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AnalogAI Selects memBrain™ SAGE Intellectual Property from Silicon Storage Technology® for its First Real-world Edge AI Processors

Proprietary on-device training built to dynamically adapt to real-world environments

AnalogAI has chosen memBrain™ Synaptic Analog Generative Engine (SAGE) neuromorphic hardware intellectual property (IP) from Microchip Technology's Silicon Storage Technology® (SST®) subsidiary for its real-world edge AI processors. AnalogAI edge AI processors feature a hardware-aware proprietary algorithm designed to simultaneously train and run inference on AI models in real-world environments.

The startup is utilizing SST's memBrain SAGE IP to deliver high levels of analog compute-in-memory (aCIM) performance at or below one watt for ultra-low power edge applications. By leveraging the robust silicon-proven SST memBrain SAGE IP based on SST SuperFlash®, AnalogAI is developing new capabilities for real-world inference applications such as environment-adapting humanoid robots, drones and vehicles.

SST memBrain SAGE IP features

- memBrain Tensor In-Memory Logic Element (TILE)
  – memBrain solution optimized ESF3 bitcell which stores up to 8 bpc at nanoamp levels
  – memBrain solution custom array, decoders and driver circuitry
- Optimized DACs and ADCs
- Summator and high voltage bias circuitry
- Nanoamp level bitcell control logic
- memBrain proprietary test circuitry
- SST memBrain technology documentation and simulation models
- Full IP integration service and support

SST's memBrain SAGE IP has been developed and deployed in 40 nm and 28 nm foundry processes using production-ready SuperFlash memory. The current technology roadmap includes 22 nm memBrain SAGE IP development. Designed to provide reliable, high-performance and low-power non-volatile storage directly on the chip, SuperFlash memory is widely used in applications that require fast access times, high endurance and data retention without the need for external memory components.

"AnalogAI is pursuing innovative co-optimized solutions for edge AI inference that enable edge devices to adapt real-time to sudden changes in the environment," ***said Mark Reiten, senior vice president of Microchip's Intelligent Compute business unit****. "As the core inference engine for AnalogAI's first products, SST memBrain SAGE IP delivers the necessary compute performance coupled with the power efficiency AnalogAI requires to meet their application targets. We are pleased to welcome AnalogAI as the newest licensee of our SST memBrain IP, joining our rapidly expanding ecosystem."*

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

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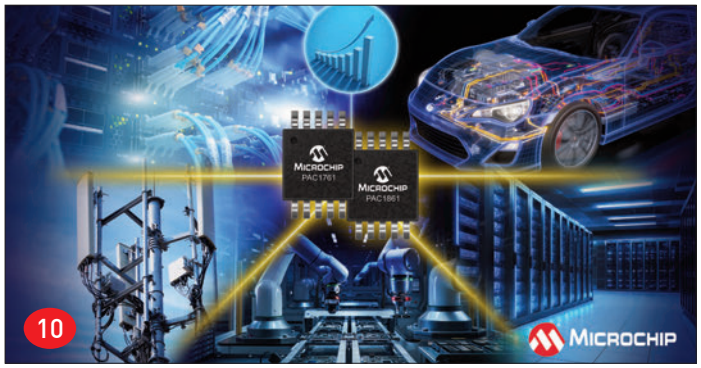
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Infineon's PSOC™ Control C3 Performance Line sets a new standard for real-time control and PQC security

Infineon announced the launch of its PSOC™ Control C3 Performance Line microcontroller family to enable real-time control for power and motor applications. The new family of microcontrollers (MCUs) offers best-in-class performance through high control loop frequency, accuracy and system efficiency. Based on Arm® Cortex®-M33 multi-core architecture, PSOC Control C3 Performance Line MCUs meet the needs of applications that require precise, high-speed control for power conversion such as AI server PSUs, solar, SMPS, EV charging or high-end motor control.

The MCUs are compliant with Post-Quantum Cryptography (PQC) requirements for firmware protection outlined in the Commercial National Security Algorithm (CNSA) Suite 2.0. In addition, the MCUs support PSA (Platform Security Architecture) Level 3 enablement. By supporting both standards, Infineon's PSOC Control C3 Performance Line meets the security needs for a wide range of industrial applications and eases their transition to increased security in the post-quantum cryptography era.

Key features and benefits

– Arm Cortex-M33-based microcontrollers with up to 180 MHz
– PPCA hardware accelerator with dual-Arm Cortex-M33-based microcontrollers with up to 200 MHz, zero wait state fast analog and digital peripherals access to enable high-performance systems to respond to real-time events with minimal delay
– Provides a high level of functional integration for multiple-output power supplies
– Wide-bandgap-ready with fast, precise analog processing and digital control to improve control loop accuracy and system efficiency
– Low standby power for battery-powered application
– Scalable and compatible portfolio in features, packages, pinouts, memory and performance
– Quicker time-to-market with ModusToolbox™ Power Suite and Motor Suite GUI as a unified and comprehensive software and ecosystem platform for developers with dedicated tools and advanced libraries
– Up to PSA L3 / EPC3 security incl. PQC support and "DICE ready"
– Enable secured on-site and cloud-based systems with secured boot, secured FW update, code protection, secured identifier for attestation, secured key storage ready, authenticity and integrity protection

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

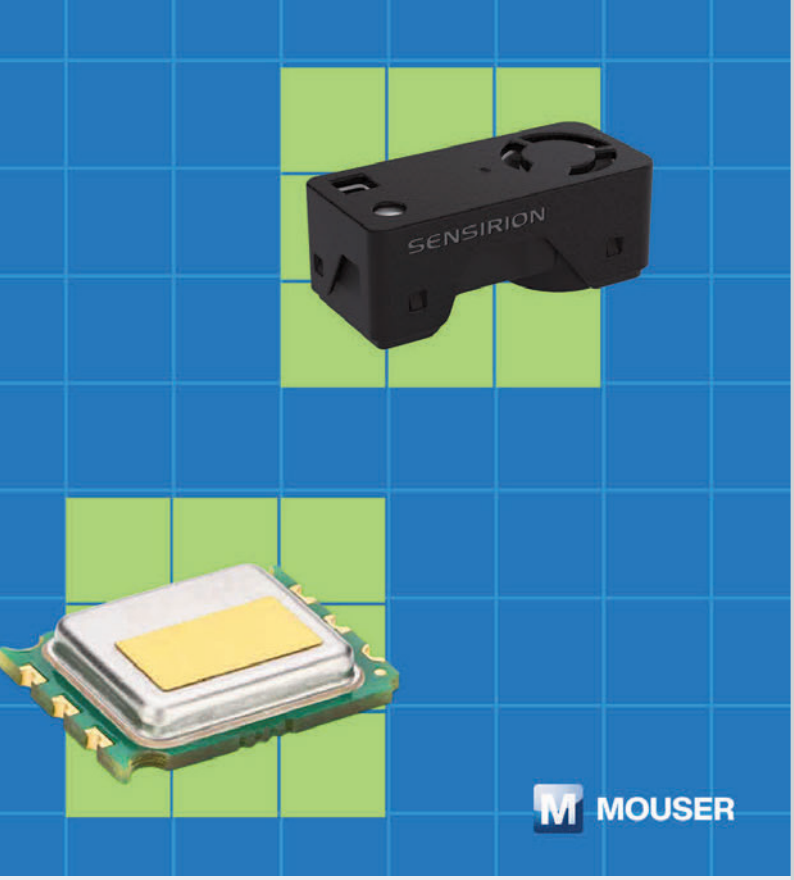


New Sensirion Environmental Sensors, Available from Mouser, Enable Advanced Air Quality Monitoring

Mouser Electronics, Inc., the New Product Introduction (NPI) leader™ empowering innovation, is stocking a wide range of authorised products from Sensirion, a leading manufacturer of environmental sensors. Since 2014, Mouser and Sensirion have partnered to provide engineers with the components and solutions needed to monitor indoor air quality, including carbon dioxide (CO_2), particulate matter (PM), and volatile organic compounds (VOCs). While sensing technologies have advanced significantly, indoor air quality monitoring remains complex due to the wide range of environmental factors that must be measured. This challenge is especially evident in hardware system design, where engineers must carefully balance performance, accuracy, and power consumption.

Refrigerant and formaldehyde detection

Sensirion's SGD4x A2L sensors, available from Mouser, are specifically designed for the HVACR industry as a complete A2L refrigerant detection system (RDS). The sensors are based on the thermal conductivity measurement principle and feature a dual-contact relay output that can trigger a signal relay to start a blower, switch off the load, or warn a control board.



With their fast response time and broad compatibility with A2L refrigerants thanks to their versatile multi-refrigerant calibration, these sensors are an essential component for both residential and commercial HVACR systems.

The SFA40 sensor from Sensirion is designed to detect formaldehyde, a common indoor pollutant found in wood-based furniture and flooring, paints, and cosmetics. Measuring just 10 × 13 × 2.4 mm, this compact sensor is designed for easy integration into air purifiers, indoor air quality monitors and air conditioners.

Compact CO_2 and multi-parameter sensing

The miniature STCC4 sensor provides direct CO_2 measurement in an ultra-small 4 × 3 × 1.2 mm package. Designed for seamless integration into compact electronic devices, it enables new applications previously limited by size and cost constraints. Leveraging the latest technological advancements in thermal conductivity sensing, the fully calibrated STCC4 delivers the accuracy required for indoor air quality applications with low current consumption. Optimised for high-volume assembly through its SMD design and tape-and-reel packaging, it is suitable for a wide range of applications, including residential, consumer, and wearables for CO_2 monitoring during sleep.

The Sensirion SEN6x sensor module family is a multi-parameter air quality monitoring platform that combines particulate matter, relative humidity, temperature, VOC, NOx, and either CO_2 or formaldehyde sensing within a compact footprint. Developed using Sensirion's extensive environmental sensing expertise, the SEN6x modules deliver high measurement accuracy and extended operational lifetime in a highly optimised form factor. The integration of multiple sensing technologies and embedded processing algorithms into a single device reduces design and integration effort, streamlines supply chain requirements, and supports rapid product deployment while ensuring best-in-class performance.

■ **Mouser Electronics** | www.mouser.com



Compact 60W and 150W DC-DC converters simplify power design for BF- and CF-rated medical equipment

XP Power introduces the QAM60T and HBM150C series of medical DC-DC converters, delivering 60 W and 150 W respectively in compact, industry-standard brick packages. Designed for BF- and CF-rated medical equipment, the new converters provide reliable, space-efficient power conversion for increasingly compact and power-demanding applications including patient monitoring, medical imaging and diagnostics, patient treatment equipment, and surgical systems and robotics.

Both series carry global medical safety approvals and meet IEC60601-1 requirements with 2 x MOPP and 5kVAC input-to-output isolation, helping simplify regulatory compliance and integration into patient-connected medical equipment. Ultra-low patient leakage current is complemented by high efficiency, which minimises power losses and heat generation. Baseplate cooling simplifies thermal management, reduces cooling requirements and supports reliable operation in compact equipment. With external components, the converters meet Class A conducted and radiated emissions requirements under EN 55032 / EN 55011. Remote On/Off, remote sense and output voltage trim provide additional system flexibility, while overvoltage, overtemperature and short-circuit protection help safeguard the converter and end application.

Quarter-brick and half-brick options for different power requirements

For space-constrained equipment requiring flexibility across different DC supply architectures, the 60W QAM60T combines a wide 4:1 input range of 9 to 36VDC with a compact quarter-brick format. The series offers single outputs of 5VDC, 12VDC, 15VDC and 24VDC, as well as ±12VDC and ±15VDC dual-output models. Patient leakage current of 4.5µA makes the QAM60T particularly well suited to CF-rated patient-connected medical equipment. Efficiency of up to 93.5% helps minimise power losses and heat generation, while operation from -40 to +105°C supports use in demanding thermal environments.
For applications with higher power requirements, the 150W HBM150C combines a 2:1 input range of 18 to 36VDC with single 12VDC, 15VDC and 24VDC outputs in an industry-standard half-brick format.

■ **XP Power** | www.xppower.com



Qorvo® Advances C-Band Radar Front Ends with BAW-Based Frequency Agility and GaN Power

Qorvo® announced a C-band radar solution that adds receiver frequency agility and reduces DC power and heat in the transmit chain. Designed for pulsed electronically scanned array (ESA) systems, the solution combines the industry's first integrated C-band bulk acoustic wave (BAW) switched filter bank with high-efficiency 50 W and 200 W GaN power amplifiers.

C-Band Architecture

At C-band, frequency agility across 5.2 to 5.9 GHz has meant assembling discrete filters, switches and RF routing because an integrated switched filter bank has not been available. At high transmit power, lower PA efficiency increases DC power and heat, and limited gain adds an external high-power driver stage.

The QPB1055 integrates BAW filtering with switching, routing and control, providing contiguous coverage with a combination of high Q, low insertion loss and small size unavailable in a discrete implementation. On transmit, both PAs reduce DC power and heat with high efficiency. The 50 W QPA2311 delivers 55% power-added efficiency (PAE), and the 200 W QPA0018 eliminates the external high-power driver stage.

"We are investing across the C-band radar front end where frequency agility and transmit efficiency are problems the market has left open," ***said Diwakar Vishakhadatta, VP, Defense & Aerospace Products at Qorvo****. "For customers, this means less custom receive design and higher transmit power without growing the DC power budget."*

The QPB1055, QPA2311 and QPA0018 join Qorvo's C-band limiters, LNAs, switches and driver amplifiers. The expanded portfolio gives radar customers receive and transmit building blocks backed by Qorvo's BAW, GaN and system-level RF expertise.

■ **Qorvo** | www.qorvo.com



TI to showcase semiconductors powering the future of intelligent systems at electronica 2026

Celebrating 70 years of innovation in Europe, Texas Instruments (TI) will demonstrate new technologies for building smarter, more efficient and more secure intelligent systems at electronica 2026, Nov. 10–13 in Munich, Germany. TI's exhibit in hall C4, booth 159, will showcase how decades of design, system and manufacturing expertise are enabling the company to continue innovating what's next across embedded development, industrial automation, automotive electronics and power infrastructure for AI.

Innovating what's next in intelligent systems

TI will demonstrate how its analog and embedded processing semiconductors, software and tool ecosystem enable innovation across key application areas:

• **Accelerating embedded development**: As embedded systems grow more complex, TI is enabling agentic AI within its CCStudio™ development tool ecosystem and adding Zephyr RTOS support across its MCU, MPU and wireless portfolios to help engineers write and migrate code, configure systems, debug and deploy systems faster.



• **Transforming industrial automation**: The shift toward physical AI in production environments requires increased reliability and deterministic control. TI provides these capabilities through a portfolio of real-time MCUs, GaN-based motor drivers and multimodal sensing, alongside supporting multi-protocol industrial communication standards for next-generation automation.

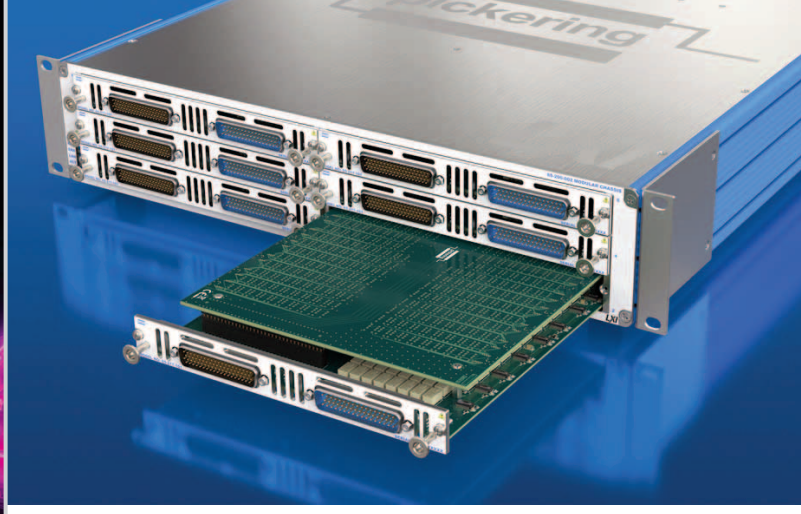
• **Architecting intelligent vehicles**: Addressing the transition to AI-defined, zonal vehicle architectures, TI processors enable real-time sensor fusion and autonomous decision-making. Complementing this, TI's scalable 12V and 48V architectures provide distributed power from driver assistance systems to chassis control.

• **Powering AI from grid to gate**: Today's AI workloads are driving an increasing need for efficient power, networking and thermal management. TI is addressing this demand by enabling next-generation energy infrastructure with solid-state transformers, GaN-based AC/DC converters and battery management with integrated EIS. Additionally, TI's complete 800VDC power solutions enable efficient and reliable AI data centers.

Visit TI at booth 159:

- A full demo list with descriptions is available upon request.
- Interviews with TI experts are available upon request. Topic areas include:
  - Embedded development and generative AI tools
  - Physical AI, factory automation and industrial communications
  - AI-defined vehicles and automotive platforms
  - Power infrastructure for AI data centers and the grid
  - Cybersecurity and Cyber Resilience Act (CRA) readiness
  - TI's 70-year legacy in EMEA

■ **Texas Instruments** | www.ti.com



Pickering Interfaces introduces scalable high-density 2A LXI matrix for changing test requirements

Pickering Interfaces has introduced the 65-217, a modular 2A Ethernet-controlled LXI matrix that lets test engineers expand system capacity as requirements change. Designed for the 65-200 scalable LXI chassis platform, the new plug-in module also simplifies servicing. It supports RF crosstalk measurements on unterminated signal paths, a specific requirement in some aerospace and automotive applications.

