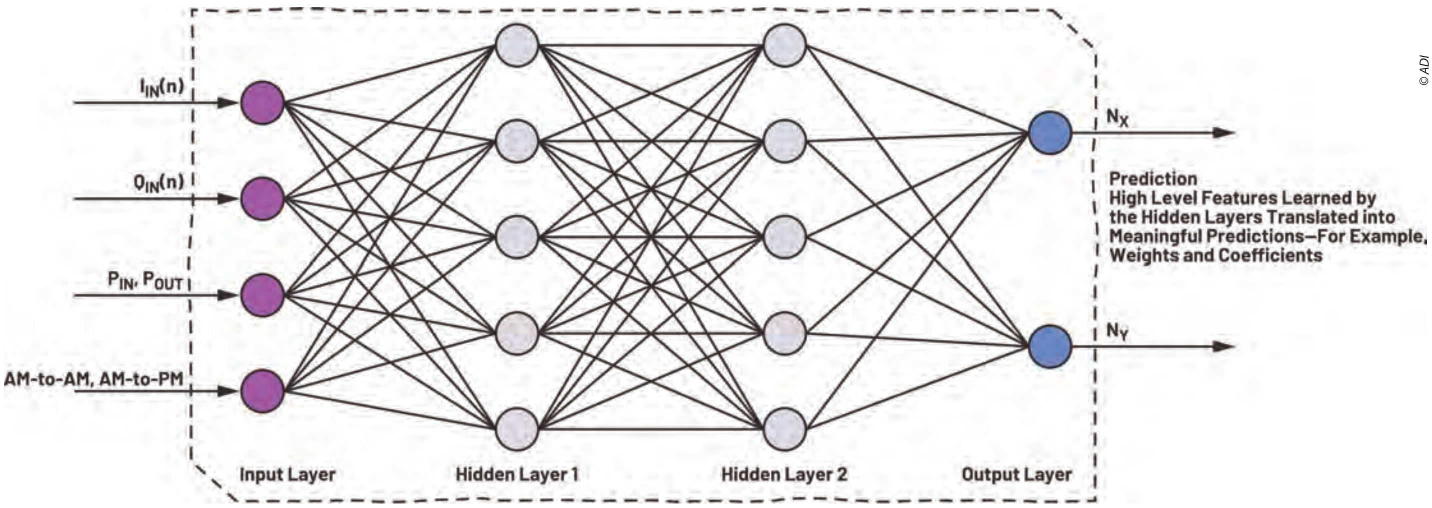


Figure 3 *Architecture of a multiclass prediction neural network in deep learning.*

Step 2: Model Training

The model training process involves feeding (a few or all) the signals collected in Table 1 into this system and optimizing the DPD model to minimize error via a loss function. The neural network architecture consists of interconnected layers of nodes (for example, artificial neurons), organized into the main core components shown in Figure 3. During training, hidden layers propagate data forward while weights and biases are optimized via backpropagation using gradient descent.

The network structure can be adjusted to include more neurons for highly nonlinear components or fewer neurons for smoother elements. While an in-depth discussion of the best AI hardware, software, and tools for creating an effective and scalable AI model training environment is beyond the scope of this article, we recommend that AI engineers explore KNIME, a no-code platform for data analytics and machine learning. KNIME features a graphical user interface (GUI) that enables users to design workflows by simply dragging and dropping nodes, eliminating the need for extensive coding knowledge. These workflows are highly visual and easy to understand, making the platform accessible to a broad audience. For those who prefer a Python-based approach, Keras with TensorFlow® offers significant advantages. This combination merges the simplicity of Keras with the robustness and scalability of TensorFlow, making it an excellent choice for projects ranging from experimentation to production-grade deep learning applications.

In the PA characterization effort, millions of samples will be collected, with 70% to be used for training and 30% reserved for testing and validation to assess the model's ability to mimic the PA's behavior. Model performance will be evaluated using metrics such as accuracy, precision, recall, F1 score, and ROC-AUC.

Step 3: Neural Network Model Validation and Deployment

The deployment process begins with validating the model to ensure robustness and accuracy, using validation data to monitor quality during training and stopping criteria, while test data independently evaluates accuracy and generalization.

