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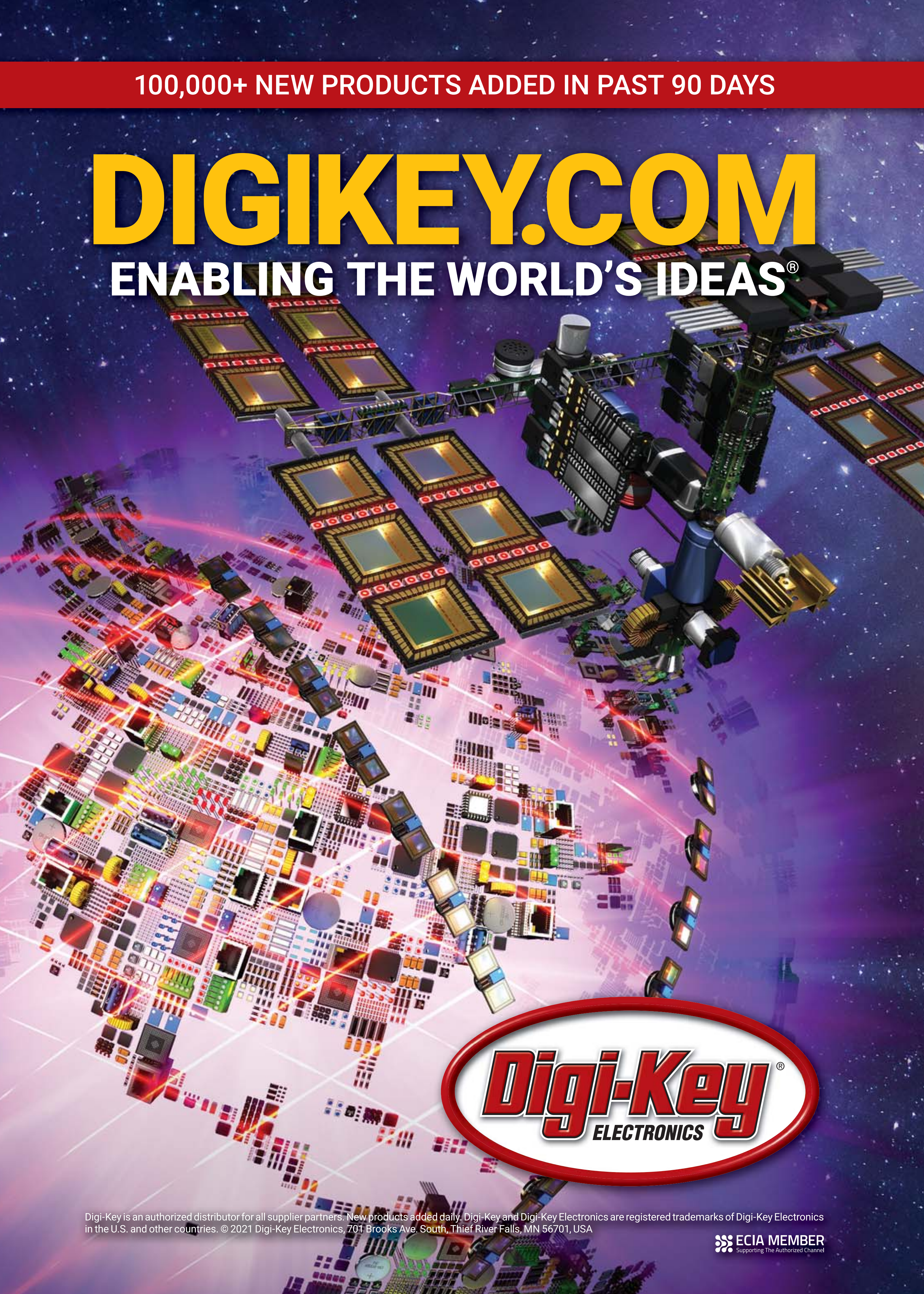
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Editorial

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Will AI Help Design Your Next Product?

Machine learning is creeping into tools used to design chips, software, and more.

MACHINE-LEARNING (ML) and artificial-intelligence (AI) models based on deep neural networks (DNNs) are being exploited in a plethora of applications from voice analysis in the cloud for smart speakers to identifying objects for self-driving cars. Many of these applications employ multiple models that perform different types of identification and optimization chores.

But consumer and business applications aren't the only places where AI/ML is coming into play. AI/ML software-development kits allow designers to incorporate these technologies into their own products, and tool developers are integrating them into their solutions so that the compiler you're using might have an AI/ML model or two tuning your next design.

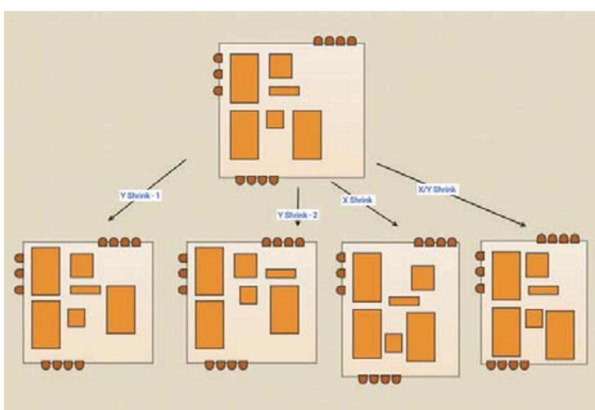
Cadence's Cerebrus Intelligent Chip Explorer is one example of a software tool that's taking advantage of AI/ML models to improve the output of the tools, as well as speed up their performance. Chip design is one of the most challenging hardware design chores that's become even more complicated with single chips now housing billions of transistors. In fact, Cerebras Systems' Waferscale Engine (WSE) incorporates trillions of transistors.

Cerebrus employs machine learning for improved power, performance, and area (PPA) determination as well as automated floorplan exploration *(see figure)*. The AI/ML support is used more as a digital assistant to augment a designer's choices by running multiple design options to find the best solution.

Xilinx's latest Vivado ML Edition takes a similar approach to improving FPGA layout. The intelligent design runs (IDRs) use a number of different ML models to improve things like timing closure. The gain in quality of results (QoR) for projects evaluated by Xilinx was 10% on average, with some solutions improving by over 50%.

AI/ML will continue to crop up in more tools. However, in conventional language compilers like gcc or LLVM, it's made fewer inroads because such compilers already have a good deal of optimization implemented by design.

AI/ML technology continues to evolve as are the applications where this technology can be used. Even if you can't take advantage of it in your application, you may still be doing so with the tools you employ to create it. ed



With Cadence's Cerebrus machine-learning-optimized automated floorplan exploration support, a floorplan can be resized in any direction to evaluate designs, eventually resulting in improved performance while reducing leakage power.

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Introducing USB4

USB4 products should be showing up soon now that the chips have arrived. Watch this latest TechXchange Talks video to find out what's on tap.

https://www.electronicdesign.com/technologies/embedded-revolution/video/21173967/electronic-design-introducing-usb4

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18 Debbie M Brady, Manager User Marketing — Date 9/14/21

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From Code Quality to Total Security

If software defects are the doors used by hackers, then code quality must be improved to address the issue. But first, how big is the problem, and how can it be fixed?

https://www.electronicdesign.com/technologies/embedded-revolution/article/21168142/iar-systems-from-code-quality-to-total-security

The Electronic Automobile: EVs Now, AVs Later

Electric vehicles are making headway, but sales lag as concerns still abound regarding cost and infrastructure, among other issues. As for autonomous vehicles, they remain in the "work in progress" stage.

https://www.electronicdesign.com/communiqu/article/21173775/electronic-design-the-electronic-automobile-evs-now-avs-later

Technology Report

ARIEL STERN | Co-Founder & CEO, Ayyeka Technologies
RAFAEL YAAR | Regional Marketing and Sales Manager, Tadiran Batteries

Revolutionize Remote Wireless Monitoring

with AI and High-Energy Lithium Batteries

With our nation's hard infrastructure, there's a growing need for battery-powered, AI-enabled remote wireless devices that communicate bidirectionally, helping decision makers apply resources more strategically to repair and maintain these assets.

Hard infrastructure is essential to our society, encompassing everything from energy exploration and distribution to solid-waste management, wastewater treatment, water, gas and electric utilities, environmental monitoring, transportation infrastructure, smart cities, and much more.

Unfortunately, America's hard infrastructure is rapidly aging, causing a growing crisis involving public safety, deferred maintenance, operational stress, labor shortages, cybersecurity, and regulatory compliance, to name a few. These difficult challenges demand the implementation of Infrastructure 4.0 to provide forward-looking information and actionable data enhanced by artificial intelligence (AI).

The long-term benefits of Infrastructure 4.0 will be significant, including more proactive maintenance; preemptive warnings; improved connectivity; greater management control (i.e., SCADA); improved environmental quality; greater cost efficiencies; and making data more visual and intuitive.