Each plug-in adds a 64 × 8, 1-pole matrix, building to a maximum 384 × 8 configuration in a 19-inch, 2U chassis. Modules are installed from the front, so users can add or replace them without removing the chassis from the test rack. Versions are available with or without front-panel Y-axis access, and switched Y-axis loop-thru connections support matrix expansion across multiple chassis.

Flexible signal routing and relay maintenance

A dual Y-axis analog bus allows multiple external instruments to access different portions of the matrix. It can also divide the system into two independent matrices. In addition, switched Y-axis points allow for the disconnection of unused sections to help maximize bandwidth.

Relay cycle counting helps users plan preventive maintenance and balance usage across signal paths. Integrated BIRST (Built-In Relay Self-Test) and optional external eBIRST self-test tools can identify failed or worn relays, and spare relays are mounted on each plug-in to simplify servicing and reduce downtime.

The 65-217 switches up to 300 VDC or 250 VAC and 2 A, with a maximum power rating of 60 W or 62.5 VA. It is backed by Pickering's standard three-year warranty and guaranteed long-term product support.

"The 65-217 gives users a practical way to start with the matrix size they need today and expand it later," ***said Steve Edwards, Head of Product Management at Pickering****. "Up to six plug-in modules can be installed in a 65-200 chassis, creating a single matrix rather than separate 64 × 8 elements. The control software handles the path identification offsets between modules, reducing programming complexity."*

■ **Pickering Interfaces** | www.pickeringtest.com/en-ro



Qorvo® Sets Benchmark with New X-Band RF Front-end Solution Tailored for Radar Systems

Qorvo®, a leading global provider of connectivity and power solutions, announced an X-band front-end solution that combines high transmit output with low-noise, high-linearity receive performance for active electronically scanned array (AESA) radar. Developed around a quad architecture, the solution reduces RF content inside the array lattice.

System-Level X-Band Architecture

X-band radar systems are increasingly adopting AESAs, including flat-panel phased-array antennas. The lattice spacing limits the area available for the beamformer, FEMs and power control devices. External driver amplifiers and discrete PA control and switching circuits consume valuable lattice space and introduce additional interfaces that customers must accommodate in their designs.

Qorvo's QPX0252 is a four-channel, 7.9 to 12 GHz beamformer IC. Its high transmit output power drives compatible Qorvo FEMs, such as the QPF5012 directly, eliminating the need for external driver amplifiers. Companion Qorvo devices provide GaN PA bias control and RF switching.

"Beamformers are typically designed as stand-alone components, leaving customers to integrate the FEMs, bias control and RF switching around them," ***said Diwakar Vishakhadatta, VP, Defense & Aerospace Products at Qorvo****. "We developed the QPX0252 as part of the X-band front-end architecture, defining its transmit, receive and control functions around the requirements of the radar system."*

In high-power radar systems, the Qorvo FEM establishes a low system noise figure while the QPX0252 operates in a high-linearity mode. Qorvo's system analysis demonstrates up to 20 dB higher cascaded input P1dB compared to other offerings in the market.

■ **Qorvo** | www.qorvo.com



Build Smarter, More Resilient 48V Power Systems with Energy-Aware Digital Power Monitoring from Microchip

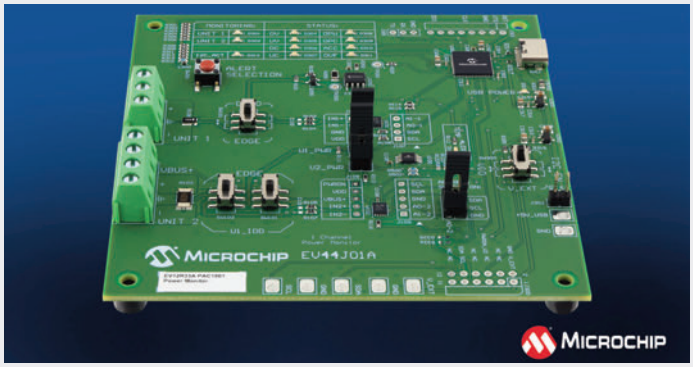
Microchip Technology announced the PAC1761 and PAC1861 families of 65 V energy-aware digital power monitors that combine accumulated power-measurement insights with the necessary high-voltage measurement headroom and transient spike protection capabilities to help make 48 V power architectures more efficient and resilient. As automotive, AI/data center, networking and industrial systems quickly migrate toward 48 V power architectures to improve efficiency and support higher power demands, designers need more than visibility into instantaneous voltage and current conditions. They need systems that understand energy use over time and can respond intelligently to changing power conditions.

The move to 48 V power architectures demands that digital power monitors have an additional operating margin, with measurement capability up to 65 V and spike protection up to 75 V to ensure transient survivability. The PAC1761 and PAC1861 devices add to these capabilities the intelligence to understand and react in real time to energy usage dynamics based on accumulated power measurement data.



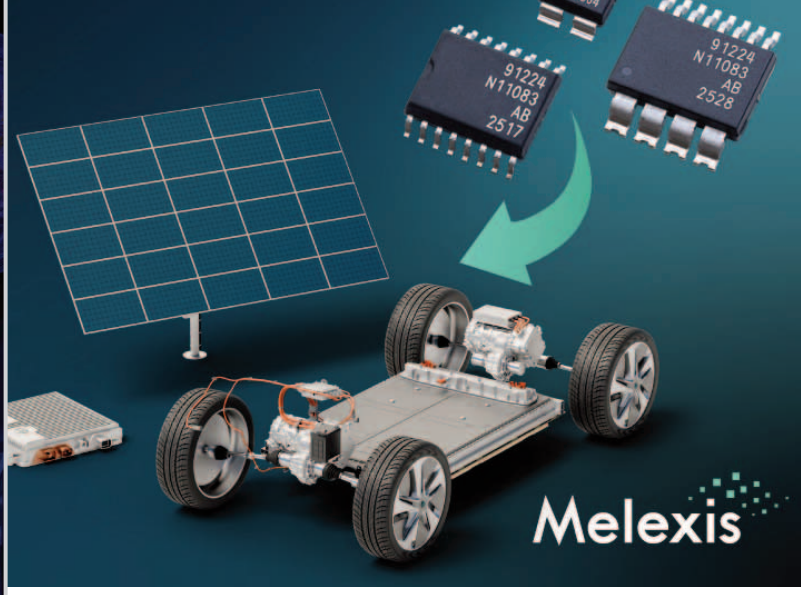
Programmable alerts and flexible monitoring options

Microchip's digital power monitoring devices feature programmable alerts for voltage, current and power excursions, step-limit detection to identify sudden load changes, and configurable accumulated-energy thresholds that enable proactive system management based on both instantaneous and long-term power behavior. Target applications include automotive, AI/data center, networking, industrial, server, telecom/Power over Ethernet (PoE) and 48 V power distribution systems. The 12-bit PAC1761 and 16-bit PAC1861 options are available in VDFN-8 (similar to SOT23-8), VDFN-10 and MSOP-10 packages including automotive-orderable variants. Pin-compatible options can reduce redesign risk, shorten qualification cycles and give customers flexibility to move between devices as requirements, availability, cost or performance change.



"The industry conversation is shifting from measuring power at a single point in time to understanding and responding to energy behavior across an entire system and its lifecycle," ***said Keith Pazul, vice president of Microchip's mixed-signal linear business unit****. "The PAC1761 and PAC1861 families are designed to help customers build better performing and more reliable 48V systems that can measure instantaneous conditions and understand energy consumption and availability over time. These scalable, low-power solutions reduce monitoring overhead and include pin-compatible package options that improve source flexibility while reducing design risk."*

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



Melexis unveils versatile integrated current sensor platform up to 100 A RMS

Melexis has introduced the MLX91224 and MLX91225, expanding its isolated current sensor portfolio for high-voltage automotive and industrial applications. Delivering plug-and-play measurement up to 100 A RMS, ASIL B readiness, and a fast analog response across three package options, these new devices simplify design for EV powertrains, DC-DC converters, chargers, and solar systems.

As electrification across various applications (renewable energies, industrial, automotive, energy storage systems…) continues to scale, current measurement is becoming more demanding. Designers need accurate, isolated measurement for system control and safety. For low-current measurements, a common solution is the shunt-based approach. However, these solutions typically lead to increased Ohmic losses, need for isolated amplifiers, assembly complexity, and effort in end-of-line calibration.

The MLX91224 and MLX91225 address these challenges by combining the current conductor, sensing element, signal conditioning, and isolation in a compact SOIC package. Current flows directly through the low-impedance lead frame of the package, while two sets of Hall plates differentially sense the magnetic flux generated by the current. The architecture minimizes disturbance from external magnetic fields and enables a high-speed linear analog output proportional to the measured current, with package-dependent isolation ratings supporting working voltages up to 1640 VRMS.

Integrated safety and fast current measurement

For automotive applications, Melexis brings an industry-first ASIL B integrated current sensor platform to high-voltage current measurement with the MLX91224 and MLX91225. Developed as ISO 26262 Safety Elements out of Context (SEooC), the devices give engineers a stronger starting point for safety-related current measurement in high-voltage automotive systems. This platform offers fast response for current measurement in motor control, electric drives, DC-DC converters, AC and DC chargers, solar systems, power supplies, and many other applications.

■ **Melexis** | www.melexis.com



© Bosch

Figure 1
Modern driver assistance systems are expected not only to detect that an obstacle is present, but also to identify what it is; for example, motorcyclists as further road users or a stationary bollard.

Automotive sensor raw data:

MORE SIGNAL. MORE SAFETY.

AI-driven automation is reshaping automotive sensors. In many current AI-based approaches, sensor raw data with its high information density is gaining importance over heavily preprocessed data. Modern chip architectures are a prerequisite for making this raw data available in real time.

Authors:
Viktor Kraus, Product Manager Ultrasonic ASICs, **Bosch**
Hendrik Seidel, Head of Product Area ADAS ICs, **Bosch**

Today's vehicle users expect far more than basic warning functions. AI-based driver assistance systems are expected to reliably detect different types of obstacles, brake automatically, park precisely, and respond safely even in complex situations. To achieve this, vehicles need an increasingly accurate picture of their surroundings. This, in turn, presents a challenge for vehicle manufacturers.
The performance of modern driving functions is not determined by the sheer number of sensors, but by the completeness of the incoming sensor data and its ability to be fused.

Raw data as the basis for intelligent vehicle perception

Initially, a sensor captures only physical signals such as sound waves, electromagnetic reflections, or light. These original measurements are referred to as raw data. Only through various processing steps are they transformed into information that electronic control units can use.

In many current driver assistance systems, initial signal processing already takes place within the sensor. Noise is filtered out, measurement data is compressed, or characteristic features are extracted. This can result in so-called envelope data (condensed signal profiles) or already interpreted object information such as distance, position, or detected obstacles. This preprocessing offers clear advantages: By reducing data rates and therefore the required computing power, it relieves the load on the control units and enables fast overall response times. This is often sufficient for conventional driver assistance functions.

However, this approach is increasingly changing. AI-based systems require sensor data that is as unprocessed as possible, as early preprocessing can reduce or even lose potentially relevant information.

In the case of ultrasonic sensors, for example, subtle differences in amplitude, signal progression, or echo shape might provide crucial information for reliable object detection. These details can help distinguish between parked vehicles, curbs, posts, pedestrians, or different surface structures. The more complex the driving situation, the more valuable complete sensor signals become (Figure 1).

Why conventional threshold-based methods reach their limits

To understand the difference between preprocessed and raw data, it is useful to take a closer look at signal processing. Many conventional systems use a highly simplified processing chain, where the raw signal is filtered, converted into an envelope, and then evaluated using a fixed or adaptive threshold.

Figure 2 illustrates this principle. The blue signal shows the temporal progression of an ultrasonic echo. Multiple reflections – for example from uneven ground, pedestrians, or bollards – produce different signal shapes. The red dashed line indicates the detection threshold. Only signal components that exceed this threshold are interpreted as an event.

The limitation of this approach lies in the significant reduction of information. Large parts of the signal structure are discarded before the actual interpretation takes place. This works well in simple scenarios. However, as traffic situations become more complex, for example with multiple smaller obstacles, some of these objects may no longer be detected.

Another key aspect is that thresholding suppresses not only weak target signals, but also what is perceived as "noise." It is treated as interference and therefore removed. In real-world environments, however, such noise can contain structured information, for example about unusual vehicle sounds or general road conditions. As a result, potentially valuable contextual information can be lost – information that could go beyond simple object detection and contribute to a more comprehensive understanding of the vehicle's surroundings or even provide indications of faulty vehicle components.

At the same time, raw data does not replace preprocessing altogether. Instead, hybrid architectures are emerging, where raw data, envelope data, or object lists are used in parallel, depending on the function.
This allows the optimal balance between data rate, computing load, and information content to be selected.

Raw data enables optimized sensor fusion

Sensor raw data is valuable for another reason: It can serve as a building block for AI-based sensor fusion. Sensor fusion combines heterogeneous data to create a consistent model of the vehicle's surroundings. No single sensor can fully capture the vehicle's environment.

The more complete and unaltered the input data, the more robust and reliable the overall perception of the system can be.
Raw data offers a decisive advantage here. While envelope data and object lists already represent highly condensed information, raw data retains the complete signal information – including multipath and scattering effects in radar and ultrasonic signals, detailed intensity and texture patterns in camera data, or finely resolved point cloud structures in LiDAR (Light Detection and Ranging). AI models can analyze these heterogeneous raw data streams and identify patterns that may remain hidden to conventional processing methods.

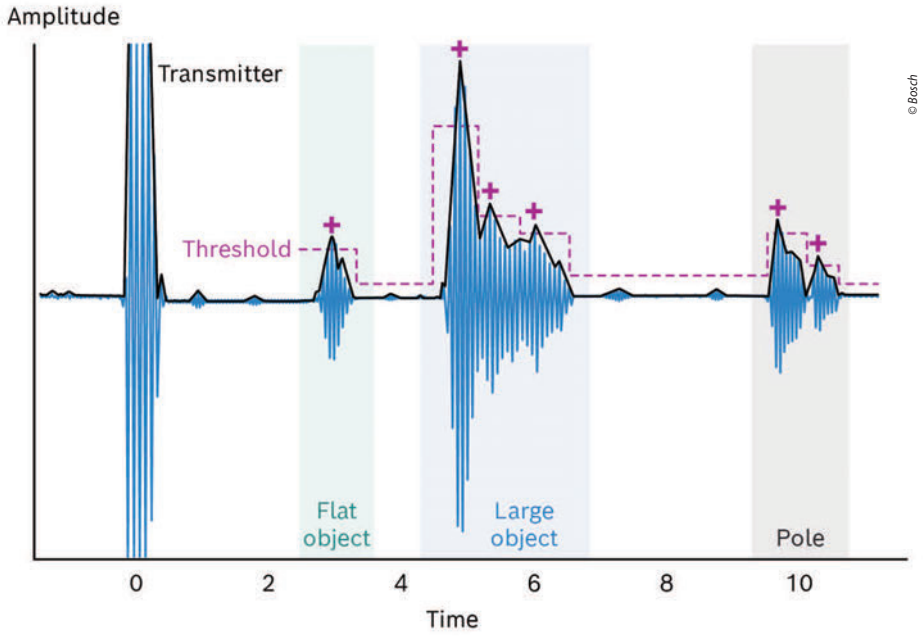


Figure 2 ***Signal components above the threshold are detected as obstacles, those below are filtered out.***

Cameras provide high-resolution image data but depend on lighting conditions. Radar performs reliably even in challenging weather conditions but offers lower angular resolution.

Ultrasonic sensors, on the other hand, provide particularly accurate sensing at close range, for example during parking or in low-speed scenarios.

Data fusion can combine multiple sensors of the same type as well as different sensing technologies to achieve comprehensive 360-degree coverage of the vehicle's surroundings. This makes it possible to leverage the strengths of each sensor type while compensating for their respective limitations.

These include cross-sensor consistencies, subtle material and surface characteristics as well as temporal dependencies across multiple measurement cycles.

Raw data can also help quantify uncertainties across different sensors more effectively, thus reducing misinterpretations in critical situations.

For example, a strong light reflection may temporarily interfere with a camera system and cause it to interpret the reflection as a potential obstacle.

Combining camera data with radar data or data from other sensors can help correctly classify such a visual anomaly and reduce the likelihood of misinterpretation.

Bosch ultrasonic chipset: an example of a modern sensor architecture

Specialized chipsets are required to make raw sensor data available in the vehicle. They not only capture sensor data directly at the source but also enable its fast transmission with high bandwidth.

With data rates of up to 1.16 Mbit/s, it enables high-performance communication while significantly simplifying the wiring architecture. This reduces wiring harness weight, cost, and complexity while enabling flexible sensor configurations within the vehicle.