Addressing overfitting and underfitting is crucial to ensure the model generalizes well to new data. Overfitting is mitigated by limiting the number of layers, hidden neurons, or parameters to simplify the model, by expanding the training dataset, or even by pruning (for example, removing redundant neurons that do not contribute significantly to performance) to enhance generalization.

On the other hand, mitigating underfitting is addressed by increasing hidden neurons to boost model complexity, by adjusting hyperparameters such as learning rate, batch size, or regularization strength to improve performance.

The ML engineer must balance these strategies and iteratively evaluate the DPD model's performance to achieve a robust and generalizable model while keeping an eye on the execution speed of the model. Figure 4 illustrates the high level block diagram of the neural network DPD model evaluation system's architecture.

In any event, determining the optimal number of hidden neurons requires empirical studies, trial and error, or adaptive methods during training. These adjustments ensure the NN achieves an appropriate balance between complexity and performance, enabling efficient and effective model deployment. Deployment of the model could be facilitated by an edge-AI embedded MCU such as ADI's MAX78000 convolutional neural network accelerator chip.

INTEGRATING AI/ML WITH DPD SYSTEMS: CHALLENGES AND OPPORTUNITIES

Integrating AI and ML into DPD systems offers significant potential for improvement but also introduces practical challenges. DPD systems require low latency and high processing speeds, which can be difficult to achieve with computationally intensive ML models. Additionally, dynamic operating conditions, such as temperature fluctuations and hardware aging, necessitate adaptive techniques like real-time learning or transfer learning to maintain optimal performance. Energy efficiency is another critical factor, as AI/ML models, particularly deep learning architectures, often consume more power than traditional DPD methods, making them less suitable for energy-sensitive environments. Future experimentations should be conducted with lightweight neural networks, which are optimized versions of standard neural networks. These lightweight NNs are designed to have fewer parameters, require less computation, and are memory efficient. They are particularly useful for applications where computational resources are limited, such as mobile