Going Remote

At the heart of Infrastructure 4.0 will be remote wireless devices powered by ultra-long-life industrial-grade lithium batteries. These robust energy sources must be capable of powering bidirectional, two-way wireless communications using IoT/edge or fixed-base communications technology.

Another important factor is the operating environment, especially for devices deployed in hard-to-access locations and harsh environments. Remote locations demand a robust, long-life power source since the cost of labor to replace a battery far exceeds the initial cost of the device itself. In addition, extreme temperatures can drain cell capacity and accelerate battery self-discharge to greatly reduce operating life.

These factors are all highly interrelated, demanding highly comprehensive end-to-end solutions that can answer these five key questions:

- Is the solution smart and intuitive?
- Is it a comprehensive end-to-end solution?
- Is the solution simple, scalable, and flexible?
- Is the data cybersecure?
- Is the right battery being specified?

What follows is a brief examination of various technical issues surrounding these questions, utilizing actual case studies to demonstrate their practical application.

Making Data Smarter and More Intuitive

Enhanced data intelligence occurs at multiple levels: first by improving data creation (the quality and quantity of the information); second, by permitting more robust data management and reporting; and third, by enhancing data utilization versus legacy platforms such as PLC and TRU.

The proper upgrade enables data to become more visual, integrated, and scalable, using AI and machine learning to autonomously enable greater data intelligence. Optimized solutions also need to adapt to cloud-based and hardwired technology platforms without intensive coding or remote management.

Comprehensive End-to-End Solutions from Software to Power Supply

Partial solutions are inherently inefficient. Intelligent edge-to-edge solutions enhance performance and reduce the cost of ownership through a holistic hardware/software solution manageable from a single source.

Triggers from field sensors generally benefit from remote cameras that provide visual verification. In addition, all data interfaces should be sensor agnostic, fast and secure, rugged and waterproof, flexible to accommodate multiple configurations (analog, serial, and discrete input), and seamlessly integrate with existing third-party software.

Often overlooked is the critical need for an energetic and robust power-management solution using ultra-long-life lithium batteries. Such a power source should be capable of delivering high pulses to power bidirectional wireless communications.

Keep It Simple, Flexible, and Scalable

In a world of constant change, wireless solutions need to be modular and flexible, evolving to address dynamic market conditions, future growth opportunities, and increasingly stringent regulatory reporting.

In a tightening labor market, you can no longer assume that devices will be installed by seasoned and experienced personnel. Therefore, "smart" solutions need to be easily installed, plug-and-play, and fully autonomous without requiring specialized coding skills.

Comprehensive Cybersecurity is Imperative

The highly disruptive Colonial Pipeline hacking incident underscores the need for military-grade cybersecurity from the bottom up to protect various access points.

For example, communications between the platform and the wireless device can be intercepted to corrupt the device configuration or modify the data. Bluetooth communications channels can become compromised to gain unauthorized configuration access. API sessions also could be hacked to gain programmatic access to specific user accounts.

Any best practices model must combine secured hardware and software along with fully encrypted communications. The gold standard for reducing vulnerability to cyberattacks when transmitting sensitive data is TLS v1.3, which applies the strongest encryption libraries to all data transmitted to and from IIoT devices. In addition, all firmware must meet TLS v1.3 standards.

Adopting the most stringent TLS v1.3 protocols will increase communication efficiency, which extends battery life. Combining lean technology with higher-capacity/higher-energy-density batteries serves to further extend product longevity.

Specifying the Right Battery Is Critical

A remote wireless device is only as reliable as its power supply, since battery failure causes system failure. While the choice of battery is a critical consideration, common misperceptions abound that all batteries are created equal—a mistake that can lead to compromised solutions.

There are two types of low-power devices:

- Those that draw average energy (background current and pulses) measurable in microamps, typically requiring an industrial-grade primary (non-rechargeable) lithium battery.
- Those that draw average energy (background current and pulses) measurable in milliamps, typically requiring an energy-harvesting device combined with a lithium-ion (Li-ion) rechargeable battery.

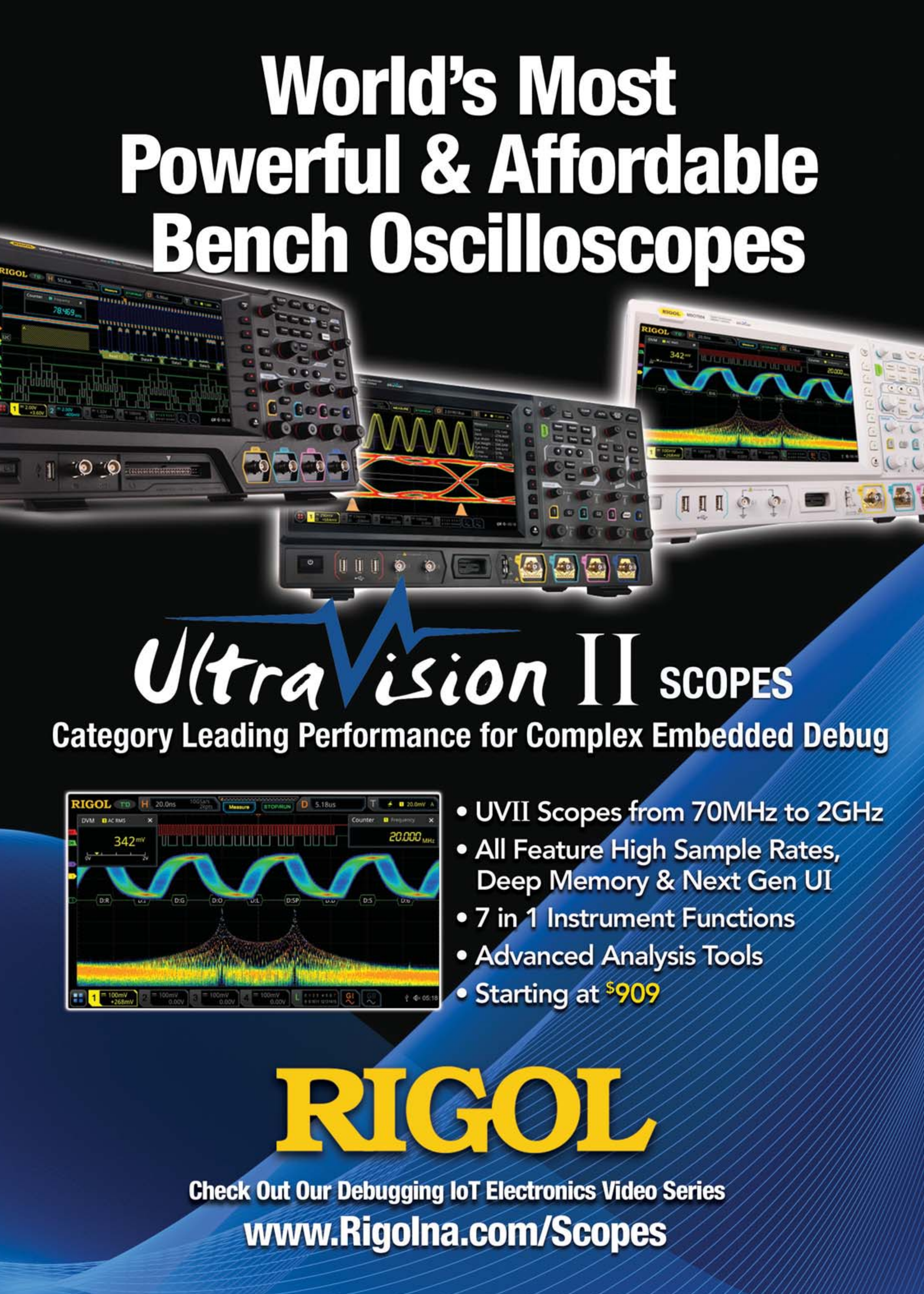
Every low-power application has specific technical requirements, such as sampling frequency; the amount of energy consumed while in "active" mode; cell capacity and energy density, minimizing losses caused by long-term exposure to extreme temperatures; and other factors that affect a battery's self-discharge rate.

Identifying ways to minimize energy consumption is especially critical for devices using bidirectional wireless communications, as this requirement draws additional energy. Ideal solutions typically combine a low-power communications protocol, low-power chipsets, and proprietary techniques designed to limit power consumption while in "active" mode.