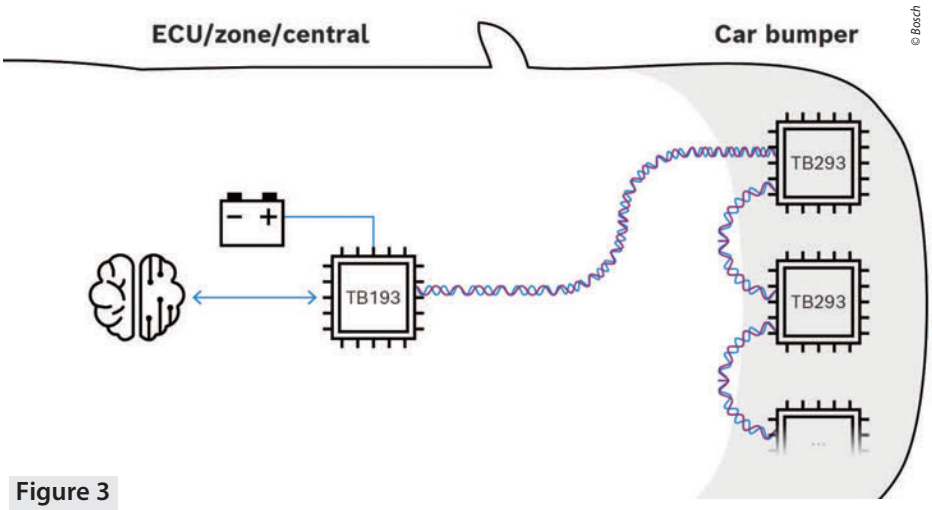


Figure 3

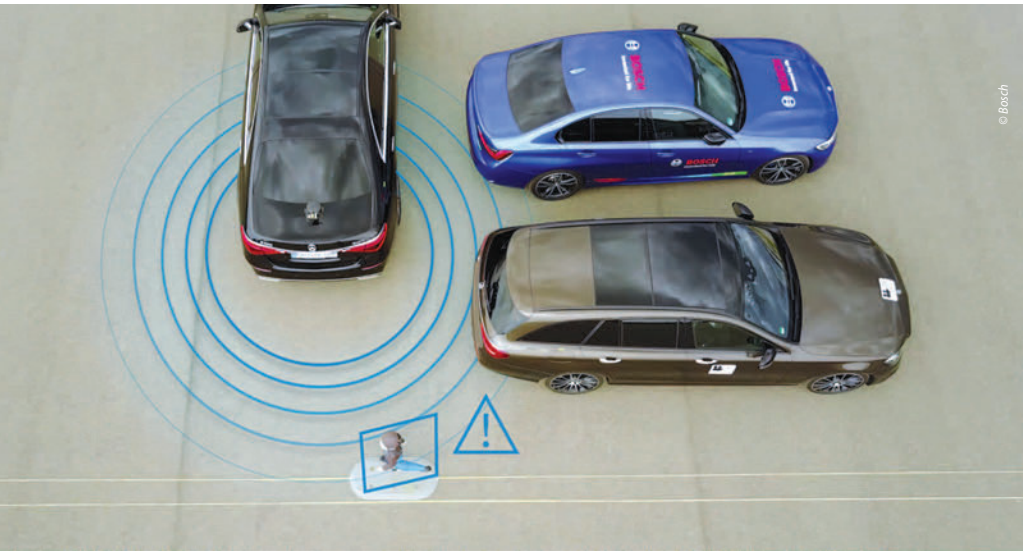
Exemplary setup with a series of TB293 sensors in the vehicle bumper area, connected to the central CPU via the TB193 sensor using a single cable.

Bosch's ultrasonic chipset provides a good example of this kind of architecture. The TB293 frontend device is integrated directly with the ultrasonic transducer and captures the raw signal at the sensor level. This makes the complete echo data available. The TB193 communication device then handles the time-critical transmission of the sensor data to the control unit.

Data transmission takes place via the VASI (Vehicle Automotive Sensor Interface) bus, a two-wire data-over-power interface that simultaneously supplies the sensors with power and transmits data.

Figure 3 shows an example of such an architecture in a vehicle bumper.

A key advantage of this architecture is its support for multiple data levels through a unified infrastructure. In addition to raw data for AI-based processing, envelope data for conventional signal processing and processed object information for established driver assistance functions can also be transmitted.
This creates a hierarchical data architecture that enables different levels of processing depth depending on the requirements of the respective function.



Raw data as basis for scalable vehicle functions

Sensor raw data is far more than a technical detail of signal processing. It provides the foundation for a vehicle architecture that can evolve throughout the vehicle's lifecycle. This aligns with the concept of the software-defined vehicle (SDV).

Vehicle functions become scalable: Software updates can enable improved object detection, new parking functions, enhanced ADAS features, or even entirely new safety-related applications without requiring fundamental changes to the sensor hardware. Architectures such as the ultrasonic chipset introduced above can therefore provide the data foundation for functions that may only be developed later in the vehicle's lifecycle.



Figure 4

The TB293 frontend device captures the ultrasonic raw signal directly at the transducer, providing complete echo data. The TB193 communication device then handles the time-critical transmission of the sensor data to the control unit.

The possibilities extend well beyond conventional environmental perception. Sensor and signal patterns can increasingly be used to derive information about conditions in and around the vehicle.
For example, changes in acoustic signatures may indicate wet or slippery road surfaces, while deviations in vibration or noise behavior can provide indications of wheel imbalance, wear, or other technical anomalies.
The additional information derived from sensor raw data can therefore expand the functionality of advanced driver assistance systems in the future, making raw sensor data a valuable resource for tomorrow's safety architectures.

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Designing low-power microcontroller systems

In this article, we will look at some of the techniques used to reduce power consumption in microcontroller applications, covering elements of both the hardware and software design.

Author:
Graeme Clark, Principal Engineer
Renesas Electronics

Designing low-power microcontroller systems is still in many ways a black art, as minimising the power consumed in your application, especially as designs become more complex, is becoming increasingly difficult. Designing your application to be low power is not only important in traditional, battery power applications, but also in most other applications, as minimising power consumption not only saves power but can have ancillary benefits such as a reduction in system cost and minimising emissions.

This can be especially in the realms of the IoT world. If you have millions of connected devices in your network, even a 10 % saving in consumed power can have significant benefits in the real world.

Let's first look at where the energy goes in a typical microcontroller.

Almost all of today's microcontrollers are built on some form of Complementary Metal-Oxide-Semiconductor (CMOS) process technology. Power consumption in these devices can be divided into two distinct classes: dynamic and static power.

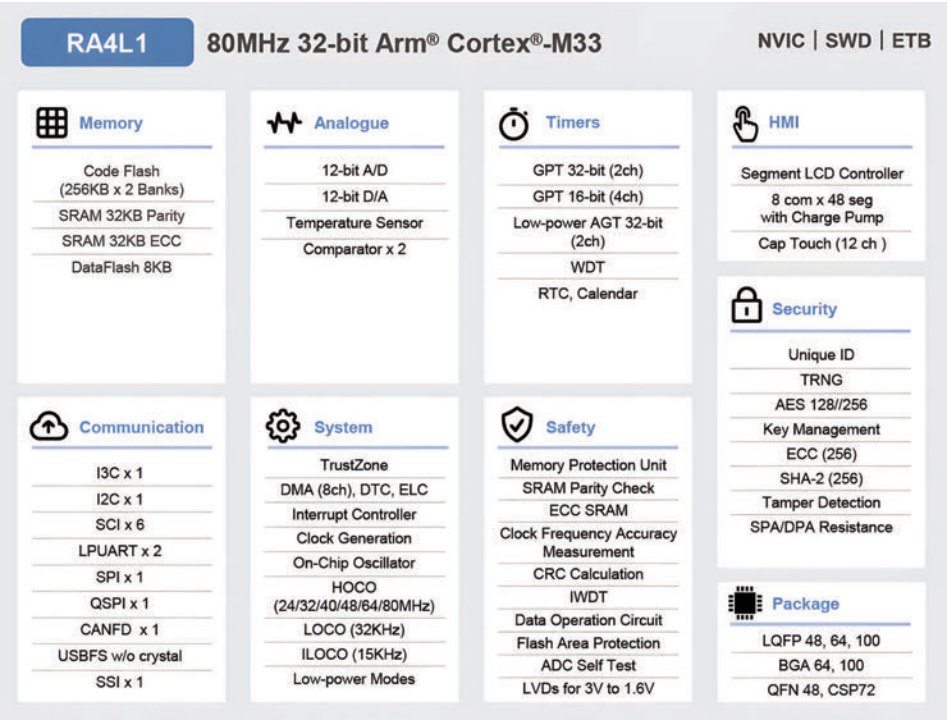
Dynamic Power = ($C \times V^2 \times f$)
Static Power = (I leakage × V)

As we can see, the dynamic or active power consumption is proportional to both the square of the operating voltage as well as the frequency.
Minimising both these values in your application, especially the operating voltage, with have a significant impact on the total power consumed.
Static power is the leakage of the semiconductor gate structure when it's idle and not being clocked.

It's harder for the designer to influence this value as it's a fundamental parameter of the chosen microcontroller and its process technology, however there are some actions we can take in our design to minimise this leakage.

The exact behaviour of the microcontroller will depend on the geometry of the process and the nature of the actual microcontroller design. The smaller the process geometry, the smaller the logic gate size, and so the smaller the intrinsic gate capacitance. Hence while the use of advanced process technology can result in a smaller active mode current, however the use of such a process will often result in much larger leakage currents.

One important comment to add here, these formulae refer to the digital behaviour of the microcontroller, there is no simple formulae that can be used to calculate the power consumed by the analogue components on the device, such as the power supply circuitry or the ADC or comparators. Most microcontroller vendors provide copious power consumption data in their hardware manuals, therefore in choosing any microcontroller, it's important not to only look at the headline figure on the front page, but at the detail contained in the electrical specification.
We will also look at the techniques that can be used to reduce power consumption on our microcontroller, but we should not forget the rest of the components on our PCB.



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Figure 1 *RA4L1 Block diagram.*

The correct choice of the other components can have a major impact on both the power consumption and the total cost of your design, and there are frequently difficult trade-offs that must be made. In any low power design, the power supply is one of the key design choices, is the system battery powered? is it powered externally, does it need battery back up? are there space or cost constraints in the design.

Is a simple LDO based supply sufficient or do I need to use a complex multistage DC-DC Converter based system. These choices will be driven by the target application, any system constraints in your design and by your choice of microcontroller.

So, let's consider the MCU itself

For the purposes of this article, we will use the Renesas RA4L1, a 32-bit low power microcontroller based on an ARM™ Cortex™ M33 CPU core. This is implemented on a 110 nm CMOS process and we will use this to illustrate some of the features we can use to reduce a microcontrollers power consumption. The RA4L1 is optimised for cost effective low power applications, has a wealth of low power features and can operate at voltages down to 1.6v. You can see the block diagram of the RA4L1 in Figure 1.

In complex microcontrollers like the RA4L1, there are many internal data busses, driving each of these busses, to the CPU, to the memory, to the peripherals, can take significant amounts of power. Choosing a microcontroller with autonomous hardware peripherals – like a Direct Memory Access (DMA) controller, a Data Transfer Controllers (DTC), low-power timers and other autonomous subsystems can gather, filter, and move data without waking up the main CPU core, so greatly reducing power consumption. The RA4L1 has some specific peripherals such as the Event Link Controller (ELC) and the Data Operating Circuit (DOC) that help automate many of the common low-level functions in an application, so allowing events and data to be processed without any CPU intervention, greatly reducing power consumption and reaction time.

As we've seen already, the active power consumption of a microcontroller is proportional to both the square of the operating voltage and the operating frequency, so in our design we want to reduce these to a minimum while maintaining the performance levels we require.

We also need to consider what our system needs to achieve, what external events we need to manage and what our processing requirements are. The longer we can stay in the lowest power states, the lower power we will consume overall.

If we're designing a water meter, most likely we will spend most of the time doing nothing, so the lowest power modes are critical. If we're designing a complex application, the CPU performance and the active current may be higher priority. All these factors will influence our choice of microcontroller.

A typical microcontroller will offer several low power modes, such as sleep mode and standby mode, where the CPU and peripherals are in low power states, along with the standard active mode where the CPU is running. You can see a comparison of the low power modes available on the RA4L1 in Figure 2: Other devices may call these by different names or have different low power modes. One common such mode is a battery back-up mode, when the power is completely removed from the device apart from a very limited number of peripherals such as a real time clock (RTC) which can be powered by a second power source.

Operating Modes	Active Mode	Sleep Mode	Software Standby Mode
CPU state	Active	Stop	Stop
SRAM	Active	Stop	Selectable
High Speed Clocks	Selectable	Selectable	Stopped
Low Speed Clocks	Selectable	Selectable	Selectable
Peripherals	Selectable	Selectable	Selectable (Limited Number)

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Figure 2 *RA4L1 Low Power Modes.*

We need to choose an operating voltage for our MCU to minimise the power consumption, but we also must consider other factors, such as external voltages that we may be required to interface to or to minimise any noise margin issues. Choosing operation 3v is often a good compromise, but the use of even lower voltages is becoming more common, especially in battery powered applications.

We can also choose the clock rate that's as low as possible but is also sufficient to provide enough performance for our application and for the clock rates required by our peripherals such as timers and serial interfaces.

A device like the RA4L1 has many different operating modes, where you can control both the operation of the CPU and peripherals and optimise the devices internal power supply to minimise power consumption.

The RA4C1 from Renesas is a similar device to the RA4L1 but supports such a battery back-up function. The choice of these low power modes is often a trade-off between power consumption, available functionality and recovery time. As the deeper the low power mode, the longer the device may take to recover.

The RA4L1 has several different power control modes, each optimised for a difference set of operating parameters, allowing the user to select an operating frequency range. The device will then optimise its power supply circuits to minimise the power consumption for each of these conditions. You can see the power control modes and their specifications in the diagram in Figure 3:

These operating modes can be changed dynamically allowing the designer to optimise the performance, and the power consumption during operating depending on the characteristics required at that time.

Low Power Modes	High speed Mode		Middle Speed Mode		Low Speed Mode	Sub-Osc Mode
Operating Clock	32 kHz – 80 MHz	32 kHz – 4 MHz	32 kHz – 8 MHz	32 kHz – 4 MHz	32 kHz – 1 MHz	27.8 – 37.7 kHz
Operating voltage	1.8 to 3.6 V	1.6 to 3.6 V	1.8 to 3.6 V	1.6 to 3.6 V	1.6 to 3.6 V	1.6 to 3.6 V

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Figure 3 *RA4L1 Power Control Modes.*

Care should be taken to make sure that the selected clock speeds never exceed the speeds supported by the chosen power control mode or the device may not operate correctly.

Devices like the RA4L1 provide complex clock systems, you can see the clock tree in Figure 4: We can choose from multiple internal and external clock sources including both high speed and low speed internal oscillators and support the use of external crystals. We should always make sure that any peripheral we are not using is switched off, and, if possible, only turned on when required.

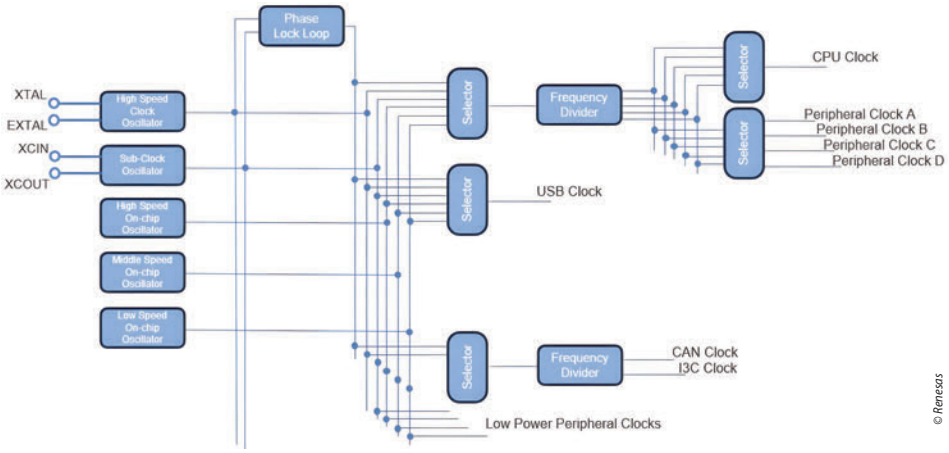


Figure 4 ***Simplified Diagram of the RA4L1 Clock Tree.***

When we're talking about oscillators, especially the use of external crystal oscillators, there are several items that it's important to take care of. External high speed quartz crystal oscillators are very accurate but require significant energy to oscillator and have long start up times, in many cases, the use of an internal oscillator, while not so accurate may be better. If using a quartz crystal, devices like the RA4L1 allow you to select the drive level of the microcontroller oscillator circuit to better match your external crystal.

As many low power applications require a real time clock (RTC) function, the use of 32 kHz crystal oscillators has become very common, but great care should be taken in the design of the oscillator circuit, especially if you would like to use a low CI type crystal, which has a very low drive requirement. We would always recommend you ask your crystal oscillator supplier to match the chosen oscillator to your microcontroller clock circuit. Peripheral clock speed should be minimised and can often be reduced when high speed performance is not required, we should use the peripheral clock dividers to minimise the clock speed to each function as much as possible.

Many microcontrollers, including those from Renesas have design tools to help you initialise the clock tree and the peripheral functions and help to minimise power consumption.

There are many other peripheral choices that can be considered to reduce power consumption, for instance the use of serial bus interfaces to talk to external devices rather than a parallel connection.

The I2C bus and the SPI bus are common serial solutions here, with many peripheral devices available for each.

While the I2C bus is popular because of its ability to address multiple devices, it uses open-drain outputs with pull-up resistors, so it when the data or clock signal is pulled low during transmission, current continuously flows through the resistor directly to ground, so it's often better to use higher transmission speeds to minimise this. An SPI doesn't use passive resistors and can operate at higher clock speeds, so for many applications it may still provide the best solution.

Many analogue peripheral functions may also be problematic, and it's often better to keep these switched off until needed to avoid extra current.

Minimising the current flowing into and out of the I/O pins is also important, it can sometimes be surprising how much current can flow into and out of the device.

We should always make sure we manage all the unused I/O pins. Input pins should not be left floating and should always be tied to ground or Vcc. Output pins should be initialised to drive as output low or should have internal pull-up/pull-down resistors enabled but also check the relevant datasheet or hardware manual for any specific device/pin requirements and using external resisters with larger values rather than the internal resisters may have a larger effect.

When we are considering the use of external devices, such as communication transceivers, memories and sensors, we should also consider if power gating is worth implementing, as many of these devices are only used intermittently and can continue to draw significant current even when idle. MOSFETs or dedicated load switches can be added to the design to completely cut off the power to these devices when they are not in use.