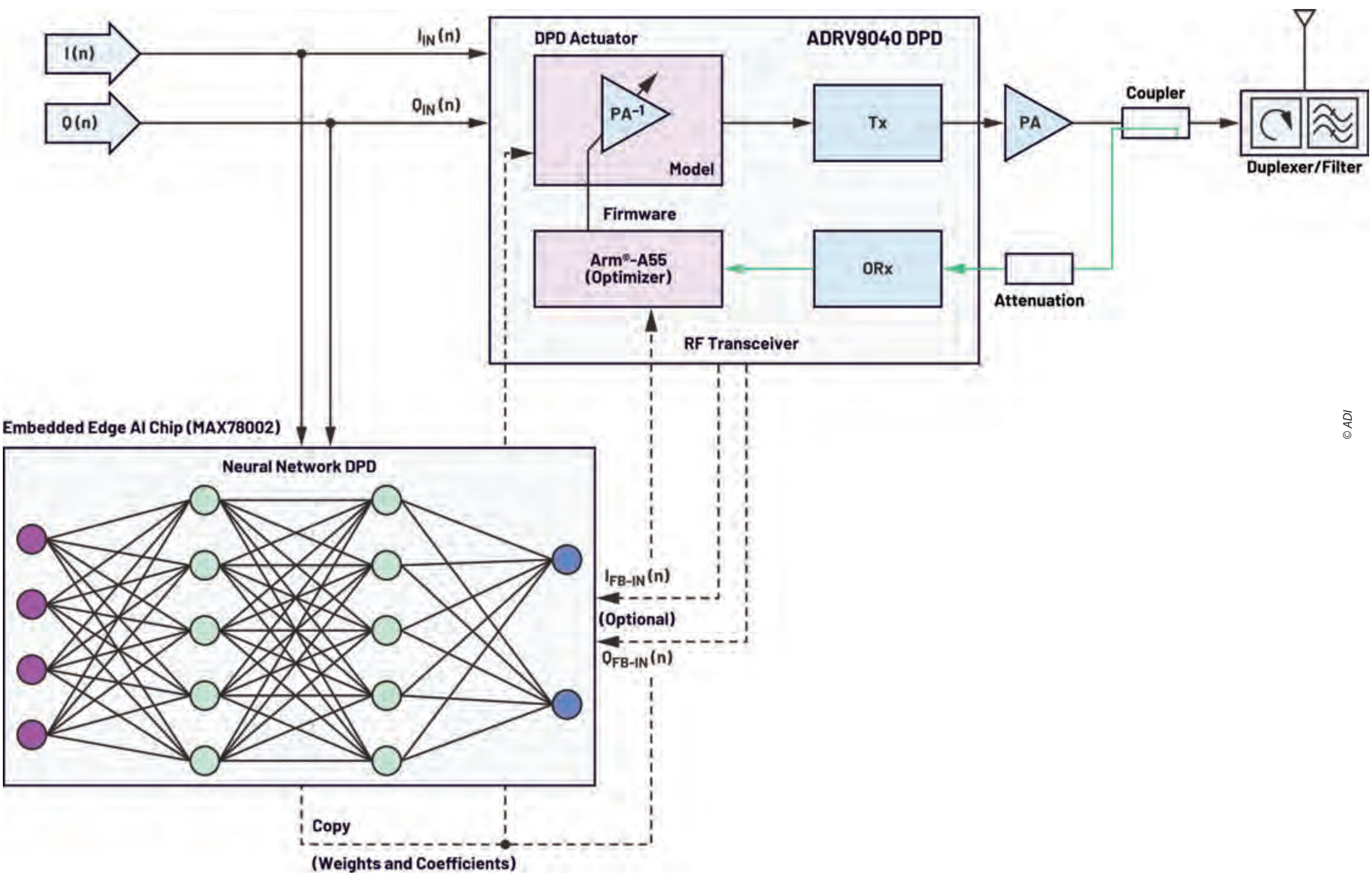


Figure 4 *A block diagram of the neural network DPD model evaluation platform.*

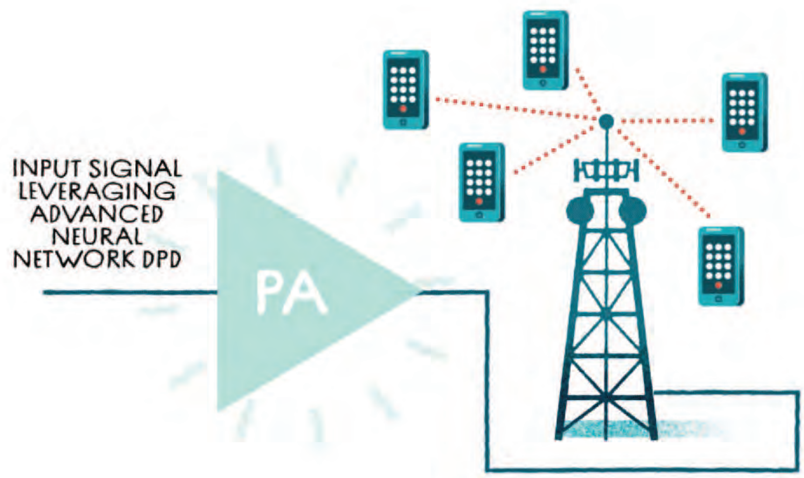
and IoT devices or other resource-limited systems. The lack of interpretability in many ML models, especially deep neural networks, further complicates their integration with DPD systems. Debugging and optimization are challenging when decision-making processes are opaque, as these models reduce complex operations to weights, biases, and activation functions.

CONCLUSION

As 5G technologies like massive MIMO demand lower power and greater precision, DPD systems must evolve to address new complexities. AI/ML will be instrumental in enabling scalable, energy-efficient solutions through innovations such as adaptive learning and hybrid modeling.

Neural networks, with their ability to model complex nonlinearities and memory effects, simplify DPD system design by approximating nonlinear functions without explicit mathematical formulations.

The integration of AI/ML enhances power efficiency, allowing PAs to operate closer to saturation while reducing costs with nonlinear PAs. Despite the challenges, AI/ML-driven systems hold great promise for enhancing the accuracy, adaptability, and scalability of DPD systems.
Hybrid approaches that combine traditional polynomial-based methods with AI/ML techniques offer a balanced solution, merging the interpretability of classical models with the advanced capabilities of AI/ML.