Commercially available primary battery chemistries include alkaline, iron disulfate ($LiFeS_2$), lithium manganese dioxide ($LiMnO_2$), lithium thionyl chloride ($LiSOCl_2$), and lithium metal-oxide *(see table below)*. Among these choices, bobbin-type $LiSOCl_2$ chemistry stands apart for its higher capacity and energy density, resulting in extended battery life. Bobbin-type $LiCOCl_2$ chemistry also

Primary Cell	$LiSOCL_2$ Bobbin-type with Hybrid Layer Capacitor	$LiSOCL_2$ Bobbin-type	Li Metal Oxide Modified for high capacity	Li Metal Oxide Modified for high power	Alkaline	$LiFeS_2$ Lithium Iron Disulfate (AA-size)	$LiMnO_2$ Lithium Manganese Oxide
Energy Density (Wh/Kg)	700	730	370	185	90	335	330
Power	Very High	Low	Very High	Very High	Low	High	Moderate
Voltage	3.6 to 3.9 V	3.6 V	4.1 V	4.1 V	1.5 V	1.5 V	3.0 V
Pulse Amplitude	Excellent	Small	High	Very High	Low	Moderate	Moderate
Passivation	None	High	Very Low	None	N/A	Fair	Moderate
Performance at Elevated Temp.	Excellent	Fair	Excellent	Excellent	Low	Moderate	Fair
Performance at Low Temp.	Excellent	Fair	Moderate	Excellent	Low	Moderate	Poor
Operating life	Excellent	Excellent	Excellent	Excellent	Moderate	Moderate	Fair
Self-Discharge Rate	Very Low	Very Low	Very Low	Very Low	Very High	Moderate	High
Operating Temp.	-55°C to 85°C, can be extended to 105°C for a short time	-80°C to 125°C	-45°C to 85°C	-45°C to 85°C	-0°C to 60°C	-20°C to 60°C	0°C to 60°C

Comparison of primary battery chemistries.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features the widest temperature range and the lowest rate of annual self-discharge, making it the preferred choice for long-term deployments in remote locations and harsh environments.

How the Passivation Effect Reduces Battery Self-Discharge

All batteries experience some amount of annual self-discharge, as chemical reactions exhaust available capacity even when a cell is disconnected or in storage. The rate of annual self-discharge is impacted by the cell's current discharge potential, the quality of the raw materials, and, most importantly, by the passivation effect.

Passivation occurs when a thin film of lithium chloride (LiCl) forms on the surface of the lithium anode, which limits its reactivity. Whenever a load is placed on the cell, the passivation layer initially causes high resistance and a temporary dip in voltage until the discharge reaction begins to dissipate the LiCl layer—a process that repeats each time the load is removed.

The passivation effect can vary based on how a cell is manufactured and the quality of the raw materials. Other factors affecting passivation include current capacity; length of storage; storage temperature; discharge temperature; and prior discharge conditions, as removing the load from a partially discharged cell increases the level of passivation relative to when it was new. Passivation increases longevity, but too much of it can overly restrict energy flow.

Standard bobbin-type $LiSOCl_2$ cells are unmatched for their ability to harness the passivation effect. However, they're unable to generate high pulses due to their low-rate design. This challenge can be easily overcome by adding a patented hybrid layer capacitor (HLC).

In essence, the bobbin-type $LiSOCl_2$ cell delivers low levels of background current while the HLC delivers high pulses to power two-way wireless communications. The patented HLC features a unique end-of-life voltage plateau that can be interpreted to deliver "low battery" status notification for routine battery replacements.

Additional factors also must be considered when specifying batteries:

- Current consumption in "active" mode (the size, duration, and frequency of pulses), and how much energy is being consumed in "standby" mode (the base current).
- Storage time (as normal self-discharge diminishes capacity).
- Prolonged exposure to extreme temperatures during storage and in-field operation.
- Equipment cutoff voltage (exhaust-

1. Florida's Orange County uses Ayyeka Wavelet devices equipped with Tadiran high-energy $LiSOCL_2$ batteries to manage the distribution of reclaimed water to golf courses, resorts, and homes.

Improving System-Level Performance and Robustness in Power Line Monitoring

Lluis Beltran Gil, Applications Engineer

Background

For many applications, monitoring power lines implies the use of current transformers and resistor divider networks in order to sense the three phases and neutral voltages and currents, as shown in Figure 1. The AD7606B, due to its high input impedance, can directly interface with a sensor, easing the data acquisition system design as AD7606B provides all the required building blocks.

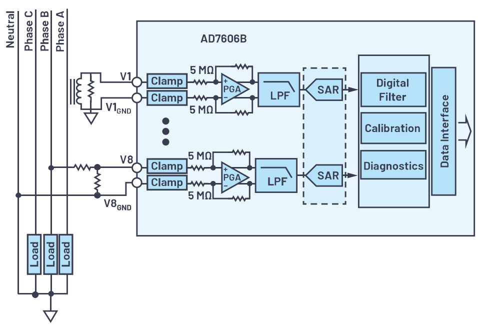


Figure 1. AD7606B in a typical power line monitoring application.

The AD7606B integrates, on-chip, eight individual signal chains that accept either ±10 V or ±5 V true bipolar analog input signals despite working from a single 5 V supply. These features eliminate the need for driver op amps and external bipolar supplies.

Each of these channels is comprised of 21 V analog input clamp protection, a resistive programmable gain amplifier with 5 MΩ input impedance, a first-order antialiasing filter, and a 16-bit SAR ADC. Also, an optional digital averaging filter with oversampling ratios of up to 256 and a low drift 2.5 V reference are included to help build a complete power line data acquisition system.

In addition to the complete analog signal chain provided, the AD7606B has plenty of calibration and diagnostic features to improve system-level performance and robustness.

Direct Sensor Interface

Unlike AD7606, AD7606B input impedance has been increased to 5 MΩ, which allows for it to directly interface with a wide variety of sensors while granting two straightforward benefits:

- The gain error introduced by external series resistors (for example, the filtering or the resistor divider network) is reduced.
- The offset seen when the sensor is disconnected decreases, allowing for easy sensor disconnect detection features.

Gain Error Due to External Resistors

In factory trimming, there is tight control over R_{FB} and R_{IN} (5 MΩ typical) on a PGA, such that the AD7606B gain is accurately set. However, if an external resistor is placed in the front end, as shown in Figure 1, the actual gain then differs from the ideal trimmed R_{FB}/R_{IN}.

The higher the R_{FILTER}, the greater the gain error becomes, which will require compensation on the controller side. But the higher the R_{IN}, the less effect the same R_{FILTER} will have. Unlike the AD7606's 1 MΩ input impedance, the AD7606B has 5 MΩ input, meaning that the gain error will reduce about 1 over 5 for the same series resistor (R_{FILTER}) without any calibration, as shown in Figure 2.

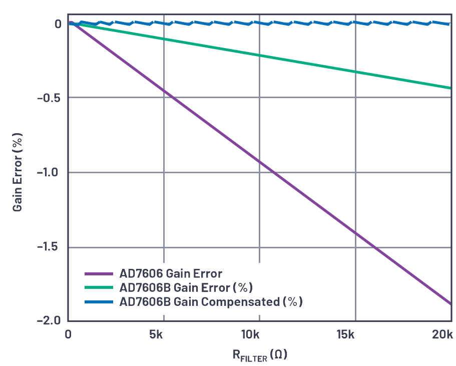


Figure 2. Gain error introduced by a series resistor.

However, by using the AD7606B in software mode, this system gain error can be automatically compensated on-chip, on a per channel basis, and completely eliminate the need for doing any gain calibration computation on the controller side.

Sensor Disconnect Detection

Traditionally, having a pull-down resistor (R_{PD}) in parallel with the sensor (current transformer shown in Figure 1) allows users to detect when the sensor disconnects by monitoring if an ADC output code lower than 20 LSBs repeats for a number of samples (N).

It is recommended to have an R_{PD} much larger than the source impedance of the sensor in order to minimize the error that this parallel resistor may introduce. However, the larger the R_{PD}, the larger the ADC output code generated when the sensor disconnects, which is not desired. A large ADC output code may lead to unnoticed sensor disconnection. Because the AD7606B has larger R_{IN} than the AD7606, for a given R_{PD}, the ADC output code is lower if the sensor disconnects, reducing the risk of false alarms.

When entering software mode for the AD7606B, there is an open-circuit detection feature, eliminating the burden on the back-end software that detects the sensor disconnection. After programming the number of samples N (N = 3 on the example of Figure 3), if the analog input remains for several samples reporting a small dc value, the algorithm will automatically run and assert a flag if the analog input signal has been disconnected.

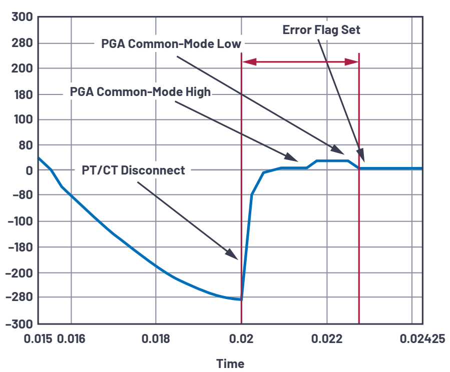


Figure 3. Sensor disconnect detection.