The firmware in your application can also have a significant impact on the power consumption of your device. We would always recommend that you use an event-driven design, based on the use of the microcontroller interrupts rather than using polling so that the CPU can stay in the lowest power mode until an actual trigger occurs. As mentioned before, try to move as much functionality from your application as possible into the autonomous functions of the device, again so the CPU can stay in the lowest possible power mode. Any computationally intensive functions should generally be executed at the highest speed possible, so the device can return to sleep as fast as possible.

If you are using a real-time operating system (like FreeRTOS) make sure you select tickless modes to suppress periodic timer ticks during long sleep intervals. A microcontroller may be low power, but if the firmware is not designed to consider the low power requirements, your final application may not be as low power as you hoped.

I hope that this article has given some idea of the techniques that can be used to reduce power in microcontroller applications, it's a complex issue, especially as the complexity of microcontroller applications continues to increase so care should always be taken in any design to reduce the power consumed. There are many benefits that can be realised in every microcontroller design if we keep an eye on the total power consumption. To find out more about low power design, and the low power microcontrollers available from Renesas, please visit our website at www.renesas.com

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Renesas Introduces Smallest Configurable GreenPAK IC with Multi-Time Programmability in Ultra-Compact WLCSP and STQFN Packages

Renesas announced the SLG46801, the industry's smallest GreenPAK configurable mixed-signal device offered in both WLCSP and STQFN packages. The 9-ball WLCSP measures just 1.155 mm × 1.155 mm and combines an ultra-small footprint with multi-time programmability to enable designers to reduce board space in compact products such as smart rings, smartwatches, fitness bands, VR glasses and portable electronics.

As consumer devices become smaller and feature-rich, designers need to integrate additional functionality while reducing component count, PCB area and bill-of-materials cost. The SLG46801 addresses these requirements by combining commonly used analog, timing and logic functions in a compact, low-power device that can complement an MCU or replace multiple discrete components.

The SLG46801 integrates two high-speed analog comparators, configurable lookup tables, counters and delays, 10 kHz and 25 MHz oscillators, voltage-tolerant GPIOs and an I²C-compatible serial interface. These resources support sensing, control, glue-logic, timing and system housekeeping functions in applications across consumer electronics, handheld devices, smart-home systems, networking and communications, computing and storage, industrial control and IoT sensor nodes.

In addition to the 9-ball WLCSP, the SLG46801 is available in a 12-lead, 1.6 mm × 1.6 mm × 0.55 mm STQFN package. The two package options allow customers to balance minimum board area with additional GPIO availability and industrial package preferences. The device also offers one of the lowest costs per GPIO in the GreenPAK family.

Renesas is a leader in configurable mixed-signal technology, with more than four billion GreenPAK devices shipped worldwide. GreenPAK ICs enable designers to combine analog and digital system functions in small, low-power devices that can be configured using the Renesas Go Configure™ Software Hub. The free GUI-based development environment helps customers develop custom hardware functions without the need for additional discrete components or complex firmware development.

The SLG46801 includes multi-time programmable non-volatile memory that can be configured in system through its I²C interface. This allows customers to implement bug fixes, configuration changes and product upgrades after the device has been integrated into the end application, helping reduce redesign cycles and additional hardware revisions.

The device supports operation and programming across the full 1.71 V to 5.5 V supply range - the widest operating and configurable range among MTP GreenPAK devices. GPIO pins can also be repurposed dynamically for the I²C interface, maximizing flexibility in designs with limited pin availability. Optional CRC-8 and read-back protection support more robust and controlled configurable implementations.

"Designers are being asked to integrate more functionality into increasingly compact products without increasing system cost or development effort, while also reducing power consumption," ***said Jason Kim, Vice President and General Manager of the Core Analog Division at Renesas****. "The SLG46801 expands our GreenPAK portfolio with an ultra-compact WLCSP option and flexible in-system configurability, helping customers create smaller, more feature-rich products and implement updates even after deployment."*

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Multimodal interface based on PSOC™

GESTURES, LANGUAGE, DISPLAY: COMPACT HMI WITH EDGE AI

Touch, language, gestures: A demonstrator shows how modern human-machine interaction can be implemented in confined spaces. Embedded intelligence combined with flexible interfaces enables responsive and intuitive operating concepts.

Authors:
Jordan Rose, Field Application Engineer, **Rutronik**
Stephan Menze, Head of Global Innovation Management, **Rutronik**

The way humans interact with machines is evolving at a rapid pace. While touch displays are now the norm, contactless operating concepts are becoming increasingly vital, especially for applications where hygiene, environmental influences or physical limitations matter.

The demonstrator presented here (Figure 1) shows how different sensor principles – radar, speech and touch – can be combined in a single embedded system to form a robust human-machine interface (HMI). The goal was to showcase the robustness of the recognition system against external influences such as bright sunlight, rain, ambient noise, or when hands are dirty or gloves are worn. Developed as part of customer and internal development projects, the demonstrator serves as a practical basis for providing expertise in hardware, software and algorithms for radar gesture recognition and voice control.

Overview of the system architecture

The demonstrator combines all the key elements of a modern, multimodal human-machine interface in a compact design. The integration of gesture and voice control, motor control and graphical display requires a carefully coordinated architecture that accommodates diverse sensor and actuator interfaces while supporting real-time parallel processing.

A key challenge was integrating heterogeneous components with varying electrical interfaces – ranging from high-speed display connections to latency-critical sensor inputs – onto a single microcontroller platform.

The Infineon PSOC Edge supplies the processing power and peripherals for signal processing and control, while the FreeRTOS real-time operating system orchestrates individual tasks and manages data streams and control commands via the internal AHB interconnect bus.



AI-generated illustration Electronica.Azi

Table 1 shows the key hardware components of the demonstrator together with their most important properties and functions.

Gesture recognition with 60 GHz radar

Gesture recognition is the key control element of the demonstrator. Left and right motions are detected, which cause the motor to turn faster or slower, as well as a "push" motion to stop the motor.

At the core lies a 60 GHz FMCW radar sensor for motion detection. Signal processing is performed entirely on the Cortex-M55 core of the PSOC Edge. As machine learning is not used here, development time is reduced and the need for training eliminated.

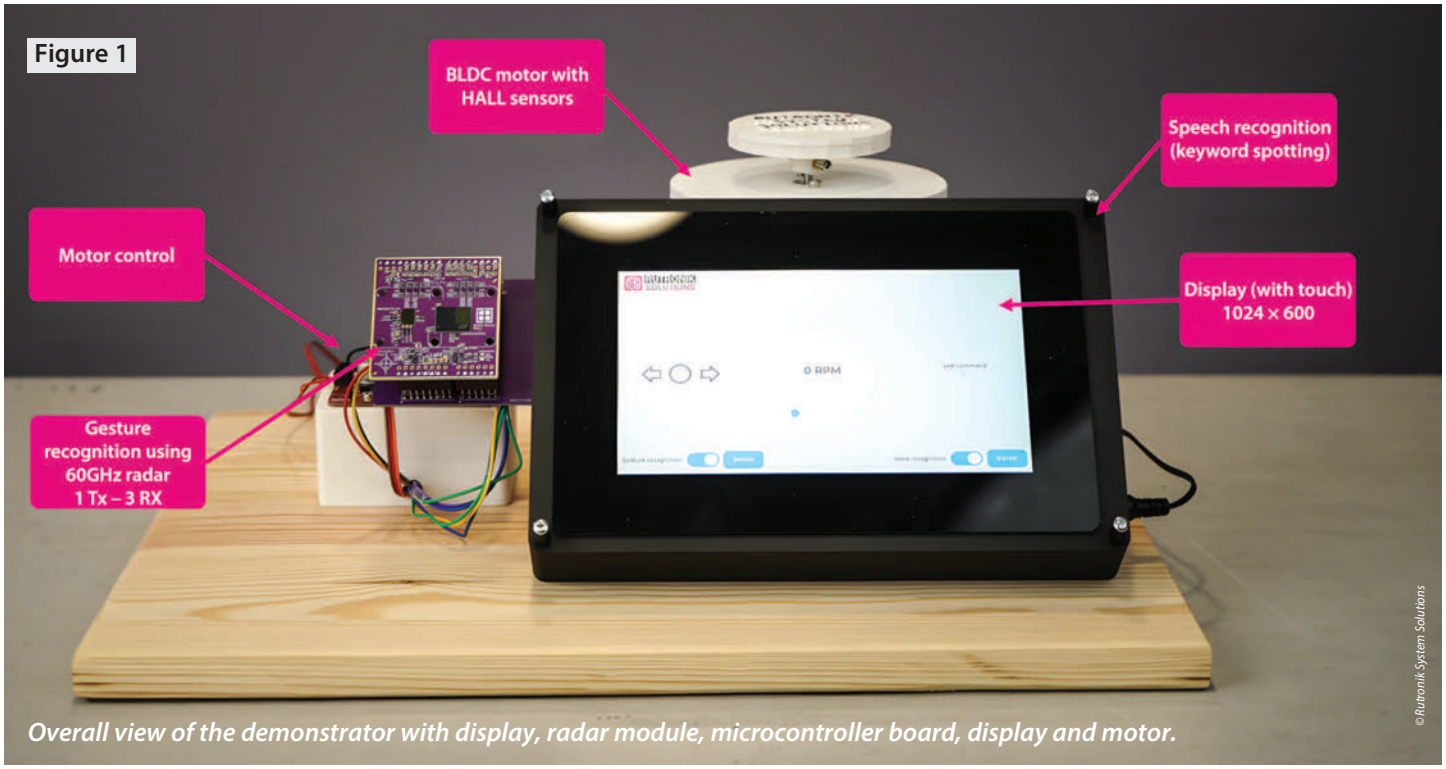
Gesture recognition process in the demonstrator (Figure 2):

- **Input data**: Magnitude and AoA (azimuth only, as currently only the directions "left" and "right" are distinguished).
- **Capture**: A 60 GHz FMCW radar sensor, featuring one transmitting and three receiving antennas, provides a separate signal per antenna.
- **Motion detection**: Doppler FFT per antenna signal for identifying moving targets and suppressing static objects.
- **Direction determination**: Calculation of the azimuth angle from the phase differences of the receiving antenna.
- **Gesture classification**: Evaluation of the temporal progression of the azimuth angle to detect motion types such as "left swipe", "right swipe" or "click".

The latency period is approximately 10 milliseconds after the motion has stopped. Gestures can be recognized at distances of around 5 to 30 centimeters, or also from a greater distance if configured accordingly, even under complex reflection conditions and typical environmental factors such as sunlight.
Incorporating elevation (vertical angle) enables potential recognition of additional gestures such as "up/down".

Gesture recognition is supplemented by voice control using keyword spotting. Voice signals are captured by a MEMS microphone, preprocessed on the PSOC Edge Cortex-M55 and evaluated using a trained neural network. The network with multiple convolution layers is specifically optimized to recognize a limited set of clearly defined keywords, such as "start" or "stop".
The model was developed in Python using the Keras and TensorFlow libraries and subsequently ported to the PSOC Edge for use with Infineon's ML Configurator. Inference runs on the Cortex-M55 with an optimized TensorFlow Lite micro runtime environment.

Figure 1



Overall view of the demonstrator with display, radar module, microcontroller board, display and motor.

Component	Property	Function
BLDC motor with Hall sensors	Control via PWM and GPIOs (Hall sensors)	Rotational speed and direction are adjustable, feedback of the rotor position
IM69D130 XENSIV MEMS digital microphone from Infineon	Connection via digital PDM interface	Capturing audio signals for keyword spotting
1024 × 600 IPS TFT LCD touch from Raystar	Connection via MIPI DSI, capacitive touch technology	Visualization of system states, touch operation
60 GHz radar IC BGT60TR13C from Infineon	Connection via SPI and GPIOs	Gesture recognition through analysis of magnitude, range and azimuth
IFX007T motor control board from Infineon	Triple half-bridge module	Power control of the BLDC motor
Evaluation board with PSOC Edge from Infineon	Multi-core microcontroller with NPU (neural processing unit)	Central processing of radar, audio, display and motor control signals

Table 1: **Key hardware components of the demonstrator with their properties and functions**.

Keyword spotting process (Figure 3):

- **Audio recording**: The digital MEMS microphone (16 kHz sampling rate) provides PDM data.
- **Pre-processing**: Conversion to a MEL filter bank using window slicing (duration: ~530 µs).
- **Inference**: Evaluation of MEL spectra by CNN (multiple convolution layers).
- **Result**: The recognized keyword is transmitted as a control command to the motor control or other system functions.

Motor control for BLDC with Hall sensors

A brushless DC motor (24 V, max. 4,800 RPM), controlled directly by the microcontroller, provides direct feedback for the gesture or voice commands. Using integrated Hall sensors, the system detects the current speed and adjusts it based on gesture or voice commands.

The IFX007T triple half-bridge module from Infineon is used for control, which in turn is controlled via PWM signals and digital control lines. The motor speed is regulated at a sampling rate of 1 kHz, ensuring that changes in speed are implemented quickly and precisely. The motor function primarily serves as a demonstration object but can easily be replaced by other actuators or display systems.

User interface with touch display

A capacitive 7" touch display (with a resolution of 1,024 × 600 pixels) is used to visualize the system states.
It displays, among other data, speed values, recognized gestures and the voice control status.

The graphical user interface is generated directly on the microcontroller using the open source LVGL library. Efficient utilization of memory and processing resources enables real-time concurrent execution of the user interface, gesture recognition and speech processing. The refresh rate of approximately 10 FPS is sufficient for status displays and operational feedback.

Special challenges and learning

A key feature of the demonstrator is the direct comparison of two approaches: conventional signal processing and machine learning (ML). ML was intentionally omitted for 60 GHz radar gesture recognition, as it was not functionally necessary.

This allows for more robust, low-latency recognition without the need for training. The method is insensitive to extraneous light, noise interference and variations in hand position.

In contrast, voice control via keyword spotting uses a pre-trained neural network specifically optimized for a limited set of clearly defined keywords such as "start" and "stop".

This is where machine learning excels, enabling specific responses to recurring, precisely specified events. The algorithms are based on publicly available datasets that were used to improve recognition stability.

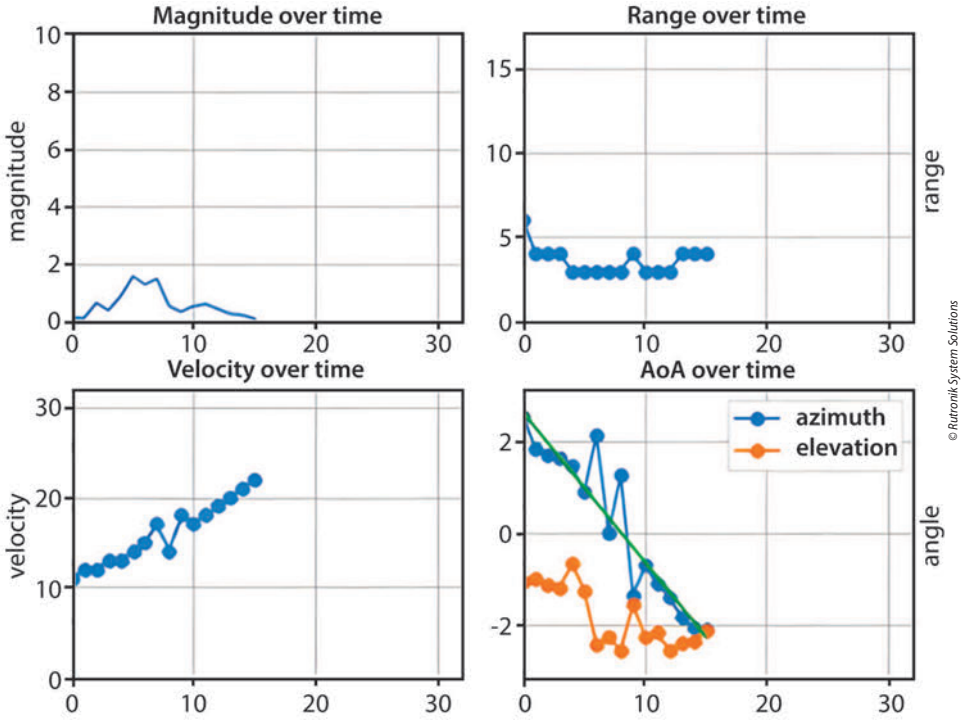


Figure 2 ***Gesture recognition with the BGT60TR13C radar from Infineon.***

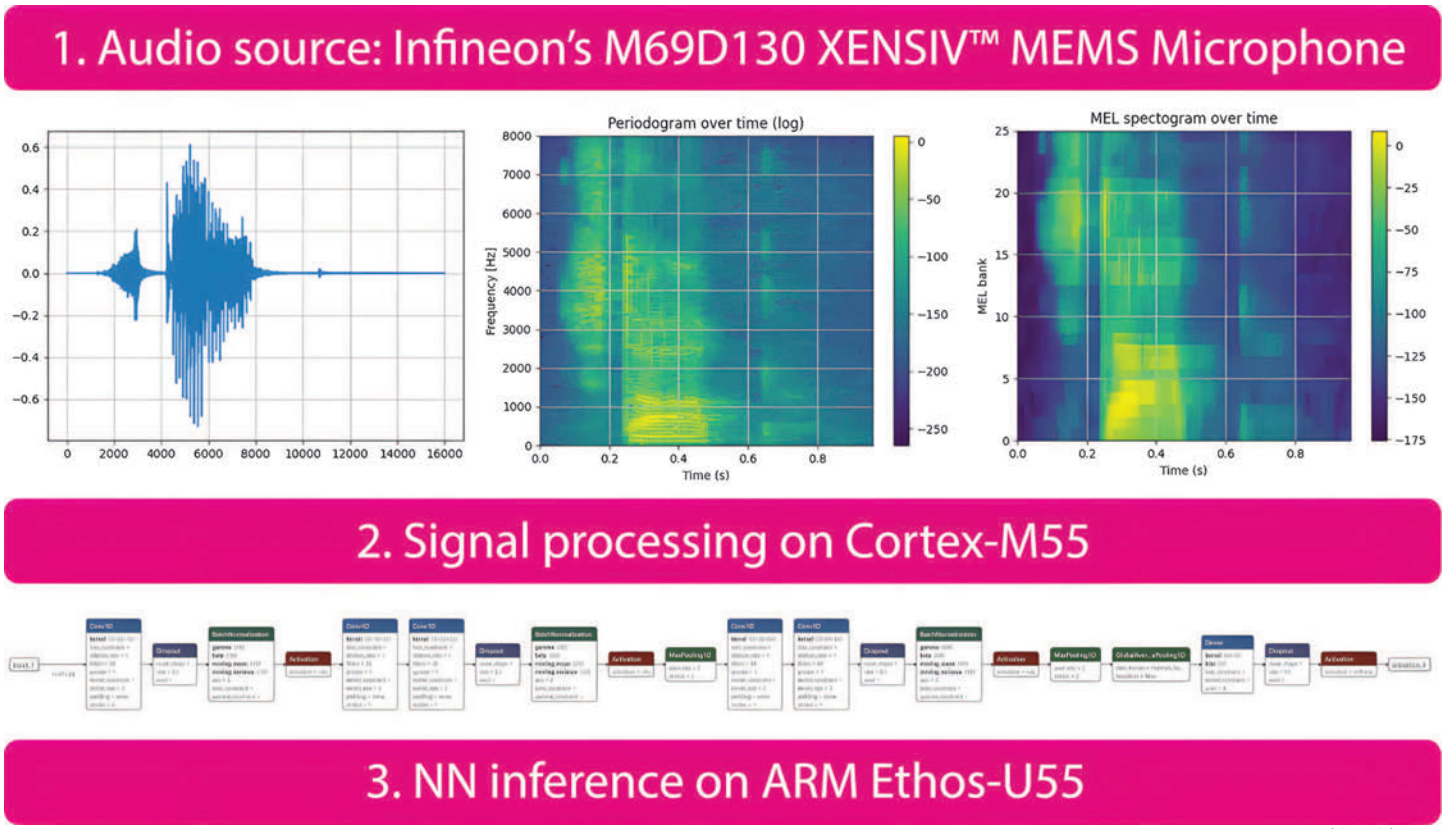


Figure 3 *Keyword spotting process.*

This hybrid approach – applying conventional signal processing where it offers speed and robustness, and machine learning where it enhances recognition – shows how different methods can be optimally combined to create a versatile and practical HMI solution.