By addressing these challenges through innovative strategies, AI/ML can drive transformative advancements in DPD systems, supporting the evolution of modern communication technologies.

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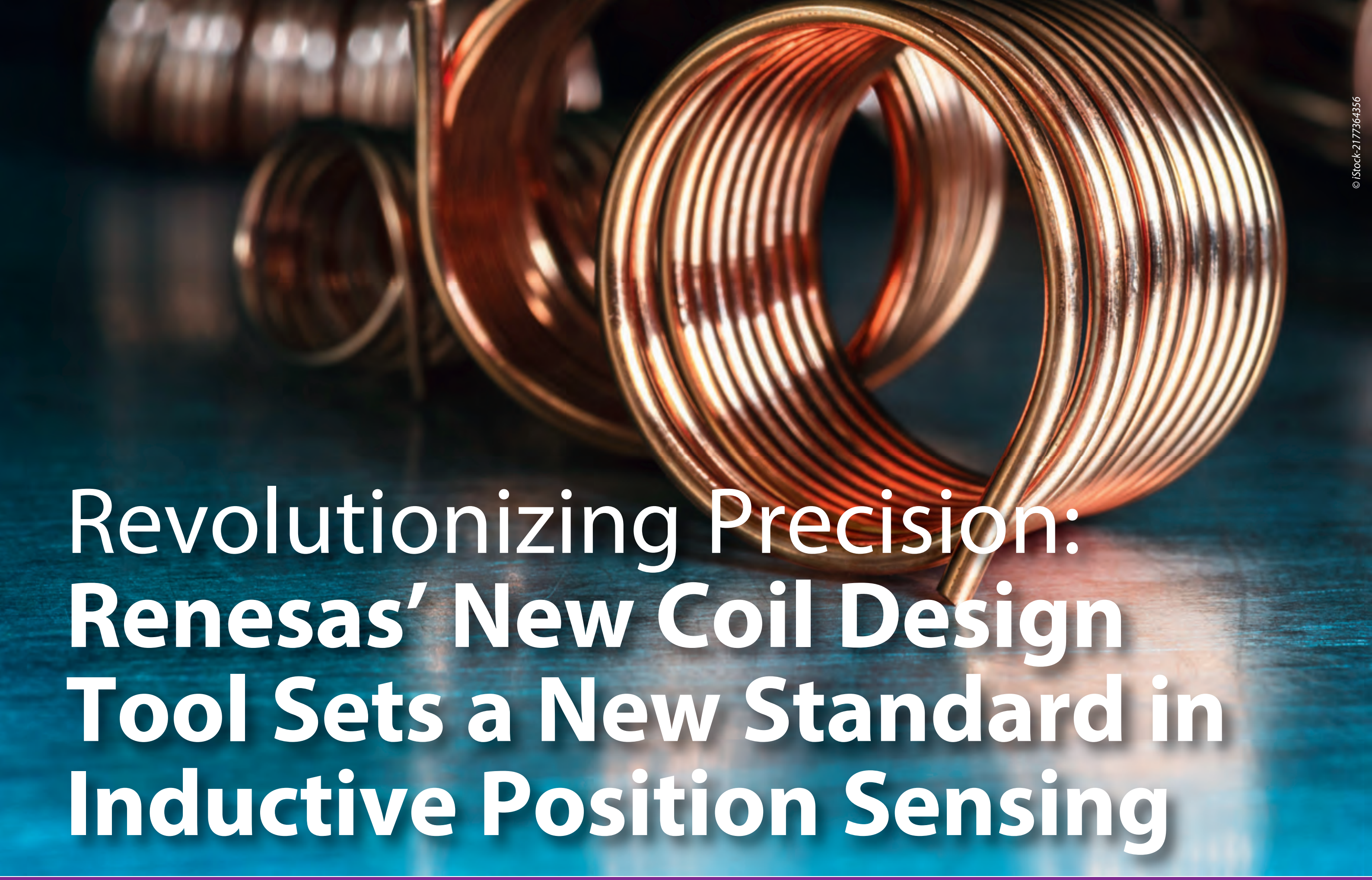
About the author:

Hamed M. Sanogo is a seasoned principal engineer in the Customer Solutions Group (CSG) at ADI, specializing in aerospace, defense, communications, and data centers. With nearly two decades at ADI, he has held diverse roles, including FAE/FAE manager, product line manager for Secure RFID & Authenticators, and his current position as an end market specialist driving cutting-edge solutions in critical industries. Hamed's expertise is built on a strong foundation – earning his M.S.E.E. from the University of Michigan-Dearborn and an M.B.A. from the University of Dallas. Before joining ADI, he was a senior design engineer at General Motors and a senior staff electrical engineer at Motorola Solutions, where he led the design of Node-B and RRU baseband cards. With a passion for innovation and problem-solving, Hamed continues to shape industry advancements at ADI.



Revolutionizing Precision: **Renesas' New Coil Design Tool Sets a New Standard in Inductive Position Sensing**

THE RISE OF INDUCTIVE TECHNOLOGY IN POSITION SENSING

In the ever-evolving landscape of position sensing technologies, inductive sensing has emerged as a robust, accurate, and cost-effective alternative to traditional magnetic and optical methods. Unlike magnetic sensors that rely on permanent magnets or optical encoders that require clean environments and precise alignment, inductive sensors operate on the principle of electromagnetic coupling between coils and metallic targets. This magnet-free approach offers immunity to stray fields, tolerance to misalignment, and durability in harsh environments – making it ideal for both automotive and industrial applications.

Author:
Ruggero Leoncavallo, Director of Inductive Position Sensors, **Renesas Electronics**

Renesas Electronics, a global leader in semiconductor solutions, has been at the forefront of this transformation. Their latest innovation – the Renesas Position Sensor Coil Optimizer – is a game-changer for engineers seeking to design, simulate, and optimize inductive sensing elements with unprecedented precision and ease.

HOW INDUCTIVE POSITION SENSING WORK

Inductive position sensing works by generating an alternating magnetic field through transmitter coils and detecting the induced voltages in receiver coils as a conductive target moves across them.

The pattern of induced signals corresponds to the target's position. For high-precision applications, especially those requiring absolute position feedback and fine resolution, a **dual receiver coil system** is essential.

This configuration enables techniques like Vernier interpolation, where two receiver coils with slightly different geometries produce overlapping signals that can be mathematically combined to achieve ultra-fine angular or linear resolution.

The dual coil setup not only enhances accuracy but also allows for absolute position detection without the need for homing routines.

WHY INDUCTIVE TECHNOLOGY OUTPERFORMS MAGNETIC AND OPTICAL ALTERNATIVES

Inductive position sensors offer several compelling advantages:

- **Stray Field Immunity**

Unlike magnetic sensors, inductive sensors are inherently immune to external magnetic interference, ensuring stable performance even in electromagnetically noisy environments.

- **No Tight Assembly Required**

Optical sensors often demand precise alignment and clean conditions. Inductive sensors, by contrast, tolerate mechanical misalignment and contamination, reducing manufacturing complexity.