System-Level Performance

System Offset Calibration

When using a pair of external resistors, as seen in Figure 1, any mismatch between them will cause an offset. This offset can be measured as the ADC output code when the sensor is shortcut to ground. An offset from –128 LSBs to +127 LSBs can be then added to or subtracted from the conversion result by programming the corresponding channel offset register in order to compensate for that system offset.

System Phase Calibration

The CONVST pin manages the start of a conversion such that it triggers the process simultaneously on all channels. However, on applications where currents are measured through current transformers (CTs) while voltages are scaled down through a voltage divider, there will be a phase mismatch between current and voltage channels. To compensate for that, AD7606B can delay the sampling instant on any channels, such that the output signals can be realigned in phase, as shown in Figure 4.

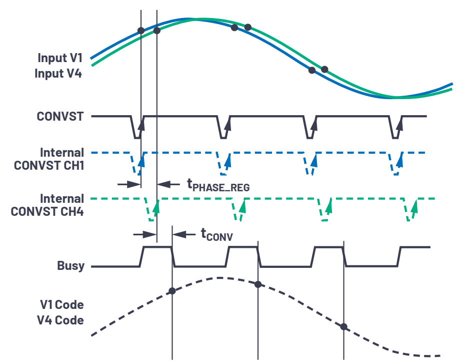


Figure 4. Phase realignment.

System Robustness

In order to increase system reliability, several diagnostic features have been included on-chip, namely:

- Overvoltage/undervoltage comparators on every channel.
- An interface check that clocks out fixed data on each channel in order to verify the communication.
- SPI invalid read/write alerts if there is an attempt to write to or read from an invalid register.
- BUSY STUCK HIGH alerts if the BUSY line continues longer than the normal time after a conversion has been initiated.
- Reset detection alerts if a reset has been detected for either a full, partial, or power-on reset on the internal LDO regulator.
- CRC can be performed in the memory map, ROM, and every interface communication in order to guarantee correct initialization and/or operation.

Conclusions

The AD7606B brings a complete data acquisition system on a chip to the market. All the analog front-end building blocks are implemented. It provides a complete set of advanced diagnostic features, as well as gain, offset, and phase-calibration. With this, the AD7606B reduces component cost and system design complexity, easing the journey to designing power line monitoring applications.

ing cell capacity and/or extreme temperatures can cause voltage to drop too low to allow the device to operate.

Two Real-Life Examples

With fresh water being a precious commodity, the municipal water system of Orange County, Fla., relies on reclaimed wastewater to irrigate golf courses, resorts, and residential gardens. Dependent on the same reclaimed water storage tanks, residential customers didn't have sufficient water for their gardens when golf resorts were watering the greens.

Ayyeka Wavelet devices track water usage at golf courses and resorts to coordinate water supplies for residential customers *(Fig. 1)*. Furthermore, detailed tracking of reclaimed water usage enables Orange County's Public Works Department to proactively plan for the placement of additional reclaimed storage tanks to meet gradually increasing demand. Highly energetic bobbin-type $LiSOCl_2$ batteries support bidirectional wireless communications while ensuring maximum uptime with less-frequent battery change-outs.

With over 600 miles of water mains, Erie County's pressure reducing valves (PRVs) serve to prevent stress on water mains that can lead to pipe leaks and bursts, which is especially critical to a 100-year-old system that serves over one million people.

Previously, service crews lacked data intelligence to anticipate potential ruptures to the main water line. Ayyeka delivered a comprehensive end-to-end solution using Wavelet devices to continuously monitor pressure levels in PRVs, making sure they function optimally and providing automatic text message, email, or automated phone call alerts if pressure levels begin to drop.

Field asset intelligence (FAI) software is used to detect small leaks before they lead to costly and disruptive water main ruptures. This is a nationwide problem, as the American Society of Civil Engineers concluded that leaking pipes are responsible for the loss of 6 billion gallons of treated drinking water each day *(Fig. 2)*.

$LiSOCl_2$ Batteries Aren't Created Equal

Comparing batteries with identical chemistries can be difficult, as the effects of a higher self-discharge rate may not become apparent for years, and predictive models often underestimate the passivation effect as well as prolonged exposure to extreme temperatures.

In reality, major significant differences exist between the highest-quality bobbin-type $LiSOCl_2$ cells that feature a self-discharge rate as low as 0.7% per year and lower-quality cells with a self-discharge rate as high as 3% per year. While seemingly small, these differences can really add up over time, as an inferior quality cell may lose 30% of its capacity every 10 years solely because of self-discharge.

Those differences aren't always readily distinguishable, though. Therefore, you need to perform thorough due diligence by obtaining fully documented long-term test results as well as in-field test data using comparable devices under similar loads and environmental conditions.

Implementing a robust and secure Infrastructure 4.0 solution can be highly beneficial, resulting in greater data intelligence, extended battery life, and a lower cost of ownership. ed

2. Erie County in Pennsylvania uses AI-enabled, battery-powered Wavelet devices to monitor pressure-reducing valves to protect a 100-year-old water system.

DEBENDRA DAS SHARMA | PCI-SIG Board Member and Intel Fellow, Intel Corp.
ANIL KUMAR | Principal Engineer, Internet of Things Group

PCI Express Leads the Way in IoT Connectivity

High bandwidth and low latency are just two of the reasons why PCI technology has evolved to become the primary I/O interconnect in the IoT space.

The Internet of Things (IoT) represents a wide range of vertical markets spanning retail, manufacturing, smart cities, energy and utilities, transportation, public sector, education, hospitality, health and life sciences, automotive, banking, gaming, and entertainment—touching practically every aspect of our human lives *(Fig. 1)*.

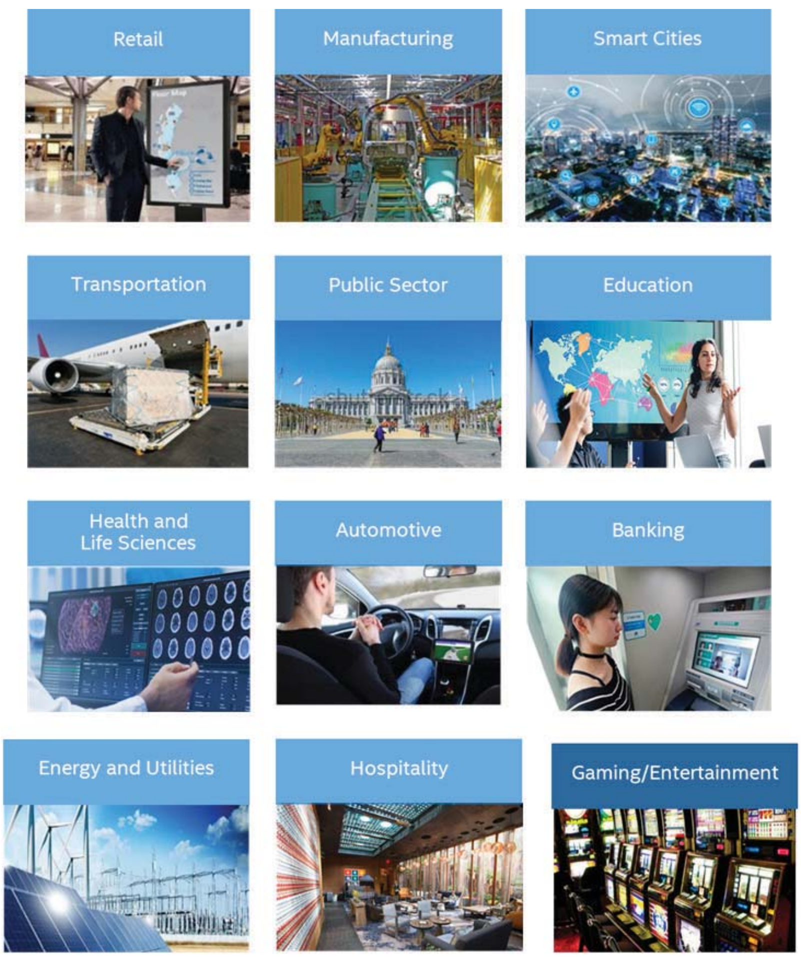
IoT also represents a wide range of diverse systems spanning edge/gateway, data-acquisition devices, automotive, modular computers, industrial PC, etc. One characteristic of the emerging edge and IoT market is the exponential growth in data as illustrated by a few statistics:

- 80 zettabytes (ZB) of data by 40+ billion IoT devices in 2025, accounting for more than half the data.[1]
- 50% of data processed outside the data center or cloud by 2022.[2]
- 43% of AI tasks taking place on edge devices (vs. cloud) in 2023.[3]
- Annual business-to-business (B2B) IoT revenue more than US$300B.[4]

Most of that data will be processed, stored, and analyzed at the edge to help deliver better latency, conserve network bandwidth, and improve reliability, security, and privacy. As data growth explodes, high-bandwidth I/O capabilities along with AI will become necessary to transport and transform this data into actionable information and valuable insights. In this article, we will delve into the role played by PCI Express (PCIe) technology as the primary I/O interconnect in the IoT space.