Another goal was to demonstrate that all functions, such as gesture recognition, voice control, motor control and graphical display, could be implemented entirely on a single microcontroller.

Achieving this required seamless integration of hardware and software components as well as real-time processing of multiple sensor data streams within the limited resources of an embedded platform. This involved coordinating different interfaces, minimizing latency and assigning priorities in a sensible manner. The modular architecture and strict separation of functional units allow flexible adaptation to diverse application scenarios and offer developers a ready-to-use foundation for custom projects.

Outlook and transferability to real-world applications

The combination of radar, audio and motor control in a single system serves not only as a technical feasibility study but also establishes a practical platform for knowledge transfer. Customers benefit from ready-to-use software examples that they can use to perform their own tests or quickly develop their own environments based on them.

This saves a considerable amount of time during project implementation.

The demonstrator is suitable as a reference platform and can be adapted to customer projects as needed. It can also be used in special laboratory environments like clean rooms or glove boxes.

The hardware and software base, together with supplementary resources, including sample code, circuit diagrams, application notes and instructions, can be provided upon request.

Adjustments to individual requirements can be implemented, for instance, by integrating additional functions, making changes to speech recognition or adding enhancements for gesture recognition.

An example of transferability is deploying a neural network on an RDK2 platform in conjunction with an RAB3 radar.

Once the principles of data collection, training and neural network deployment are understood, these methods can be transferred to other platforms. Infineon's toolset supports this process and simplifies porting.

Moreover, further developments in radar technology are planned to implement additional application examples and expand the range of functions. The demonstrator is therefore not only an actual technology component but also an open platform for developing smart, sensor-based HMI solutions in embedded environments.

References

[1] https://github.com/RutronikSystemSolutions/RAB3-Radar_Documents/blob/main/RAB3-Radar_AppNote_Signal_Processing.pdf *(application note "Signal Processing" from Rutronik System Solutions, August 2024)*

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How to Get Better Measurements, Faster, and Accelerate Product Development



Developing advanced electronic and electromechanical products can be a race against time. Powerful new data acquisition (DAQ) tools can help simplify and accelerate the development process and win the race.

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

Those DAQ tools deliver high performance like 20-bit, ±10 V inputs for sensors, batteries, and other devices at up to 1 MS/s/ch sample rate, up to 16 digital I/O lines, counters, inputs for quadrature encoders, resolvers, pulse/event counting sensors like meters, high-speed voltage signals, voltage drops across a shunt resistor for current measurement and more.

There is also the need to automate and generate multiple functions, including read/write to TTL digital lines, drive low current relays using digital lines, generate ±10 V output control signals and ±10 V signals to simulate sensors, generate pulse-width-modulated (PWM) signals, and synchronize voltage, digital, and counter signals.

To win the race to market, those comprehensive tools must also be simple to use with features like independent timing engines for analog and digital I/O, self-calibration, USB connectivity, and quick setup and integration.

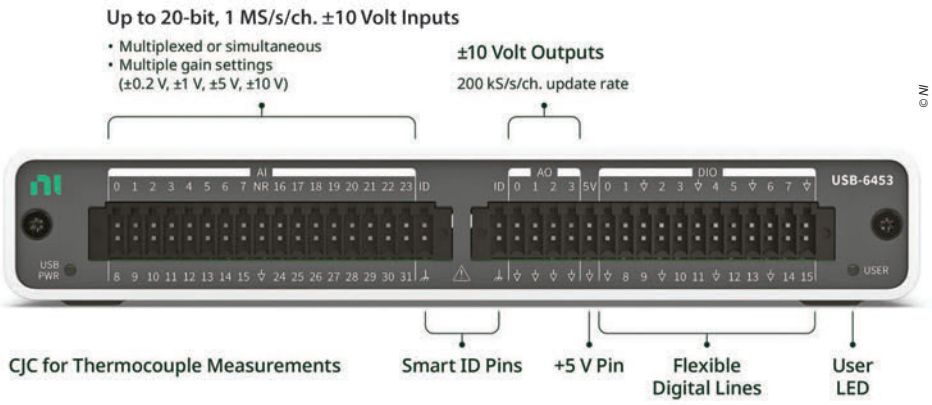


Figure 1 *This side of the mioDAQ USB includes various I/Os. The USB connector is on the opposite side.*



The system should have software options like free logging software, APIs, and example programs, plus advanced support for Python and C/C++.

USB DAQ

NI's new mioDAQ USB system has the performance and flexibility to accelerate time to market for a wide range of electronic and electromechanical systems.
It starts with the use of USB type C connectivity. The mioDAQ USB quickly connects to a laptop or desktop computer with a single cable for data collection, analysis, and powering.
It offers up to 16 channels of 20-bit resolution, ±10 V measurements, and can support 1 million simultaneous samples per second. Plus, it has a variety of digital I/O and counter/timer channels for high performance, flexible test and product development systems (Figure 1).

The smart ID pins communicate with a user-supplied EEPROM so intelligence can be built into a test bench. An EEPROM can be connected directly to the spring terminal plug, or designed into prototype boards. The EEPROM can be queried to:

- Confirm that the cables are plugged into the correct port
- Capture device under test (DUT) information for use in channel and constant mapping
- Automate metadata logging

Cold Junction Compensation (CJC) is used with thermocouples. It corrects for the temperature difference between the thermocouple's hot junction (where the temperature is being measured) and its cold junction (where the thermocouple wires are connected to the measurement system). CJC significantly improves the accuracy of thermocouple measurements, especially when the cold junction temperature fluctuates.

Robust performance

Designed to sit on a desktop, the mioDAQ is robust enough for use in fully automated test fixtures. It's designed to maintain accuracy for up to 10 years without recalibration, making it suitable for use in manufacturing tests or field applications where frequent recalibration can hinder productivity. Models are also available with two-year recalibration cycles, which is ideal for lab bench testing and validation applications.

Self-calibration can adjust for differences in the operating environment and any manufacturing component variances. It's initiated by simply clicking a button in the hardware configuration utility.
The mioDAQ driver stores the self-calibration adjustments in an onboard EEPROM as a multivariable polynomial implemented without significantly impacting processing speed while providing superior performance compared to a simpler linear calibration equation.

Examples of measurements supported by the mioDAQ include:

- Sensors and other ±10 V signals at up to 1 MS/s/ch
- Voltage drops across shunt resistors
- Battery voltages (±10 V peak measurement)
- Power rails on USB or battery-powered designs
- Pulse and event counting
- Quadrature encoders
- Resolvers
- String potentiometers for measuring linear displacement
- Low-voltage current sensors and transformers

Some mioDAQ devices support multiplexing to achieve higher channel counts. Multiplex mode uses a single analog-to-digital converter for multiple analog input channels. While that effectively increases the number of channels, it requires that the overall sample rate is shared by the multiplexed channels, reducing the sample rate for individual channels.

Also, control signals can be automated for a variety of functions like:

- ±10 V output signals
- Digital output signals
- External relay (control with digital lines)

mioDAQ model	USB-6421	USB-6423	USB-6451	USB-6453
Part number	789887-01	789882-01	789888-01	789884-01
Analog input channels (single-ended/differential)	16/8	32/16	16/8	32/16
Maximum sampling rate	250 kS/s (1 channel)	250 kS/s (1 channel)	1 MS/s/ch (8 channels)	1 MS/s/ch (16 channels)
Number of ADCs	1	1	8	16
Simultaneous*	No	No	Yes	Yes
Resolution	16-bit	16-bit	20-bit	20-bit
Analog output channels	2	4	2	4
Digital I/O channels	16	16	16	16
Counters	4	4	4	4

** USB-6451/53 have a multiplexed mode to achieve higher channel counts. See manual for details*

(Table source: NI)

Table 1: **mioDAQ USB is available in four models, enabling users to match performance to application requirements.**

- Generate pulse-width modulated signals
- Simulating sensors
- Connect to LEDs
- Clocks and triggers

Four mioDAQ models, including part numbers 789887-01, 789882-01, 789888-01, and 789884-01, enable the user to purchase the exact performance needed to quickly design better products and pursue research activities (Table 1).

Under the hood

A solid understanding of device specifications and capabilities is needed to realize the maximum benefit. For example, mioDAQ supports three analog input terminal configurations.

Differential mode measures the voltage difference between two input terminals and can be used to minimize the effect of common mode noise. The referenced single-ended (RSE) mode measures the voltage of a signal for a specific reference point isolated from earth ground.

When it is needed to measure the voltage of a signal for a floating or isolated ground with no external ground reference, the non-referenced single-ended (NRSE) mode can be used.

Separate timing engines allow for setting different rates for analog input (AI) channels, analog outputs (AO), and digital I/O (DIO) lines.

For example, the user can choose to:

- Synchronize systems to the same clock and use AI, AO, and DIO, all at the same rate and time
- Trigger on an analog input voltage value
- Trigger multiple subsystems starting at the same time with different run rates
- Re-trigger data acquisition, acquiring a fixed number of samples based on a trigger, then reset and wait for the next trigger event

The NI mioDAQ USB Programmable Function Interface (PFI) is a series of digital I/O lines that can be configured as static digital I/O or used with counter/timer, triggering, and timing functions. They enable greater flexibility of control and monitoring.

For example, the PFI lines can be used for functions like analog acquisition, generating waveforms, or counter events.
Software support, including the NI-DAQmx driver and configuration utilities, simplifies the process of using the PFI lines.

Quick start for a project

Inside the NI mioDAQ box, the user will find the hardware needed for a quick start including an NI mioDAQ, a 2-meter USB-C to USB-C cable with a locking screw (part number **789956-02**), spring terminals (part number **785502-01**), a backshell for the terminals to provide strain relief (part number **785080-01**) and an NI screwdriver for tightening the locking screw on the USB connector. The cable, spring terminals, and backshell can also be purchased separately (Figure 2).

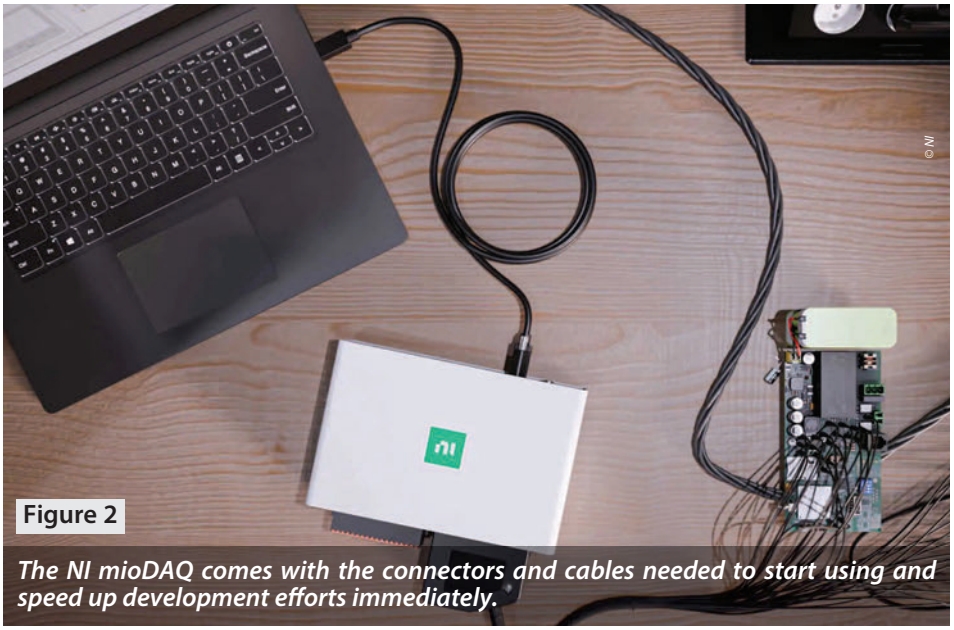


Figure 2

The NI mioDAQ comes with the connectors and cables needed to start using and speed up development efforts immediately.

Software speeds setup and supports flexibility

The user begins mioDAQ setup by scanning the QR code on the device. That takes the user to the NI website page, where the necessary software and documentation can be downloaded. Available resources include the user manual, setup videos, pinout map, and software, including links to download FlexLogger Lite and drivers for LabVIEW, Python, and C/C# to ensure a smooth setup process and minimal setup time.

NI Measurement & Automation Explorer (MAX) free software provides access to NI hardware and acts as a central hub for interacting with NI hardware and software. It's automatically installed with all NI drivers and system configurations. MAX allows configuration of devices, troubleshooting of issues, and even creation of simulated devices for testing purposes without physical hardware.

NI FlexLogger Lite is a free software application for simple projects or new users who want to acquire and log data. Without programming, it lets the user quickly configure, visualize, and log data from sensors and other measurement devices.
FlexLogger Lite automatically detects NI DAQ hardware and provides sensor-specific configuration options. It enables real-time visualization of acquired data, allowing users to monitor measurements as they are being taken. It also supports logging data into common formats like Excel or binary .tdms files.

FlexLogger Lite is a companion to the full-featured FlexLogger software, and the user can choose to upgrade to the full version for more advanced features like automated testing, custom measurements, and scaling to multiple chassis.
For more complex needs, the user can turn to LabVIEW. It runs in Windows and Linux and provides a graphical programming language and development environment for automation, testing, and measurement applications. Its graphical interface makes it easier to visualize and understand complex processes than traditional text-based programming.
It's widely used in industries like aerospace, automotive, and process industries for automating measurements, testing, and data acquisition.

It supports data visualization and analysis and real-time control with deterministic behavior.

For an even more powerful and comprehensive software environment, mioDAQ is compatible with the NI LabVIEW+ Suite, a bundled collection of NI test software designed to streamline the testing and validation processes. It's a comprehensive suite of tools for automation, data acquisition, analysis, and reporting.

Built on LabVIEW, key components of the LabVIEW+ Suite include:

- NI TestStand test framework for designing, managing, and executing test sequences
- InstrumentStudio for interactive instrument configuration and control
- FlexLogger for quick and scalable data logging
- DIAdem provides data analysis and reporting capabilities

Mounting options

mioDAQ USB is more than a desktop device. The user has a selection of vertical or horizontal DIN rail, flat panel, and 19-inch rack mounting for building test stands and automation systems.

The mounting kits are supplied with USB-C cables with right-angle connectors to complete the installation.

Replacement USB-C connectors are also available, part number **789957-02**.

The mounting specifics include (Figure 3):

- Horizontal DIN clip-only kit (part number **789986-01**) is available for horizontal mounting on a standard 35 mm DIN rail. Includes a USB-C cable with right-angle connectors.
- Vertical DIN rail and flat panel mounting using keyholes can be implemented using part number **789955-01**. Includes a USB-C cable with right-angle connectors.
- 19-inch rack mounting using part number **789953-01** that can mount up to two mioDAQ devices and includes two USB-C cables with right-angle connectors.

Conclusion

NI's mioDAQ USB gives the user the depth of hardware performance and the breadth of software tools needed to speed development of advanced electronic and electromechanical products and win the race to market.

It starts with a simplified setup and configuration and continues with measurement calibrations guaranteed for up to 10 years. Models are available with various channel counts to optimize the configuration to the needs of the project. In every case, they provide the accuracy and precision the user demands.

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.