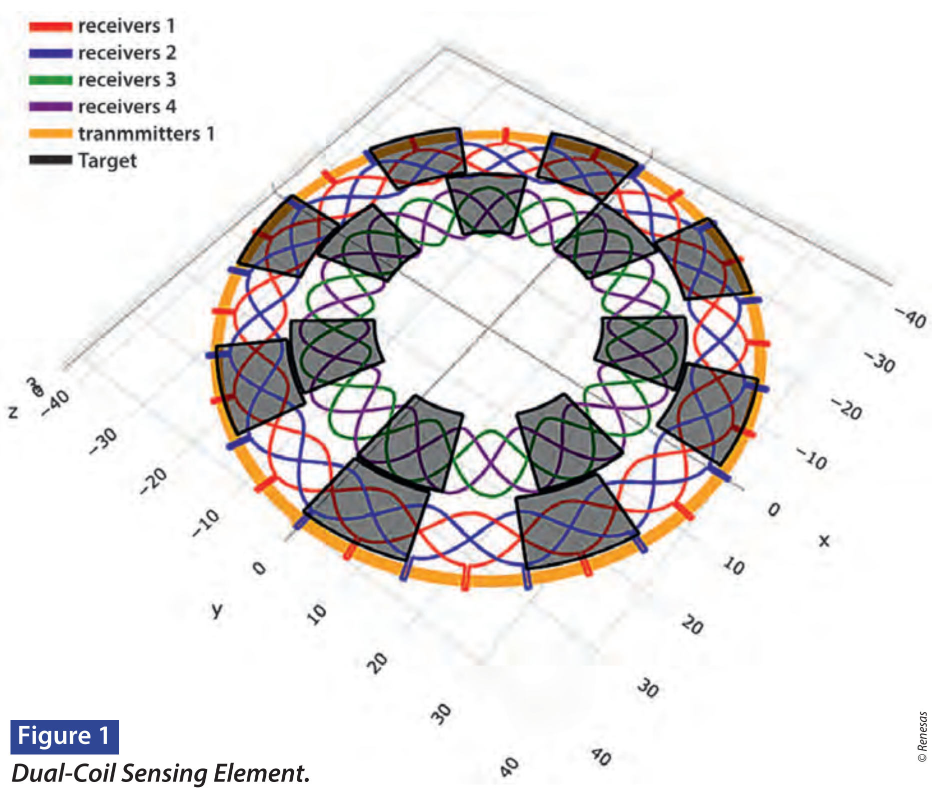


Figure 1

Dual-Coil Sensing Element.

- **Cost Efficiency**

Inductive sensors eliminate the need for expensive magnets and optical components, lowering the bill of materials (BOM) while maintaining high performance

- **Durability**

With no moving parts and robust PCB-based coil designs, inductive sensors excel in environments with vibration, dust, moisture, and temperature extremes

These attributes make inductive technology particularly attractive for applications where reliability, accuracy, and cost are critical.

APPLICATIONS ACROSS AUTOMOTIVE AND INDUSTRIAL DOMAINS

Renesas' inductive position sensors are already deployed across a wide range of applications:

– **Automotive**: From steering-by-wire systems to motor commutation and resolver replacements, inductive sensors offer high-speed, high-accuracy feedback with ISO26262 compliance for functional safety

– **Industrial**: In robotics, automation, and factory equipment, inductive sensors provide precise angular and linear measurements, enabling closed-loop control and predictive maintenance

While automotive applications benefit from the robustness and safety features, it is in industrial settings – particularly robotics and precision machinery – where the technology truly shines.

INDUSTRIAL PRECISION: MEETING THE DEMANDS OF HIGH ACCURACY AND RESOLUTION

Industrial applications often demand ultra-precise measurements, especially in robotics, CNC machines, and semiconductor equipment. Renesas' latest inductive IC, the **RAA2P3226**, is designed to meet these exacting standards. This dual-coil inductive sensor supports configurations such as **Vernier mode**, which combines two coil systems with slightly different pole pair counts (N and N-1). This setup enables:

- **Absolute Position Sensing**

The Vernier principle allows the sensor to determine position over multiple periods, eliminating the need for homing routines.

- **High Resolution and Accuracy**

The RAA2P3226 achieves up to **19-bit resolution** and **15-bit accuracy**, making it suitable for applications requiring sub-degree precision.

This dual-coil capability is particularly impactful in industrial robotics, where angular measurements with **accuracy up to 0.01°** are now achievable.

THE SENSING ELEMENT: A CRITICAL COMPONENT IN INDUCTIVE DESIGN

At the heart of every inductive position sensor lies the **sensing element** – a set of transmitter and receiver coils etched into a PCB. The geometry, spacing, and layout of these coils directly influence the sensor's performance.

Designing this element is a complex task. Engineers must consider:

– **Coil Geometry**: The shape and size of the coils affect inductance, signal strength, and resolution.

– **Mechanical Displacement**: The sensor must maintain accuracy across the full range of motion.

– **Performance Optimization**: Factors such as air gap, material properties, and environmental conditions must be accounted for.

Until now, this process required extensive simulation, manual tuning, and iterative prototyping.