PCIe architecture has provided I/O connectivity for computing platforms for more than three decades. This is due to the ability of PCIe technology to seamlessly deliver a cost-effective, HVM (high volume manufacturing) friendly, power-efficient, high-bandwidth, and low-latency solution through six generations of technology evolution, doubling the data rate every generation and having full backward compatibility with prior generations *(Fig. 2 on page 20)*.

Additional protocol enhancements such as precision time measurement (PTM), I/O virtualization, and security features like link encryption are essential in the IoT space. Even though a multitude of form factors (e.g., PXI, M.2, U.2, CEM, various flavors of small form factors) have evolved to meet the needs of diverse systems across the IoT compute continuum, they all use the same silicon ingredients based on a common PCI Express specification.



1. IoT is ubiquitous and at the center of our rapidly changing world.

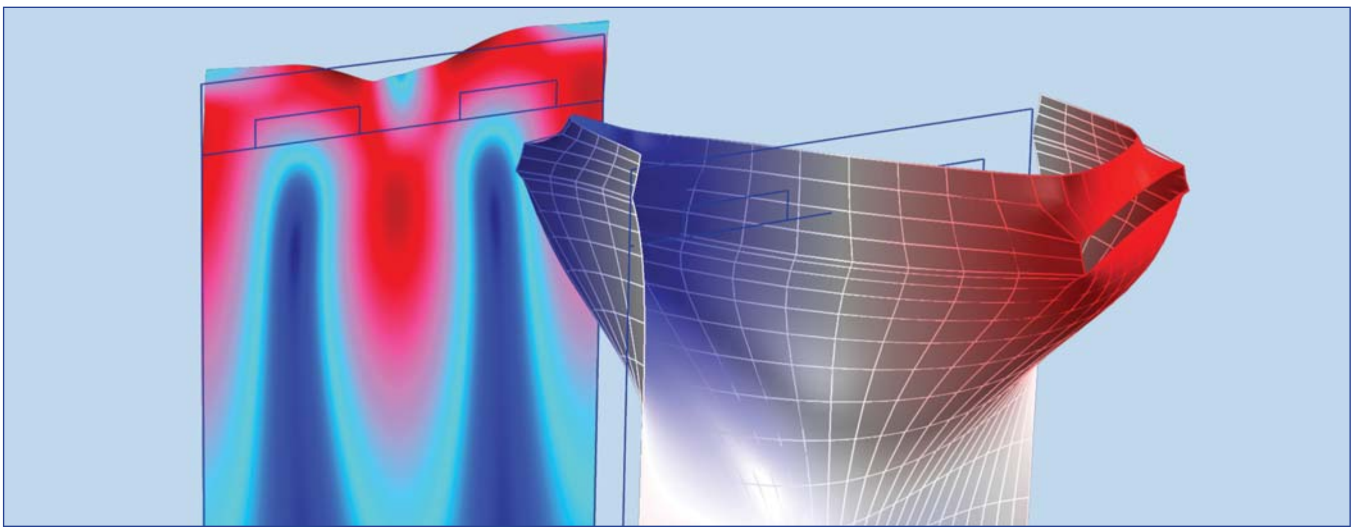
FREE ARCHIVED WEBINAR

Registration URL: https://www.electronicdesign.com/resources/webinars/webinar/21169687/using-simulation-in-the-analysis-and-design-of-ultrasonic-devices?sti=ED-COMSOL0908

Using Simulation in the Analysis and Design of Ultrasonic Devices

A large number of applications, such as nondestructive testing (NDT) units, flowmeters, and medical ultrasound, involve the modeling of ultrasonic wave propagation in fluids and solids. Very often, the size and complexity of ultrasonic models make them hard to solve with the classical finite element method.

During this webinar, we will discuss the modeling techniques available in the COMSOL® software for the design of ultrasound and NDT devices, as well as the study of their interaction with the operating environment. Examples ranging from piezoelectric transducers to the nonlinear propagation of finite amplitude ultrasonic waves in fluids will be shown to demonstrate how to efficiently model these applications using COMSOL Multiphysics®.



SPEAKER: Jinlan Huang, Applications Engineer, COMSOL

Jinlan Huang is an applications engineer for vibrations and acoustics and instructs acoustics training courses. She received her PhD from Boston University, Department of Aerospace and Mechanical Engineering, investigating acoustic wave propagation in complex-tissue environments and ultrasound-induced tissue heating and bleeding control. She joined COMSOL in 2011.

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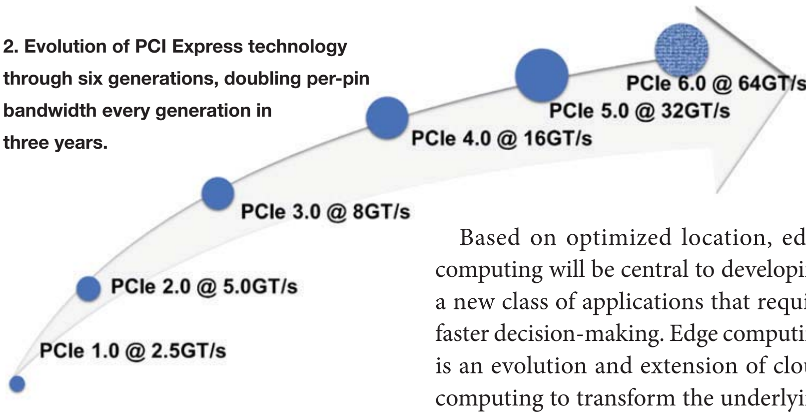


2. Evolution of PCI Express technology through six generations, doubling per-pin bandwidth every generation in three years.

The success of PCIe architecture as a ubiquitous I/O interconnect in the IoT space is due to it being an open industry standard. And it's backed by a robust compliance program to ensure seamless interoperability between devices made by different companies.

PCI-SIG, a consortium of more than 800 member companies spread across the globe, owns and manages PCI specifications and runs the compliance program. We expect PCIe technology to continue to evolve to meet the I/O needs of the IoT segments for many more years to come. Let's take a closer look at how PCIe architecture is used in the following IoT segments: edge computing, test equipment, embedded/industrial PCs, and automotive.

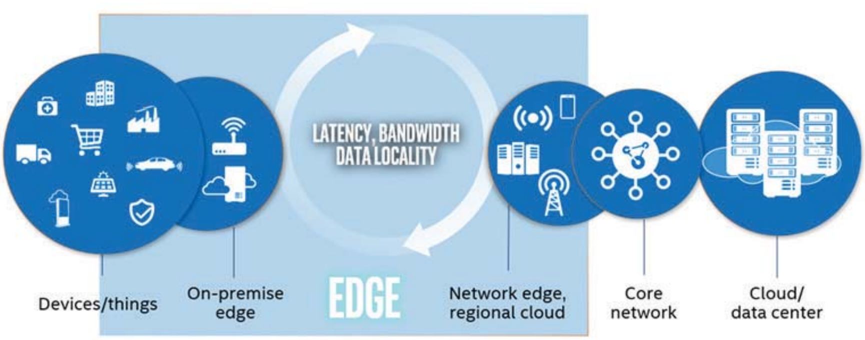
Edge Computing

Edge computing allows for the placement of resources needed to move, store, and process data closer to the source of the data or the point of service delivery *(Fig. 3),* catering to different levels of quality-of-service (QoS) expectations.

Based on optimized location, edge computing will be central to developing a new class of applications that require faster decision-making. Edge computing is an evolution and extension of cloud computing to transform the underlying architecture and create an environment ripe for application, service, and business model innovation.

The PCIe specification, which is widely deployed in the data-center market, is thus uniquely positioned to accelerate the development of edge solutions. The three key performance indicators driving edge value proposition and how PCIe technology capabilities fit into this big picture include:

- *Latency and determinism:* Advanced applications such as factory automation, robotics, industrial process control systems, video surveillance and security, immersive media applications, autonomous vehicles, and content delivery demand sub-milliseconds to tens of milliseconds of end-to-end latency and deterministic deadline-based response. A traditional cloud-based solution can't meet this requirement.
- *Bandwidth:* By 2022, 82% of IP traffic will be video content. This traffic is expensive to transport to the cloud and process at a cloud data center. End users and service providers are motivated to process video data at the edge to lower latency, reduce jitter, improve video quality, and create new revenue with value-added services such as content delivery networks (CDNs), cloud gaming, or video analytics for enhanced retail experiences and smart-city applications.
- *Data locality and regulatory compliance:* Data privacy and security are driving the need for broad edge deployments as governments implement policies to protect customer data and maintain data within their geographies, such as the General Data Protection Regulation (GDPR) in the EU.