Recommended reading:

1. How to Build a Compact Data Acquisition System
2. Test Software Bundle Simplifies the Creation of Test Programs
3. How to Speed System Design, Validation, and Production Test Using Modular Instruments and Software
4. Implementing a Compact and Flexible Automated Test System Using Multifunction PXI I/O Bundles

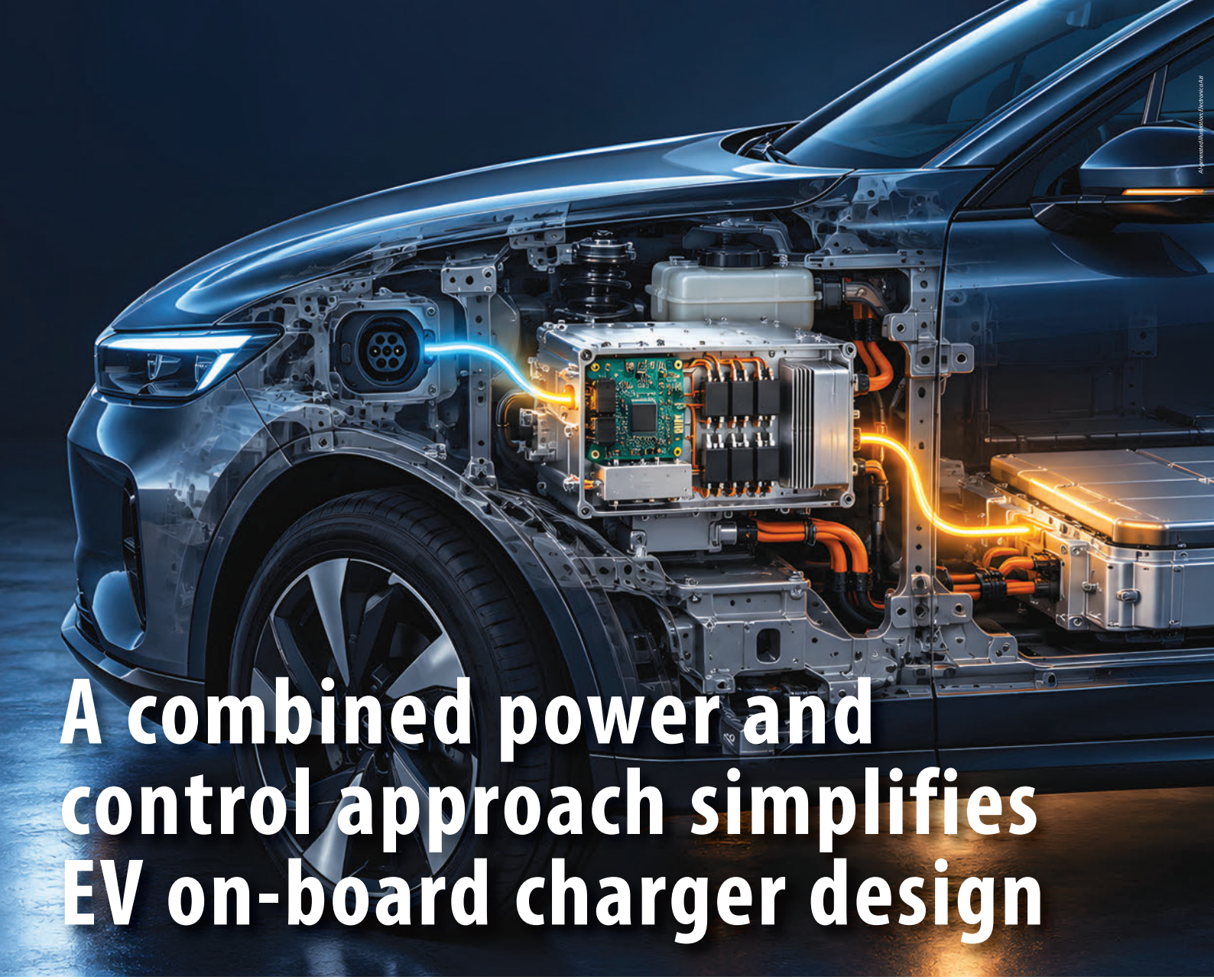
Figure 3



© NI

In addition to sitting on a desktop, mioDAQ mounting assemblies are available for horizontal DIN rail (top left), vertical DIN rail, flat panel mounting (top right), and in a 1U high 19-inch rack configuration (bottom).

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A combined power and control approach simplifies EV on-board charger design

An essential component for electric vehicles (EVs) is the On-Board Charger (OBC), which transforms alternating current (AC) into direct current (DC) to replenish the vehicle's high-voltage battery. The efficacy and dependability of OBCs significantly influence the entire performance and user experience of EVs, rendering them a critical focal point for EV makers.

MICROCHIP

An all-in-one solution

At PCIM 2024 in Nuremberg, Germany, Microchip Technology unveiled an **On-Board Charger (OBC) solution** that incorporates a range of its automotive-qualified digital, analog, connectivity, and power devices in an industry-standard D2PAK-7L XL package. They also released a white paper that offers additional details regarding the optimization of a design's performance and the acceleration of its time to market through the implementation of this OBC solution.

Through advanced control, high-voltage isolation, noise immunity, reduced switching losses, and enhanced thermal management, Microchip's solution improves the efficiency and reliability of OBCs. Microchip provides software modules for power-factor correction (PFC), DC-DC conversion, communication, and diagnostics, which expedites system development and enables customization to satisfy OEM requirements. Figure 1 shows the totem-pole PFC demonstration application with dsPIC33C developed by Microchip.

Microchip's solution aims to enhance the efficiency and reliability of an OBC system by utilizing the advanced control functions of the dsPIC33 DSC and the reduced switching losses and improved thermal management capabilities of the mSiC MOSFETs. To streamline the supply chain for customers, Microchip offers essential technologies that underpin the various operations of an OBC, encompassing communication interfaces, security, sensors, memory, and timing.

Trends in the OBC market

Clayton Pillion, Vice President of Microchip's SiC business unit, anticipates consistent expansion of the EV market in the next two to three years, despite the recent plateau in regions like the U.S.

This underscores the necessity of enhancing charging infrastructure and mitigating range anxiety by using expedited charging cycles.



"Microchip's comprehensive system solution from "dsPIC DSCs through mSiC solutions" can help engineers designing OBC applications to accelerate time-to-market and significantly reduce design complexities"
Clayton Pillion, Corporate Vice President of Microchip's SiC Business Unit.

Enhanced power levels

Higher power density redefines the end-user experience by enhancing the speed and convenience of charging.
Joe Thomsen, Vice President at Microchip's Digital Signal Controller Business Unit, emphasizes the importance of the EV charging infrastructure. During his business trips to China, he could see that EV charging infrastructure in China has almost ten times more EV chargers than the U.S. The voltages that the charging stations provide have also increased. As Thomsen underlines, every time you double the voltage, you halve the current, and that makes it a lot easier to transfer that energy into the vehicle.



"Microchip established an E-Mobility megatrend team with dedicated resources to support this growing market, so in addition to providing the control and power stage for an OBC, we can also provide customers with connectivity, timing, sensors, memory and security solutions"
Joe Thomsen, Corporate Vice President of Microchip's Digital Signal Controller Business Unit

According to Thomsen, another interesting thing related to the charging infrastructure is what some startups and universities research are doing, consisting of attaching the charging station directly to the high-voltage power lines from the power company. These high voltages require a solid-state transformer in the charger.

This solution saves cost, weight, and efficiency, and ultimately it saves electricity.

Bi-directionality

Smart energy management and connectivity support vehicle-to-grid (V2G), vehicle-to-home (V2H), vehicle-to-load (V2L), and vehicle-to-vehicle (V2V) functionalities, enabling bi-directional power management of on-board chargers.

Compact size

The emphasis on compact design and high integration in OBCs is essential for the efficacy and flexibility of EV charging systems. To effectively convert high-voltage power (400V or 800V) to low voltage (12V or 48V) and accommodate various AC inputs (single-phase or three-phase), the integration of low-voltage DC-DC converters is essential.

Thermal management is essential for the correct operation and longevity of OBC systems, particularly at higher power levels.

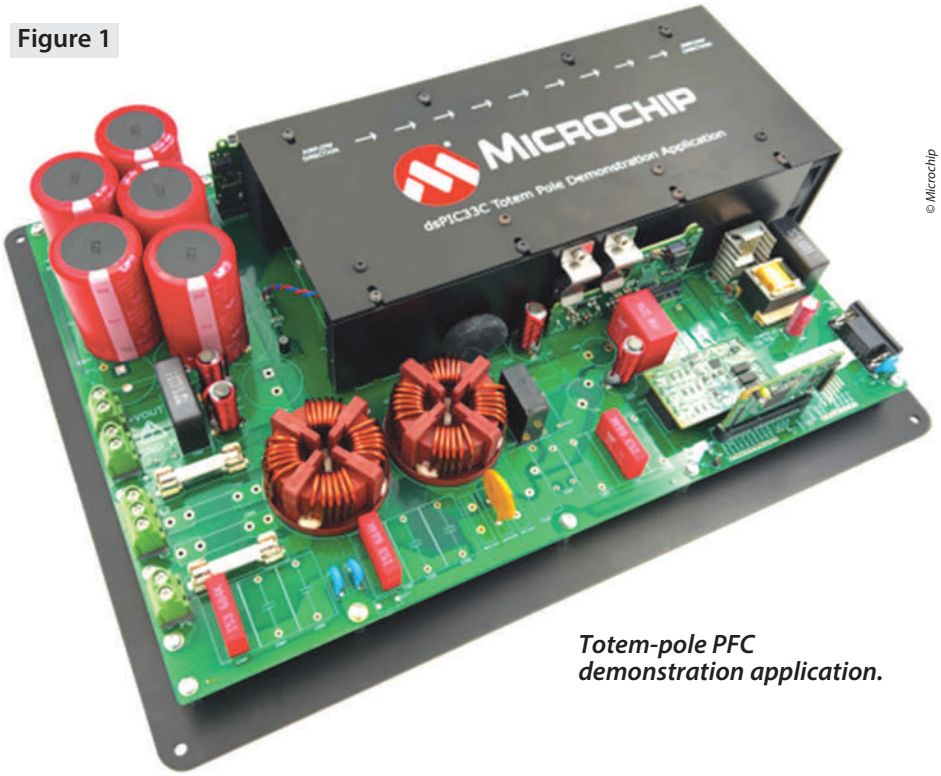
Additionally, OBC systems must adhere to pertinent safety standards and regulations, including IEC 61851 and SAE J1772. To ensure seamless integration with the vehicle's onboard network and external charging infrastructure, OBC systems should support communication interfaces.

Key components

Microchip's OBC solution facilitates the smooth integration of essential components, including the following:

- dsPIC33C Digital Signal Controller (DSC) – This DSC is AEC-Q100 qualified and is designed for power conversion applications.

Figure 1



© Microchip

Totem-pole PFC demonstration application.

The future of EV charging infrastructure and the promotion of sustainable transportation practices on a global scale will be significantly influenced by the adoption of high-power, bi-directional, and integrated on-board chargers as EVs continue to acquire momentum in the automotive industry.

Addressing OBC requirements

To ensure optimal performance and endurance in EVs, OBCs must provide high efficiency, compact physical dimensions, and high reliability ratings.

It includes a high-performance DSP core, high-resolution Pulse-Width Modulation (PWM) modules, and high-speed Analog-to-Digital Converters (ADCs). It is safety-ready, functional, and supports the AUTOSAR® ecosystem

- mSiC MOSFET – The AEC-Q101-qualified D2PAK-7L XL surface mount package features five parallel source sense leads, which minimize switching losses, enhance current capacity, and reduce inductance.

This apparatus accommodates battery voltages of 400V and 800V.

Digital control

The dsPIC33 line of DSCs from Microchip is equipped with a 100 MIPS dsPIC® DSC core, which includes an integrated Digital Signal Processor (DSP) and advanced peripherals. The dsPIC33 series provides significant advantages in OBC applications. The high-performance core and high-speed peripherals collaborate effectively to satisfy the stringent demands of controllers in OBC applications.

The dsPIC33 product line possesses numerous capabilities that facilitate the simplification of functional safety certification for ASIL-B/C automotive safety-critical applications. The dsPIC33 device family encompasses ISO 26262 functional safety packages, FMEDA reports, safety manuals, and diagnostic libraries.

The dsPIC33CH series has a dual-core architecture, with one core assigned to high-performance signal processing and control duties, such as Power Factor Correction (PFC), while the second core oversees control and communication activities. This division of duties enhances system efficiency, enabling the dsPIC to manage intricate control algorithms and communication protocols concurrently without sacrificing speed.

Moreover, being equipped with sophisticated digital signal processing capabilities, the dsPIC can effectively execute intricate algorithms for power conversion, control, and modulation. High-speed signal processing facilitates accurate control of voltage and current waveforms, enhancing power quality and efficiency during the charging process.

SiC power MOSFET

Microchip's SiC solutions in OBC systems provide multiple advantages compared to conventional silicon-based architectures. The recently launched surface mount SiC MOSFET alternatives are optimal for 400V and 800V electric vehicle applications, particularly in space-constrained scenarios like an OBC.

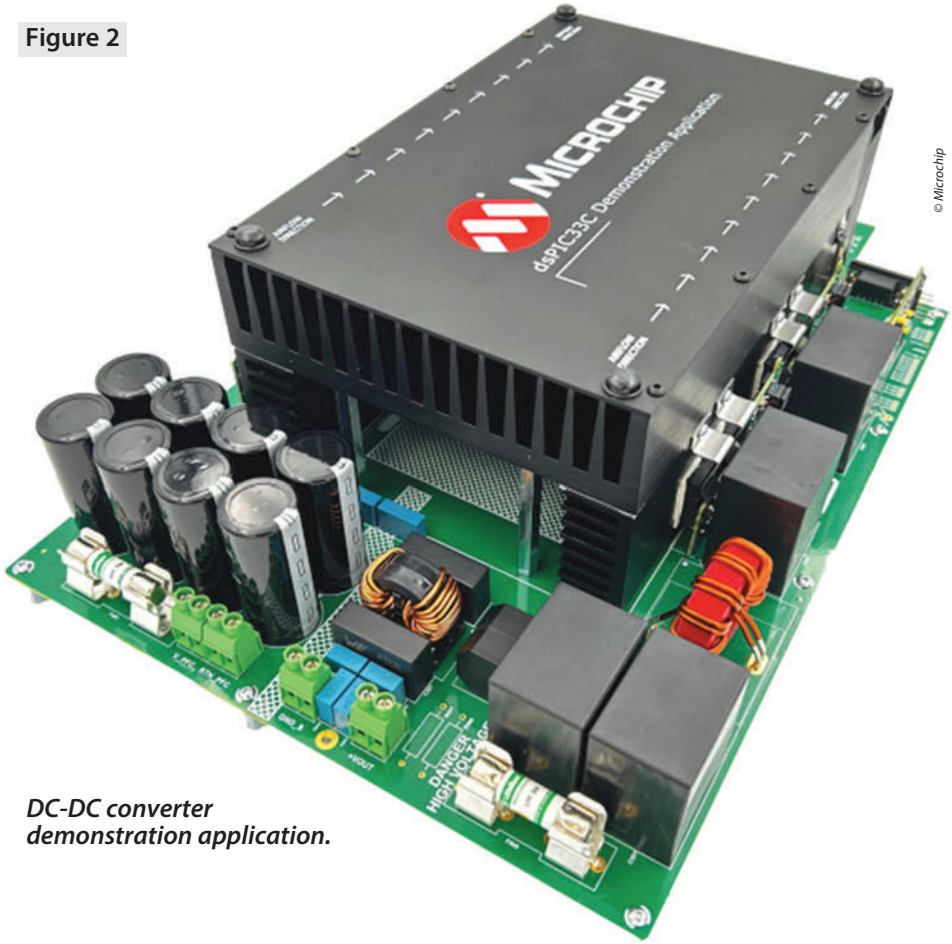
The mSiC MOSFET in a D2PAK-7L XL surface mount package is AEC-Q101 approved, with five parallel source sense leads to minimize switching losses, enhance current capacity, and reduce inductance.

Figure 2 shows the DC-DC demonstration application. Besides the dsPIC33C board, we can see four mSiC power MOSFETs, two on the primary side, and two on the secondary side, separated by the isolation transformer.

Gate drivers

Microchip's configurable mSiC™ gate drivers enhance system power density and minimize switching losses. These digital gate drivers are entirely software configurable and prevent false faults, as well as mitigate ringing, EMI, overshoot, and undershoot in SiC and IGBT power modules integrating the patented Augmented Switching™ technology and robust short-circuit protection.

Figure 2



© Microchip

DC-DC converter demonstration application.

Microchip has implemented a digital strategy to regulate SiC devices while simultaneously guaranteeing the highest levels of reliability and efficiency. Analog control is unreliable for SiC devices and frequently experiences varying degrees of ringing, overshoots, and undershoots, despite the fact that standard analog solutions are excellent alternatives for Silicon devices.

Augmented Switching technology for digital programmable gate drivers offers accurate configurations for activating and deactivating devices, resulting in a smoothing effect on the edges of a gate's output. This technology effectively mitigates voltage overshoot and ringing, enhances system efficiency, and minimizes electromagnetic interference.

Conclusion

Microchip established E-Mobility as one of six key megatrends and has created a team with dedicated resources to support this growing market.

Using Microchip's "dsPIC DSCs through mSiC solutions" as a whole, engineers developing OBC apps can cut down on design complexity and speed up time-to-market.

Microchip, a reliable source for automotive original equipment manufacturers and top suppliers, supplies the core technology for an OBC system, which improves supply chain management and streamlines operations.