ENTER THE RENESAS COIL DESIGN TOOL: AUTOMATING EXCELLENCE

Renesas' new **Inductive Coil Design Tool (ICDT)** revolutionizes this process. Built on a flexible, template-based architecture, the tool enables users to:

– **Design**: Choose from rotary, arc, or linear motion templates, and configure single, dual, or redundant coil setups.

– **Simulate**: Run real-time simulations with 3D visualizations, inductance estimations, and predicted signal voltages using machine learning models.

– **Optimize**: Automatically generate performance-optimized coil layouts, including Gerber files for PCB manufacturing.

The tool supports configurations such as:

– **Single Coil**: Simple and cost-effective for basic sensing.

– **Dual Coil**: High-resolution and absolute position sensing.

– **Redundant Coil**: Galvanically isolated systems for safety-critical applications.

RENESAS' NEW COIL DESIGN TOOL

Each user receives a dedicated workspace via MyRenesas, allowing them to track simulations, review results, and download files seamlessly.

IMPACT ON ROBOTICS: SETTING A NEW BENCHMARK

In robotics, precision is paramount. Whether it's joint angle feedback, motor commutation, or end-effector positioning, even minor inaccuracies can lead to performance degradation or safety risks.

With Renesas' dual-coil inductive sensors and the ICDT, engineers can now achieve:

- **Ultra-Precise Angular Measurements**
Accuracy up to **0.01°**, enabling fine-grained control in robotic arms and autonomous systems.

- **Compact Integration**
PCB-based coils allow for slim, integrated designs that fit within tight mechanical envelopes.

- **Robust Operation**
Immunity to dust, moisture, and vibration ensures reliable performance in industrial environments.