3. The different edge locations in a things-to-cloud IoT system.

PCIe architecture, being a high-bandwidth, low-latency, and secure data-connectivity standard, is ideally suited for these applications. *Figure 4 (page 22)* shows a simplified block diagram of an on-premises edge gateway and how PCIe technology provides the connectivity for the various subsystems within it.

Let's look at this in detail:

- Every business needs to proactively plan for network failover for seamless operation. Wide-area network connectivity can be implemented using cellular 4G LTE/5G or wired solutions such as DSL, cable, or fiber-optic connections, each connected through PCIe. In this example, if a wired WAN connection goes down, one can failover to LTE/5G.
- The router can provide multiple LAN connections using wired Ethernet or wireless LAN based on Wi-Fi modules. For example, Ethernet-based cameras can be connected to the CPU via an Ethernet switch for a digital surveillance and security (DSS) system. Wireless peripherals such as a point-of-sale (PoS) system in a retail store can connect via the Wi-Fi module.

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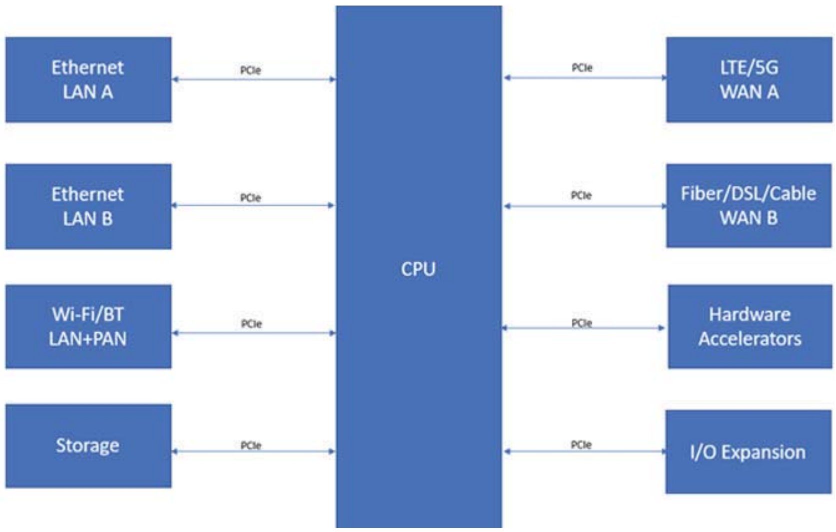

4. Shown is a simplified edge gateway block diagram: PCIe technology is the preferred choice within the system connectivity.

- Low data-rate wireless connections, such as a handheld barcode scanner or a temperature and humidity sensor on the shelf in a retail store, can connect to the edge system via Bluetooth. Therefore, office automation, light bulbs, window shades, remote controls, etc. can communicate via Bluetooth, Zigbee, or Z-Wave wireless connectivity solutions.
- DSS and networked video recorders, medical imaging systems, etc. need to store the captured data for further processing. Storage that's fast, reliable, and secure is critical for IoT applications. A high ratio of capacity to physical footprint, along with the ability to withstand harsh environmental conditions, also is an important consideration as edge devices are installed in outdoor harsh environments such as a petroleum refinery.
- The NVM Express (NVMe) specification is an interconnect protocol used to access high-speed storage media. It's designed to connect high-performance NAND flash memory to compute resources over native PCIe links. It's a streamlined memory interface with 64K I/O queues, each supporting up to 64K I/O operations, eliminating the legacy SCSI command stack and direct-attached-storage (DAS) bottlenecks associated with traditional hard-drive interfaces. This results in a uniquely tuned I/O architecture optimized for solid-state media.

Storage at the edge needs the ability to support 24x7x365 ingestion of new data and must have enough extra bandwidth and I/O capacity to handle batch and ad hoc queries against this data. A PCIe-based host interface also provides NVMe SSDs with the high bandwidth needed to process this aggregated data at the edge into knowledge and convert it into actionable intelligence.

- Depending on the vertical market, IoT gateways support a host of legacy and I/O standards as well as custom I/O interfaces. Since the same CPU design is typically used to develop edge solutions servicing multiple markets to achieve economies of scale, PCIe technology provides an efficient way to connect a variety of I/O controllers to expand and aggregate these interfaces. For example, in the industrial-automation market, industrial Ethernet solutions such as EtherCAT, EtherNet/IP, PROFINET, CC-Link-IE, and serial protocols such as CIP (Common Industrial Protocol), PROFIBUS, Modbus, etc. are commonly implemented using PCIe interface aggregator chips. Similarly, BACnet for building automation and control networks, KNX, etc. are used in the building-automation industry.
- Emerging applications like augmented reality, depth perception, and gesture recognition require multiple image-sensor interfaces to connect to the application processor with minimal latency between frames. A MIPI-to-PCIe bridge can interface multiple MIPI CSI image sensors and aggregate data to a PCIe output. In the industrial sector, an intelligent automation system captures and processes video for building security and quality control. A PCIe bridge captures videos from HDMI, DVI, or SDI interfaces and can transfer full uncompressed video and audio to a host processor for further processing. Similar bridges with LVDS as the video input also are available to support cameras that have LVDS as the video-output interface.

Edge computing is seeing increased deployment of heterogeneous computing with the PCIe interconnect due to its low-latency, high-bandwidth load-store semantics. For example, the growth in data processing at the edge has led to the use of dedicated accelerators for artificial intelligence (AI), machine learning (ML) and deep-learning workloads. These PCIe-based accelerators perform parallel computation, leading to faster execution of AI workloads compared to traditional CPUs.

Similarly, vision processing units (VPUs) are helping to offload vision workload involving multiple camera streams with high frame rates that have latency-critical processing requirements. A graphics processing unit (GPU) with

5. An overview of workload consolidation based on industrial PCs.

its massive potential of parallel computing can be used in a vision workload to accelerate the processing of pixel data, in data mining, as well as other AI and ML workloads.

In applications where the algorithms and deep-learning neural networks are still evolving, reconfigurable field-programmable gate arrays (FPGAs) play a major role. Besides the acceleration functions, FPGAs provide many different connectivity options to connect to cameras, sensors, and other devices.

Test Equipment

Data acquisition is the process of measuring an electrical or physical phenomenon, such as voltage, current, temperature, pressure, or sound. From semiconductor device validation to automated production tests, PCI eXtensions for Instrumentation (PXI) systems deliver high-performance modular instruments and other I/O modules that feature specialized timing and synchronization, as well as key software features for test and measurement applications.

PXI systems use commercial PC-based PCI and PCI Express bus technology while combining rugged modular packaging. With this approach, one can meet requirements for timing, synchronization, and throughput across high-channel-count test applications.

Measurement accuracy is the most important consideration in designing any data-acquisition system. The overall performance of the system, including I/O sampling rates, throughput, and latency, are other top considerations. PXI can meet the ever-more-demanding application needs by incorporating the new PCIe standards into future products.[5]

Embedded/Industrial PCs

Industrial and embedded PCs (IPCs) are rugged PCs designed to operate continuously (24x7) in a harsh environment, including outdoor applications such as mining, agriculture, and energy distribution, and industrial applications like plant automation and process automation. They take advantage of the open PC architecture and deploy advanced video and AI technologies.

To realize the promise of the fourth industrial revolution, known as Industry 4.0, modern automation systems have moved away from purpose-built hardware to user-friendly networked PCs with high reliability, more data storage, and greater computing power. Supervisory control and data-acquisition (SCADA) systems and manufacturing execution systems (MES) are examples of such systems.

PCIe technology plays a key role in these PCs for storage, networking, accelerator attach, and even to connect to traditional automation systems using purpose-built hardware. It's resulted in reduced capital costs (CapEx), increased efficiencies, and simplification of operations to lower operational costs (OpEx), leading to seamless convergence of operational technology (OT) and information technology (IT) infrastructure.[6]

Systems utilized for workload consolidation *(Fig. 5)* are leveraging virtualization. Virtualization partitions the host platform into multiple software-defined, isolated environments with shared resources managed by a hypervisor.

Such a software-defined infrastructure has been made possible by advances in multicore CPUs, real-time operating systems (RTOS), lightweight hypervisors, and hardware-assisted virtualization technologies. I/O virtualization support in the PCIe specification has facilitated offloading of packet processing to network adapters, as well as direct assignment of virtual machines (VMs) to virtual functions, including disk I/O.