■ **Microchip Technology**
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MICROCHIP



Mouser Offers Engineers the Latest in Power Solutions from Bourns

Mouser Electronics, Inc., the authorised global distributor with the newest electronic components and industrial automation products, offers an extensive selection of solutions from Bourns, a leading manufacturer of automotive sensors, circuit protection solutions, magnetic products, and resistive products serving markets, including industrial, automotive, telecommunications, computing, and consumer electronics. Mouser currently stocks over 21,000 Bourns parts, with more than 50,000 parts available to order. Over the past 15 years, Mouser has received eight Global Distributor of the Year awards from Bourns, along with two European Distributor of the Year awards.

Components for efficient power conversion and delivery

Available from Mouser, the MAG-3002584 high-power inductor offers 87 µH inductance for high-frequency power factor correction (PFC) and inverter applications in high-voltage three-phase power systems. The inductor features low direct current resistance (DCR) and a 42A saturation current, enabling high efficiency and high-power-density operation for applications such as data centres, servers, onboard chargers, string inverters, and fast-charging stations.

The Bourns High-Power Modular Contacts provide current ratings of up to 8A per contact, making them ideal for applications requiring enhanced power delivery. Available in the 75AB, 76AA, and 78AD series, these contacts feature compact footprints, auto-centring capability, pick-and-place compatibility, and a minimum lifecycle rating of 50,000 cycles. Typical applications include industrial automation, medical equipment, handheld communications devices, eMobility systems, and portable consumer electronics.

The HCTSM110304HAL transformer is engineered to meet demanding isolation requirements in power conversion systems. The transformer's high-clearance and creepage design helps engineers develop reliable, high-efficiency power solutions while supporting the stringent safety requirements of modern industrial and power electronics applications.

The CSS4C-1216 current-sense resistors deliver accurate current measurements in a compact package optimised for high-power designs. Featuring low resistance values and robust thermal performance, these resistors help improve power efficiency and measurement accuracy in applications such as power supplies, battery management systems, motor drives, and industrial controls.

To learn more about the complete selection, visit www.mouser.com/en/manufacturer/bourns/.

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Building High Performance Robotic Vision with GMSL

This article examines how cameras are deployed in robotics, the connectivity challenges they face, and how GMSL can enable scalable, robust, and performance-driven robotic platforms.

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Analog Devices

Robotic systems increasingly rely on vision to perceive and interact with their environment, creating growing demands for high speed, low latency data links. Gigabit Multimedia Serial Link (GMSLTM) offers a promising solution by transmitting video, control signals, and power over a single cable with high reliability.

Introduction

Robotic systems increasingly depend on advanced machine vision to perceive, navigate, and interact with their environment. As both the number and resolution of cameras grow, the demand for high speed, low latency links capable of transmitting and aggregating real-time video data has never been greater.

Gigabit Multimedia Serial Link (GMSL™), originally developed for automotive applications, is emerging as a powerful and efficient solution for robotic systems. GMSL transmits high speed video data, bidirectional control signals, and power over a single cable, offering long cable reach, deterministic microsecond-level latency with an extremely low bit error rate (BER).

It simplifies the wiring harness and reduces the total solution footprint, ideal for vision-centric robots operating in dynamic and often harsh environments.
The following sections discuss where and how cameras are used in robotics, the data and connectivity challenges these applications face, and how GMSL can help system designers build scalable, reliable, and high performance robotic platforms.

Where Are Cameras Used in Robotics?

Cameras are at the heart of modern robotic perception, enabling machines to understand and respond to their environment in real time.

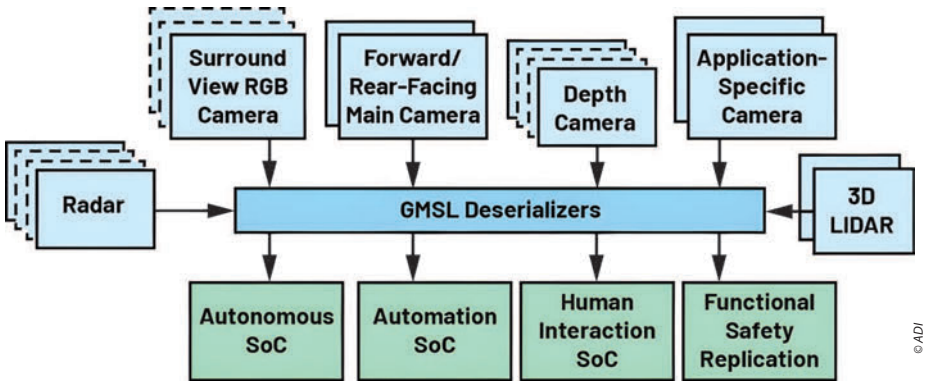


Figure 1 *Example multimodal robotic vision system enabled by GMSL.*

Whether it's a warehouse robot navigating aisles, a robotic arm sorting packages, or a service robot interacting with people, vision systems are critical for autonomy, automation, and interaction. These cameras are not only diverse in function but also in form – mounted on different parts of the robot depending on the task and tailored to the physical and operational constraints of the platform (see Figure 1).

Autonomy

In autonomous robotics, cameras serve as the eyes of the machine, allowing it to perceive its surroundings, avoid obstacles, and localize itself within an environment. For mobile robots – such as delivery robots, warehouse shuttles, or agricultural rovers – this often involves a combination of wide field-of-view cameras placed at the corners or edges of the robot. These surround-view systems provide 360° awareness, helping the robot navigate complex spaces without collisions.

Other autonomy-related applications use cameras facing downward or upward to read fiducial markers on floors, ceilings, or walls. These markers act as visual signposts, allowing robots to recalibrate their position or trigger specific actions as they move through structured environments like factories or hospitals. In more advanced systems, stereo vision cameras or time of flight (ToF) cameras are placed on the front or sides of the robot to generate three-dimensional maps, estimate distances, and aid in simultaneous localization and mapping (SLAM). The location of these cameras is often dictated by the robot's size, mobility, and required field of view. On small sidewalk delivery robots, for example, cameras might be tucked into recessed panels on all four sides.

On a drone, they're typically forward-facing for navigation and downward facing for landing or object tracking.

Automation

In industrial automation, vision systems help robots perform repetitive or precision tasks with speed and consistency. Here, the camera might be mounted on a robotic arm – right next to a gripper or end-effector – and the system can visually inspect, locate, and manipulate objects with high accuracy. This is especially important in pick-and-place operations, where identifying the exact position and orientation of a part or package is essential.

Other times, cameras are fixed above a work area – mounted on a gantry or overhead rail – to monitor items on a conveyor or to scan barcodes. In warehouse environments, mobile robots use forward-facing cameras to detect shelf labels, signage, or QR codes, enabling dynamic task assignments or routing changes.
Some inspection robots, especially those used in infrastructure, utilities, or heavy industry, carry zoom-capable cameras mounted on masts or articulated arms. These allow them to capture high resolution imagery of weld seams, cable trays, or pipe joints – tasks that would be dangerous or time-consuming for humans to perform manually.

Human Interaction

Cameras also play a central role in how robots engage with humans. In collaborative manufacturing, healthcare, or service industries, robots need to understand gestures, recognize faces, and maintain a sense of social presence. Vision systems make this possible.
Humanoid and service robots often have cameras embedded in their head or chest, mimicking the human line of sight to enable natural interaction. These cameras help the robot interpret facial expressions, maintain eye contact, or follow a person's gaze. Some systems use depth cameras or fisheye lenses to track body movement or detect when a person enters a shared workspace.

In collaborative robot (cobot) scenarios, where humans and machines work side by side, machine vision is used to ensure safety and responsiveness. The robot may watch for approaching limbs or tools, adjusting its behavior to avoid collisions or pause work if someone gets too close.
Even in teleoperated or semi-autonomous systems, machine vision remains key. Front-mounted cameras stream live video to remote operators, enabling real-time control or inspection. Augmented reality overlays can be added to this video feed to assist with tasks like remote diagnosis or training.
Across all these domains, the camera's placement – whether on a gripper, a gimbal, the base, or the head of the robot – is a design decision tied to the robot's function, form factor, and environment. As robotic systems grow more capable and autonomous, the role of vision will only deepen, and camera integration will become even more sophisticated and essential.

Robotics Vision Challenges

As vision systems become the backbone of robotic intelligence, opportunity and complexity grow in parallel. High performance cameras unlock powerful capabilities – enabling real-time perception, precise manipulation, and safer human interaction – but they also place growing demands on system architecture.

It's no longer just about moving large volumes of video data quickly. Many of today's robots must make split-second decisions based on multimodal sensor input, all while operating within tight mechanical envelopes, managing power constraints, avoiding electromagnetic interference (EMI), and maintaining strict functional safety in close proximity to people.

These challenges are compounded by the environments robots face. A warehouse robot may shuttle in and out of freezers, enduring sudden temperature swings and condensation. An agricultural rover may crawl across unpaved fields, absorbing constant vibration and mechanical shock. Service robots in hospitals or public spaces may encounter unfamiliar, visually complex settings, where they must quickly adapt to safely navigate around people and obstacles.

Solve the Challenges with GMSL

GMSL is uniquely positioned to meet the demands of modern robotic systems. The combination of bandwidth, robustness, and integration flexibility makes it well suited for sensor-rich platforms operating in dynamic, mission-critical environments. The following features highlight how GMSL addresses key vision-related challenges in robotics.

High Data Rate and Low Latency

The GMSL2™ and GMSL3™ product families support forward-channel (video path) data rates of 3 Gbps, 6 Gbps, and 12 Gbps, covering a wide range of robotic vision use cases. These flexible link rates allow system designers to optimize for resolution, frame rate, sensor type, and processing requirements (Figure 2).

A 3 Gbps link is sufficient for most surround view cameras using 2 MP to 3 MP rolling shutter sensors at 60 frames per second (FPS). It also supports other common sensing modalities, such as ToF sensors and light detection and ranging (LIDAR) units with point-cloud outputs and radar sensors transmitting detection data or compressed image-like returns.

The 6 Gbps mode is typically used for the robot's main forwardfacing camera, where higher resolution sensors (usually 8 MP or more) are required for object detection, semantic understanding, or sign recognition.

This data rate also supports ToF sensors with raw output, or stereo vision systems that either stream raw output from two image sensors or output processed point cloud stream from an integrated image signal processor (ISP).

Many commercially available stereo cameras today rely on this data rate for high frame-rate performance.

At the high end, 12 Gbps links enable support for 12 MP or higher resolution cameras used in specialized robotic applications that demand advanced object classification, scene segmentation, or long-range perception.

Across all link rates, GMSL maintains impressively low latency: the added delay from the input of a GMSL serializer to the output of a deserializer typically falls in the lower tens of microseconds – negligible for most real-time robotic vision systems.

The deterministic reverse-channel latency enables precise hardware triggering from the host to the camera – critical for synchronized image capture across multiple sensors, as well as for time-sensitive, event-driven frame triggering in complex robotic workflows. Achieving this level of timing precision with USB or Ethernet cameras typically requires the addition of a separate hardware trigger line, increasing system complexity and cabling overhead.

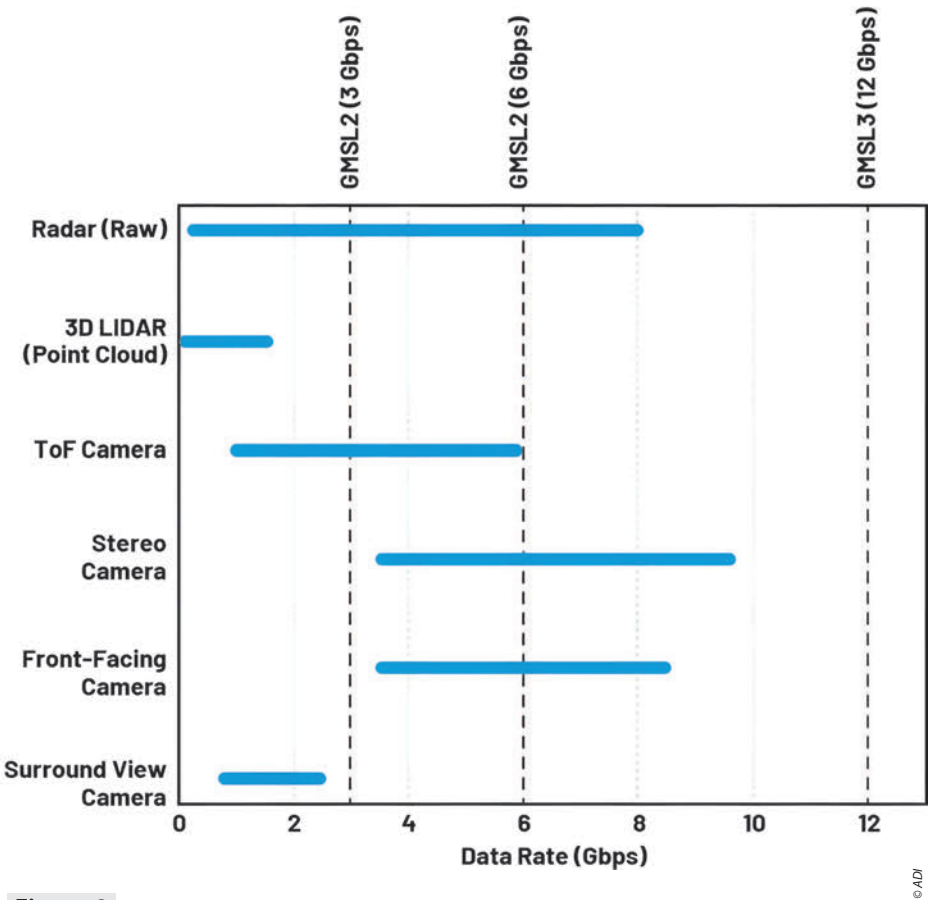


Figure 2 *Sensor bandwidth ranges with GMSL capabilities.*

Interestingly, even some low resolution global shutter sensors require higher speed links to reduce readout time and avoid motion artifacts during fast capture cycles, which is critical in dynamic or high speed environments.

Because GMSL uses frequency-domain duplexing to separate the forward (video and control) and reverse (control) channels, it enables bidirectional communication with low and deterministic latency, without the risk of data collisions.

Small Footprint and Low Power

One of the key value propositions of GMSL is its ability to reduce cable and connector infrastructure. GMSL itself is a full-duplex link, and most GMSL cameras utilize the power-over-coax (PoC) feature, allowing video data, bidirectional control signals, and power to be transmitted over a single thin coaxial cable.

This significantly simplifies wiring, reduces the overall weight and bulk of cable harnesses, and eases mechanical routing in

compact or articulated robotic platforms (Figure 3). In addition, the GMSL serializer is a highly integrated device that combines the video interface (for example, MIPI-CSI) and the GMSL PHY into a single chip. The power consumption of the GMSL serializer, typically around 260 mW in 6 Gbps mode, is favorably low compared to alternative technologies with similar data throughput.

All these features will translate to smaller board areas, reduced thermal management requirements (often eliminating the need for bulky heatsinks), and greater overall system efficiency, particularly for battery-powered robots.

Sensor Aggregation and Video Data Routing

GMSL deserializers are available in multiple configurations, supporting one, two, or four input links, allowing flexible sensor aggregation architectures.

This enables designers to connect multiple cameras or sensor modules to a single processing unit without additional switching or external muxing, which is especially useful in multicamera robotics systems.

In addition to the multiple inputs, GMSL SERDES also supports advanced features to manage and route data intelligently across the system. These include:

- I²C and GPIO broadcasting for simultaneous sensor configuration and frame synchronization.
- I²C address aliasing to avoid I²C address conflict in passthrough mode.
- Virtual channel reassignment, allowing multiple video streams to be mapped cleanly into the frame buffer inside the systems on chip (SoCs).
- Video stream duplication and virtual channel filtering, enabling selected video data to be delivered to multiple SoCs – for example, to support both automation and interaction pipelines from the same camera feed or to sup port redundant processing paths for enhanced functional safety.

Safety and Reliability

Originally developed for automotive advanced driver assistance systems (ADAS) applications, GMSL has been field-proven in environments where safety, reliability, and robustness are non-negotiable. Robotic systems, particularly those operating around people or performing mission-critical industrial tasks, can benefit from the same high standards.

Most GMSL serializers and deserializers are qualified to operate across a –40°C to +105°C temperature range, with built-in adaptive equalization that continuously monitors and adjusts transceiver settings in response to environmental changes. This provides system architects with the flexibility to design robots that function reliably in extreme or fluctuating temperature conditions.

In addition, most GMSL devices are ASIL-B compliant and exhibit extremely low BERs. Under compliant link conditions, GMSL2 offers a typical BER of 10–15, while GMSL3, with its mandatory forward error correction (FEC), can reach a BER as low as 10–30. This exceptional data integrity, combined with safety certification, significantly simplifies system-level functional safety integration.

Ultimately, GMSL's robustness leads to reduced downtime, lower maintenance costs, and greater confidence in long-term system reliability – critical advantages in both industrial and service robotics deployments.