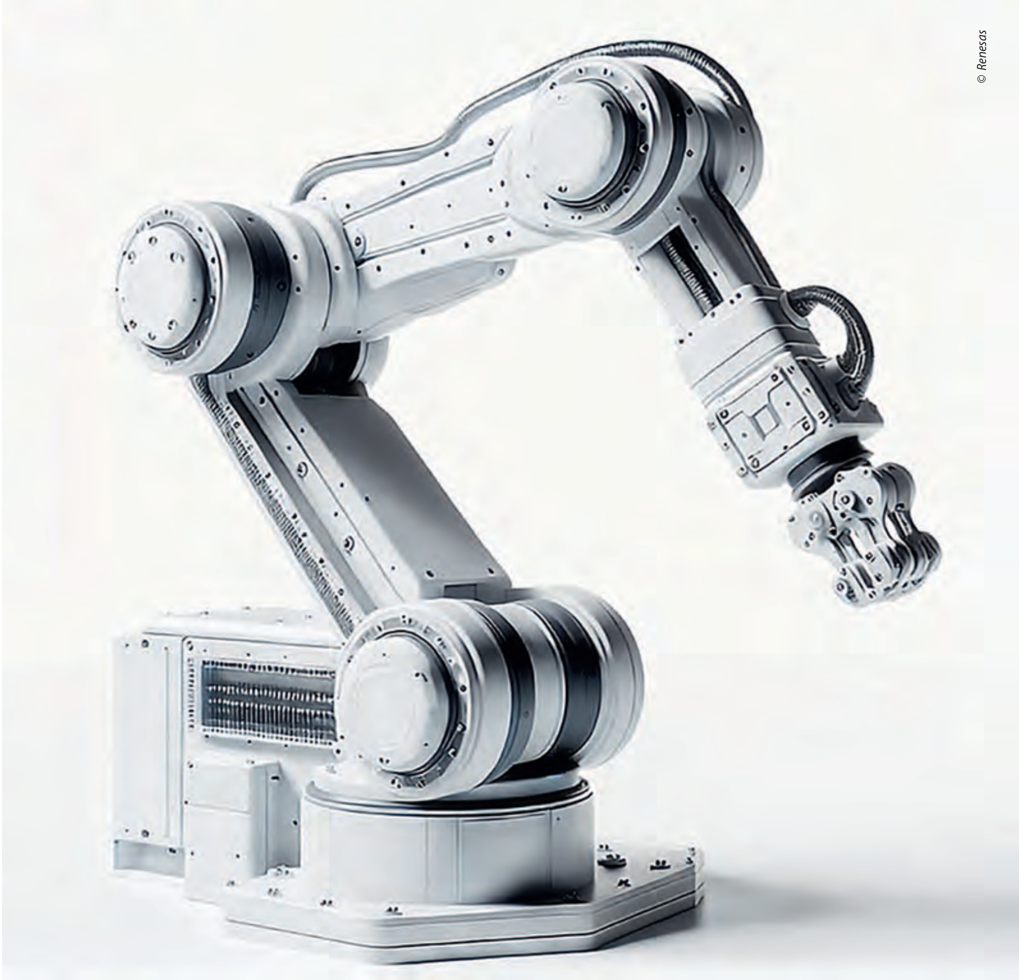


Figure 2 *Robotics as next revolution.*

This combination sets a new standard in inductive position sensing, empowering robotics engineers to push the boundaries of automation.

RENESAS PUSHING THE BOUNDARIES IN INDUCTIVE POSITION SENSING

Renesas' new coil design tool marks a significant milestone in the evolution of inductive position sensing. By automating the design, simulation, and optimization of sensing elements, it removes barriers to adoption and accelerates innovation.

Whether you're designing a robotic joint, an industrial actuator, or a safety-critical automotive system, Renesas offers the precision, flexibility, and reliability needed to succeed.

As industries continue to demand smarter, safer, and more efficient systems, tools like Renesas' coil design tool will play a pivotal role in shaping the future of sensing technology.

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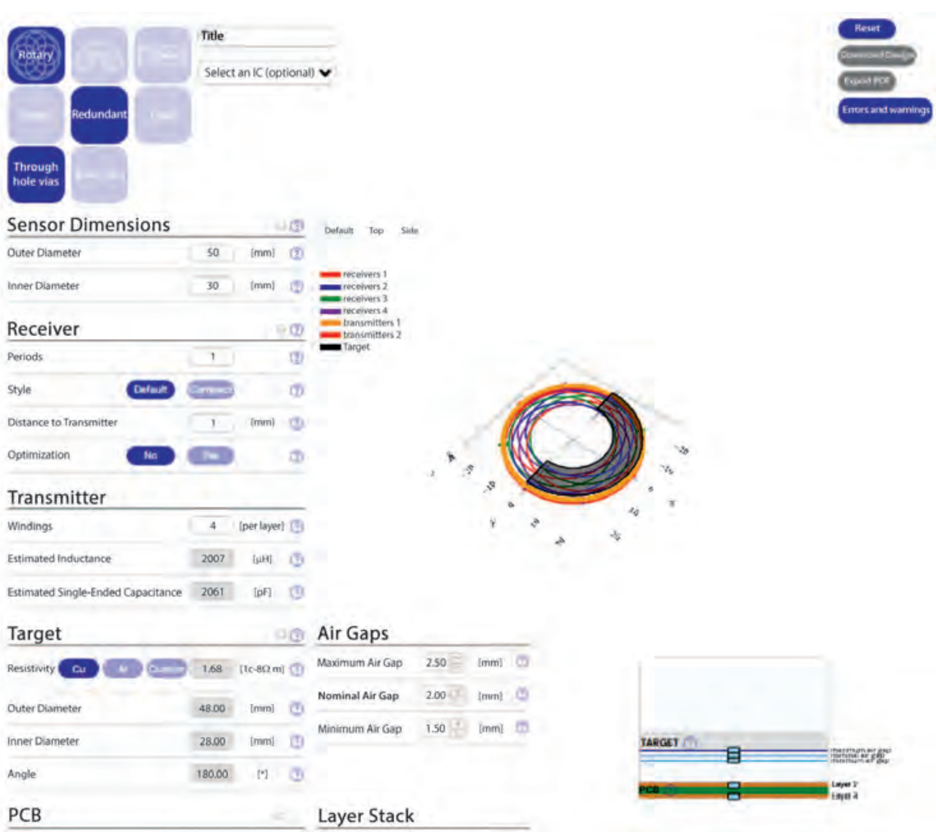

Figure 3 *Renesas Inductive Position Sensor Coil Optimizer.*

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