In control and automation systems, applications often are required to be synchronized across the network or devices within the subsystem to a common clock, with different levels of accuracy depending on the end usage. Ethernet time-sensitive-network (TSN)-based connectivity ensures synchronization between systems using the IEEE1588 and 802.1AS standards.

The PCIe specification's Precision Time Measurement (PTM) protocol enables TSN network interface cards (NICs) or other peripherals to synchronize the network time to the CPU timestamp and ultimately to the software application. PTM minimizes the translation errors and thus increases the coordination of events across multiple components with very fine precision. Data from different sources, such as cameras, transducers, etc., can be reassembled in the host proces-

sor or accelerators through timestamps enabled by PTM to perform accurate analysis and take actions, even in safety-critical applications.

IPCs offer greater customization, reliability, and scalability, plus a longer product lifecycle. The wide range of systems include low-power and fanless designs in space-constrained environments, industrial panel-mounted PCs installed on surfaces, industrial rackmount PCs fastened to walls or in cabinets, industrial workstation PCs in closets, and embedded PCs in kiosks or medical equipment.

6. The connected car is akin to a data center on wheels.

A popular form-factor is COM Express developed by the PCI Industrial Computer Manufacturers Group (PICMG).[7] The ability to plug a COM Express module or standard SFF wireless modules like M.2 onto a carrier board reduces the time and cost to develop a product. The user doesn't need to understand the typically complex details associated with high-speed signaling, RF design and tuning, etc. for the latest SoCs.

This approach also streamlines the effort needed to get regulatory approvals such as FCC certification for the final product. Moreover, a modular design approach allows us to address the "mile wide and inch deep" IoT market by customizing the solutions based on common solutions driving economies of scale and wider adoption.

Automotive

Automotive electronics has been growing in sophistication and complexity for over a decade.[8] Modern cars with their in-vehicle infotainment (IVI) systems, advanced driver-assistance systems (ADAS), and vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) connectivity can be considered as data centers on wheels *(Fig. 6)*. To satisfy the consumer expectations for comfort and meet regulatory requirements for passenger and pedestrian safety, these systems are becoming prevalent in mass-market models and not just limited to luxury automobiles.

With the increased amount of data to be transported, stored, and processed, proven data-center technologies such as PCIe architecture are becoming very common in automotive electronic systems to connect powerful multi-socketed CPU systems. Beyond PCIe-connected GPUs, Wi-Fi, V2X, and LTE/5G cellular modules, specialized vision and AI accelerator ASICs, Ethernet NICs, and FPGAs are common in automotive electronic control units (ECUs).

As expected, this segment has very stringent regulatory, safety, and reliability requirements while operating under extreme conditions, with an expectation of availability without replacement for the entire useful life of about 15 years of a car. PCIe technology, with its high reliability and availability features, is the interconnect of choice to interface to multiple data sources comprising cameras, LiDAR, radar, and ultrasound and infrared sensors. It provides wireless connectivity through Wi-Fi, BT, LTE, 5G, and satellite for the car. It's also used for connection to storage devices and accelerators.

Conclusion

The PCIe interface is natively supported by most high-performance CPUs. In addition, the ecosystem includes a large range of available devices for AI/ML acceleration, networking, storage, and wireless connectivity. Availability of IP blocks, off-the-shelf standard form factor/modular components, debug tools, and a large ecosystem of developers familiar with the technology from the IT world is accelerating the penetration of PCIe architecture into IoT applications.

With a rich and successful history of navigating several technology transitions in a backward-compatible manner spanning three decades, PCI-SIG is well-positioned to continue leading the evolving IoT landscape going forward. The power and promise of this open standards organization, backed by the combined innovation capability of 800+ member companies, makes the technology nimble, scalable, cost-effective, power-efficient, and multi-generational with relevance across all IoT segments and usage models for the foreseeable future. ed

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STEVE TARANOVICH | Freelance Technical Writer, Phoenix Information Communication LLC

MINIMIZING EMI *in Commercial Aircraft*

Portable electronic devices may cause levels of EMI in aircraft equipment, acting as transmitters that can be detected by radio receiver antennas. So, as the pilot says, "your portable electronic devices must be turned off or set to 'airplane' mode."

The FAA advisory circular, AC 91.21-1D, "Use of Portable Electronic Devices Aboard Aircraft," prohibits operation of portable electronic devices (PEDs) not installed aboard U.S. registered civil aircraft, while operating under instrument flight rules (IFR). The measurement of the radiated-field coupling between passenger cabin locations and aircraft communication and navigation receivers, via antennas, is called interference path loss (IPL).

Boeing states that operators of commercial aircraft have reported numerous cases of PEDs affecting aircraft systems during flight. This article will delve deeply into this controversial subject of electromagnetic interference (EMI) in commercial aircraft. Let's see what one of the largest aircraft manufacturers has to say on this subject.

We will not be discussing aircraft vulnerability to onboard intentional Electromagnetic Environmental Effects (E3) or terrorism. We will discuss EMI effects inside the aircraft from a technical point of view.

Boeing Aircraft Commentary on EMI in Commercial Aircraft

It's been reported that many cases of PEDs have affected aircraft systems while in flight. Such devices include, but aren't limited to, what's listed here:

- Laptop and palmtop computers
- Audio players/recorders
- Electronic games
- Cellular phones
- CD players
- Electronic toys
- Laser pointers

These devices are suspected of causing such events as autopilot disconnect, erratic flight deck indications, aircraft going off course, and uncommanded turns.

EMI Onboard the Aircraft Due to Wireless Technology

There's ever-increasing growth in portable wireless devices in our world, and they all could cause disruption in aircraft navigation and communication systems. Such PEDs can act as transmitters whose signals might be detected by aircraft radio receiver antennas[1,5] *(Fig.1 on page 30).*

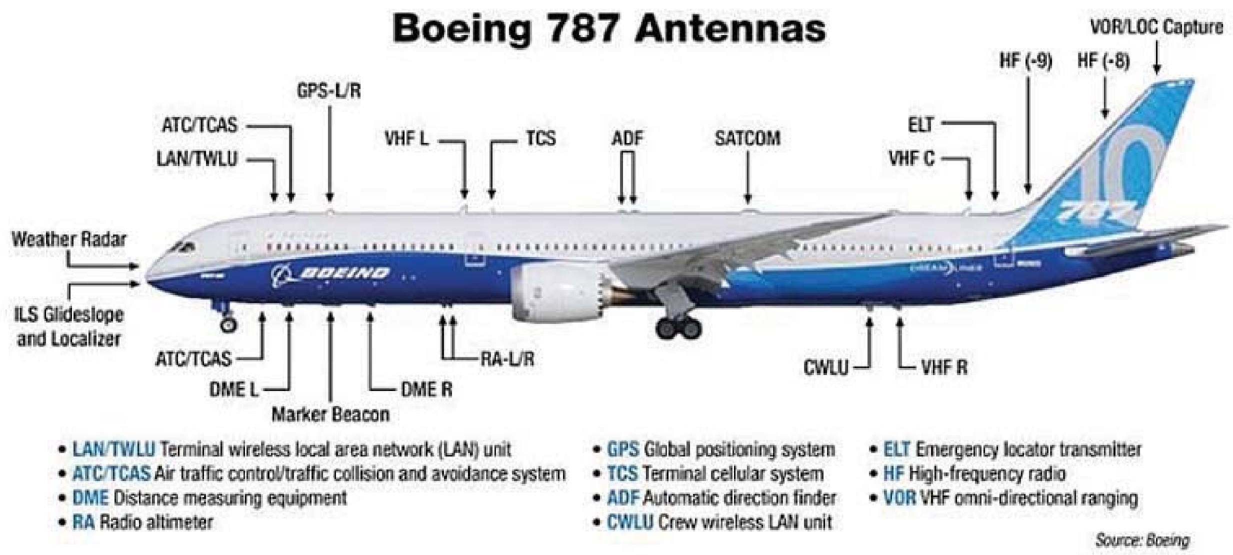
In addition to the 20 antennas on the 787 fuselage, others are used for:

- Satellite communications
- Marker beacons
- Weather radar
- Ultra-high-frequency (UHF) distance measuring equipment (DME)
- Instrument landing system (ILS)
- Wireless local-area networks (WLAN)
- Air traffic control (ATC) and traffic collision-avoidance systems
- Terminal cellular systems
- Crew wireless LAN units

Passenger seat distances from aircraft doors

Electromagnetic waves will typically propagate and "leak" more freely from the aircraft doors than from the fuselage or small windows of the aircraft.

It's obvious that the location of the antenna was the most important factor in determining the coupling intensities throughout the aircraft. As observed from graphical plots,[5] as the distance from the antenna increased, the coupling decreased. The distance from the antenna was estimated such that if the distance was less than four seat units, the coupling would be maximum, while if the distance was greater than nine seat units, zero coupling would exist.