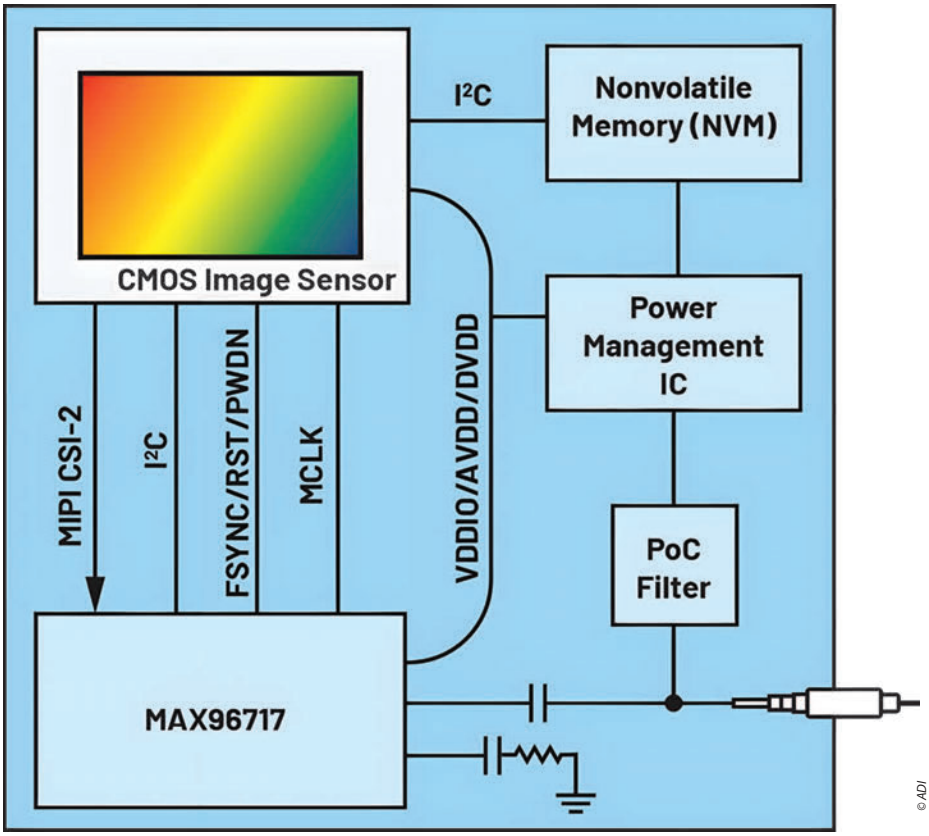


Figure 3 *A typical GMSL camera architecture using the MAX96717.*

Mature Ecosystem

GMSL benefits from a mature and deployment-ready ecosystem, shaped by years of high volume use in automotive systems and supported by a broad network of global ecosystem partners. This includes a comprehensive portfolio of evaluation and production-ready cameras, compute boards, cables, connectors, and software/driver support – all tested and validated under stringent real-world conditions. For robotics developers, this ecosystem translates to shorter development cycles, simplified integration, and a lower barrier to scale from prototype to production.

GMSL vs. Legacy Robotics Vision Connectivity

In recent years, GMSL has become increasingly accessible beyond the automotive industry, opening new possibilities for high performance robotic systems. As the demands on robotic vision grow with more cameras, higher resolution, tighter synchronization, and harsher environments, traditional interfaces like USB and Ethernet often fall short in terms of bandwidth, latency, and integration complexity.

Feature/Criteria	GMSL (GMSL2/GMSL3)	USB (for example, USB 3.x)	Ethernet (for example, GigE Vision)
Cable Type	Single coax or STP (data + power + control)	Separate USB + power + general-purpose input/output (GPIO)	Separate Ethernet + power (PoE optional) + GPIO
Max Cable Length	15+ meters with coax	3 m reliably	100 m with Cat5e/Cat6
Power Delivery	Integrated (PoC)	Requires separate or USB-PD	Requires PoE infrastructure or separate cable
Latency (Typical)	Tens of microseconds (deterministic)	Millisecond-level, OS-dependent	Millisecond-level, buffered + OS/network stack
Data Rate	3 Gbps/6 Gbps/12 Gbps (uncompressed, per link)	Up to 5 Gbps (USB 3.1 Gen 1)	1 Gbps (GigE), 10 Gbps (10 GigE, uncommon in robotics)
Video Compression	Not required (raw or ISP output)	Often required for higher resolutions	Often required
Hardware Trigger Support	Built-in via reverse channel (no extra wire)	Requires extra GPIO or USB communications device class (CDC) interface	Requires extra GPIO or sync box
Sensor Aggregation	Native via multi-input deserializer	Typically point-to-point	Typically point-to-point
EMI Robustness	High—designed for automotive EMI standards	Moderate	Moderate to high (depends on shielding, layout)
Environmental Suitability	Automotive-grade temp, ruggedized	Consumer-grade unless hardened	Varies (industrial options exist)
Software Stack	Direct MIPI-CSI integration with SoC	OS driver stack + USB video device class (UVC) or proprietary software development kit (SDK)	OS driver stack + GigE Vision/ GenICam
Functional Safety Support	ASIL-B devices, data replication, deterministic sync	Minimal	Minimal
Deployment Ecosystem	Mature in ADAS, growing in robotics	Broad in consumer/PC, limited industrial options	Mature in industrial vision
Integration Complexity	Moderate—requires SERDES and routing config	Low—plug and play for development High—for production	Moderate—needs switch/router config and sync wiring

Table 1: ***GMSL vs. Ethernet: Trade-Offs in Robotic Vision.***

GMSL is now emerging as a preferred upgrade path, offering a robust, scalable, and production-ready solution that is gradually replacing USB and Ethernet in many advanced robotics platforms. Table 1 compares the three technologies across key metrics relevant to robotic vision design.

Conclusion

As robotics moves into increasingly demanding environments and across diverse use cases, vision systems must evolve to support higher sensor counts, greater bandwidth, and deterministic performance. While legacy connectivity solutions will remain important for development and certain deployment scenarios, they introduce trade-offs in latency, synchronization, and system integration that limit scalability.

GMSL, with its combination of high data rates, long cable reach, integrated power delivery, and bidirectional deterministic low latency, provides a proven foundation for building scalable robotic vision systems. By adopting GMSL, designers can accelerate the transition from prototype to production, delivering smarter, more reliable robots ready to meet the challenges of a wide range of real-world applications.

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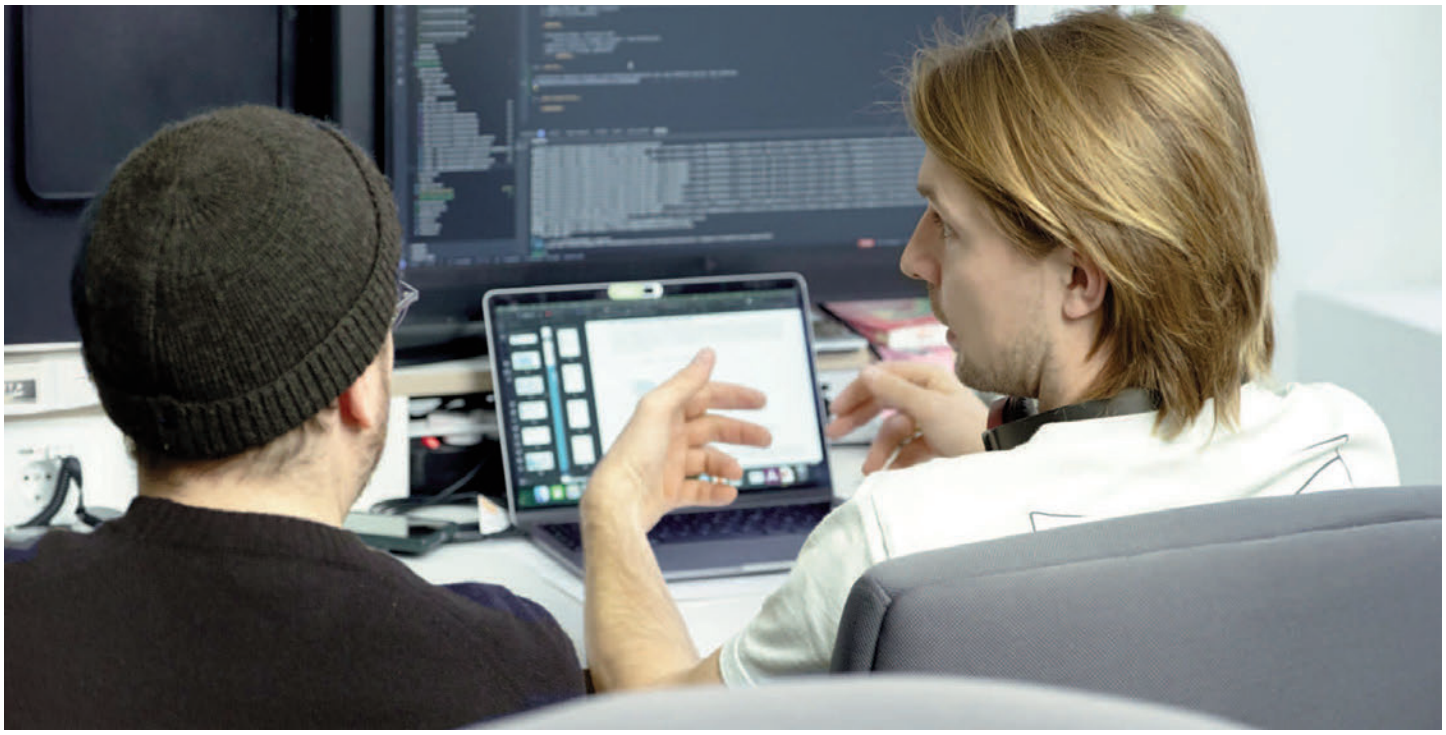
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About the Author:

Kainan Wang is a systems applications engineer in the Automotive Business Unit at Analog Devices in Wilmington, Massachusetts.

He joined Analog Devices in 2016 after receiving an M.S. in electrical engineering from Northeastern University in Boston, Massachusetts. Kainan has been working with 2D/3D imaging solutions from hardware development and systems integrations to applications development.

Most recently, his work focus is to expand ADI automotive technologies into other markets beyond automotive.



OPTIFICIENT™ software solution by Industrial Analytics helps reduce energy consumption and operating costs of heating, ventilation and air conditioning systems

Industrial Analytics IA GmbH, an Infineon Technologies AG company, will showcase its software solution OPTIFICIENT™ at EXPO REAL 2026. Rising temperatures and increasing cooling demand are putting growing pressure on facility management teams to optimize heating, ventilation and air conditioning systems across entire buildings and facility portfolios – not only through new equipment, but through smarter operation of existing infrastructure. Developed and validated under semiconductor-grade operational requirements, OPTIFICIENT helps building operators and facility management providers reduce heating, ventilation and air conditioning (HVAC)-related energy costs, lower emissions and improve operational efficiency across large facility portfolios.

OPTIFICIENT can be integrated seamlessly into existing building automation environments. It is based on hybrid AI models that combine advanced AI capabilities with physics-based models capturing the operational expertise of HVAC specialists and engineers. This enables automated optimization based on real-world system behavior. Rather than simply reporting inefficiencies, OPTIFICIENT continuously identifies optimal operating conditions for HVAC systems and automatically adjusts setpoints in real time to improve energy performance while safeguarding operational constraints. Compared to purely statistical approaches, this methodology provides greater transparency and operational confidence, particularly in mission-critical environments such as industrial production facilities, data centers and hospitals, as well as in office buildings.

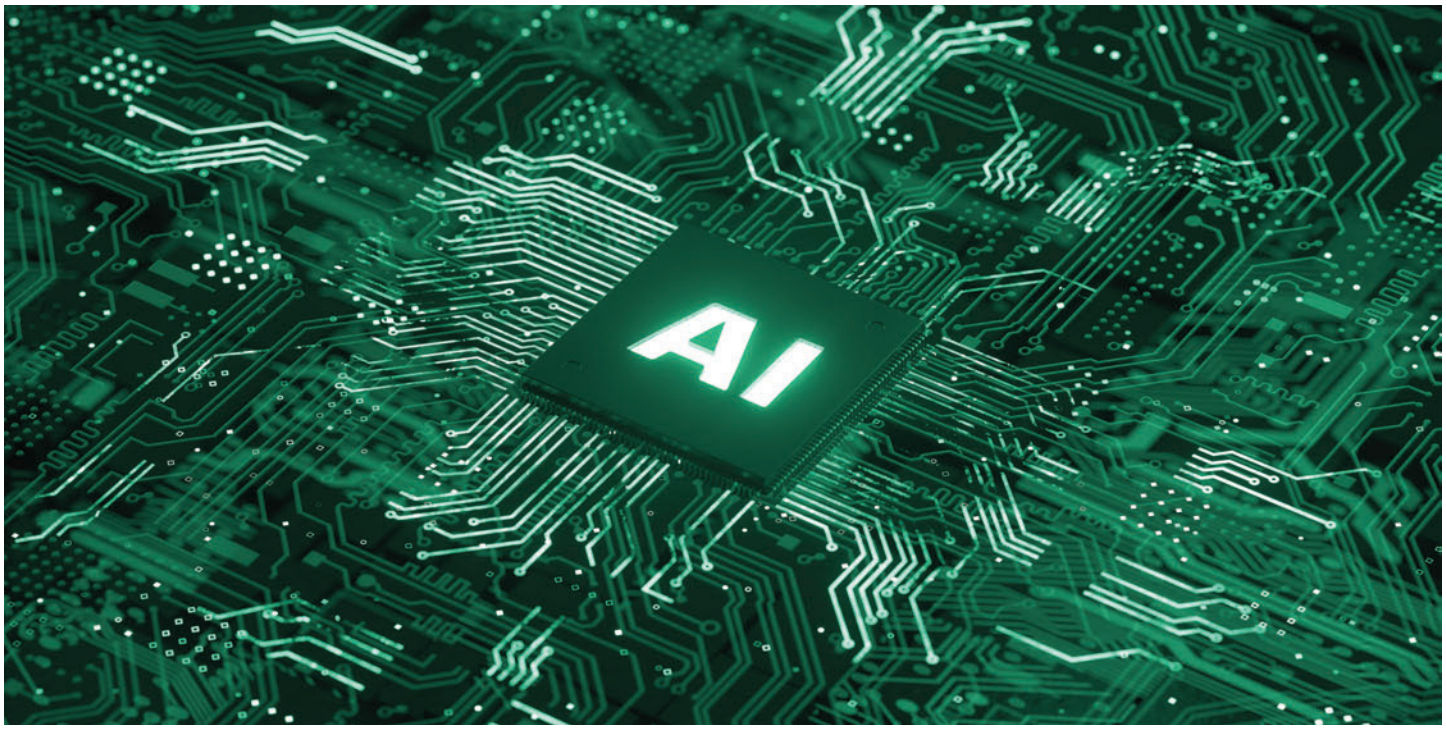
Depending on the building type and baseline operating conditions, OPTIFICIENT has delivered annual HVAC-related energy cost savings ranging from five to 30 percent in completed projects. It supports optimization across key HVAC functions, including heating and cooling generation, air treatment and distribution, making it applicable to a wide range of commercial and industrial facilities. This flexibility enables organizations to address optimization opportunities across different facility types and scale deployments consistently across entire building portfolios.

As a white-label software solution, OPTIFICIENT enables facility management companies and building automation providers to offer AI-powered HVAC optimization services under their own brand. This allows organizations to expand their service portfolios without developing in-house AI expertise or committing significant development resources. OPTIFICIENT can be deployed in cloud environments or entirely on-premises to meet customer data governance and security requirements.

OPTIFICIENT was designed as a software add-on and integrates with existing building management, energy management and operational systems, regardless of the underlying hardware or software infrastructure. This minimizes implementation effort and investment risk, allowing operators to continue using their existing IT and building automation systems.

Originally developed for highly demanding industrial environments and validated in real-world production and building operations, including facilities and manufacturing sites operated by Infineon, the technology now brings this experience to commercial real estate, office buildings and industrial facilities.

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Farnell Expands Access to Emerson's NI Nigel™ AI, Helping Test Engineers Accelerate Development with Purpose-Built AI

Farnell is expanding access to Emerson's NI Nigel™ AI, a purpose-built AI technology for test and measurement. New enhancements, now available through Farnell, advance the technology from AI advisor to AI author with new code generation and automated test development capabilities across the NI software portfolio. These enhancements help bring Emerson's AI-enabled test capabilities to more engineers worldwide, accelerating development while maintaining the rigor, oversight and validation essential to modern test and measurement environments.

As engineering systems become increasingly software-defined and connected, test engineers face growing pressure to manage more complex development and validation workflows without compromising quality or increasing development time. Unlike general-purpose AI tools, NI Nigel AI is designed by Emerson for test engineering environments, providing context-aware assistance that understands engineering code and workflows, existing test systems and application data. Embedded within the NI software, Nigel AI helps engineers accelerate tasks such as code generation, debugging, sequence development and system understanding. With Emerson's latest enhancements, Nigel AI is moving beyond supportive guidance into AI-assisted authorship, including prompt-based code generation within NI LabVIEW™ and automated sequence generation in NI TestStand™. This enables engineers to move from design to validation more quickly while remaining in control of reviewing, validating and deploying their work.

At NI Connect 2026, Emerson engineers demonstrated Nigel AI's practical impact by reducing a task that had previously required about 20 hours of work spread across two weeks using conventional coding AI tools into a workflow completed in approximately 20 minutes, delivering working results on the first attempt.

Built on the AI-ready NI platform, Nigel AI connects hardware, software, data and engineering workflows to provide intelligent assistance across the full test lifecycle. Rather than operating as a standalone AI tool, it integrates into existing engineering environments, supporting development, validation, troubleshooting and deployment while helping reduce repetitive tasks and streamline complex workflows.

***Andy Weatherill, Global Head of Product and Technology, Farnell, said**: "AI has enormous potential to improve engineering productivity, but its real value comes when it fits naturally into the way engineers already work. By making Emerson's NI Nigel AI available through Farnell, we're helping customers adopt purpose-built AI that complements engineering expertise, accelerates development, and supports the high standards of quality and validation that modern test environments demand."*

***Siddarth Sethi, Vice President and General Manager, NI Test and Analytics Software, Test & Measurement, Emerson, added**: "The future of AI in engineering isn't about replacing engineers - it's about enhancing the way they work. Nigel brings AI directly to the systems, workflows, and data that engineers rely on every day, combining speed with rigor and helping teams solve increasingly complex challenges with confidence."*

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