1. This Boeing 787 has more than 20 antennas on the fuselage *(Image from Reference 3)*

UWB or 5G NR devices

Wireless short-range ultra-wideband (UWB) and 5G New Radio (NR) handhelds or laptops may be a cause of EMI disturbance on an aircraft. FAA rules state passengers must turn off or put devices in airplane mode.

Aural Warning Systems

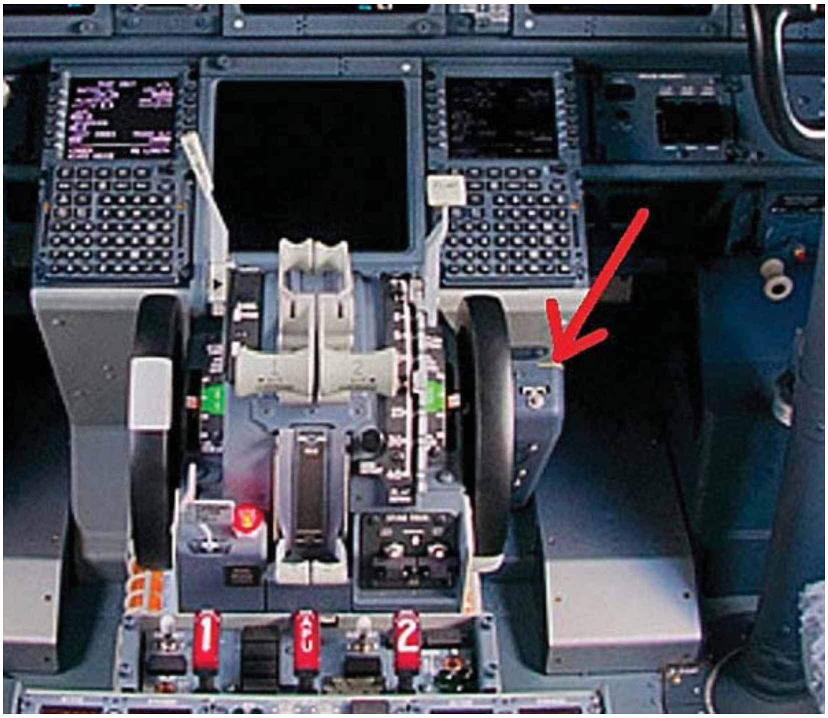
Aircraft for commercial or military use carry aural warning systems[6] that will alert the pilot with audio signals for various situations. These events include the following: abnormal takeoff configuration, landing gear configuration, stall, pressurization, MACH or airspeed overspeed, an engine or wheel-well fire, calls from the crew call system, collision-avoidance recommendations, and more *(Fig. 2)*.

The function of aural warning systems is considered critical. Thus, aircraft manufacturers are required to prove that they're not susceptible to outside environmental threats such as thermal stress, vibrational impact, or EMI.

The aerospace industry has become more dependent on electrical and electronic systems. As such, there's a concern to protect aircraft electrical and electronic systems from radiated and conducted susceptibility. This is sometimes called a fly-by-wire system. An aircraft's fly-by-wire capability is critical for continued safe flight and landing.

Today's aircraft are constructed with a significant amount of composite materials that provide less electromagnetic shielding than the aluminum materials used for older aircraft. Modern aircraft also utilizes more data buses and microprocessors with higher processing speeds. This results in higher-density IC cards, which are more susceptible to high-intensity radiated fields (HIRF).

Aural warning system electronics, in



2. Shown is an Aural Warning module on an aircraft flight deck *(Image from Reference 6)* conjunction with their circuit cards, are no exception to this modern aerospace industry trend—they may be more susceptible to HIRF than before. Moreover, the HIRF environment has become more severe due to an increase in the number, and radiated power, of RF transmitters such as radar, radios, television, and other ground-based, shipborne, or airborne RF transmitters.

Cargo Bay EMI Sources

Interference to avionics systems may lurk from sources in baggage stowed in aircraft cargo bays. It could involve devices such as electronic baggage tags, or from other inadvertent—or even intentional—transmissions from baggage. And the walls in these areas could be radio-transparent.

EMI sources in cargo bays[7] may be a possible threat source to the avionics in adjacent bays, avionics in the cargo bays themselves, as well as to the CNI (communication, navigation, and identification) antennas mounted on the aircraft outer surface. Path-loss calculations and measurements are used to determine the coupling of these sources to the avionics, and susceptibility assessments can be determined depending on these calculations/measurements.

Aluminum containers in the cargo bays can't be relied upon to provide any shielding to EMI. Thus, RF monitoring sensors in the avionics bays and/or cargo bays should be considered if potentially unsafe EMI levels exist. In addition, bulkheads between cargo bays, adjacent to avionics bays, can be coated, covered, or embedded with metal to provide a level of EMI protection.

Shielding in an Aircraft with Braided-Shield Cable

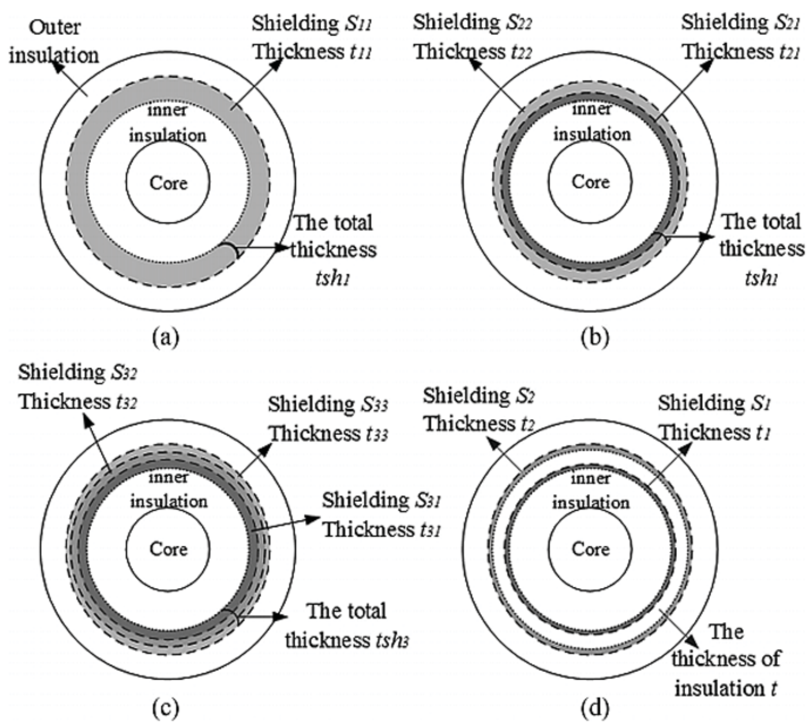
There's a strong push underway to deploy electric aircraft in the coming generations for commercial aircraft. Electrical energy is being used instead of traditional hydraulic and pneumatic energy. This means that the onboard electromagnetic environment is becoming much more severe than in past models.

As a result, interconnecting cables—the major coupling path of EMI—are required to provide more adequate EMI protection capability basics. Shielded cables[8] are considered reliable signal and power carriers and have been widely used in aircraft for years. However, any differences in shielding structure or the number of shielding layers can lead to a significant change in shielding performance.

The most common aircraft cables are single-shielded cables, contact double-shielded cables, double-shielded cables, and multi-shield cables *(Fig. 3)*.

EMI can cause avionic equipment performance to degrade or even malfunction. EMI also may affect cockpit radios and radar signals, interfering with communication between pilot and control tower. Aircraft doors and passenger windows will pass signals from wireless handsets, computers, etc. to external antennas on the aircraft. Cargo holds are major sources of EMI, too.

EMI can cause avionic equipment performance to degrade or even malfunction. EMI also may affect cockpit radios and radar signals, interfering with communication between pilot and control tower.



3. These cross-sections of cables show a single-shielded cable (a), a contacted double-shielded cable (b), a triple-shielded cable (c), and a double-shielded cable (d). *(Image from Reference 8)*

Aircraft cables are important components of the electrical wiring interconnection system. Still, they're susceptible to complex electromagnetic environments like thunder, lightning, and HIRF. Reference 8 determined the following:

- When the thickness of the shielding is constant, improved shielding effectiveness cannot be obtained just by dividing the shielding. However, when each shielding layer is of equal thickness, as the number of layers increases, the shielding effectiveness of the cable will improve.
- When the thickness of the inner and outer shielding layer is different, the transfer impedance of each is not equal. Also, when the ratio of the thickness between the inner and outer shield layers is larger than 1, the larger the ratio is, the better the shielding performance is, and vice versa.
- An insulating layer between the shield layers of the double-shielded cable will provide better shielding effectiveness. In addition, the thicker the insulating layer between the two shielded layers, the better the shielding effectiveness.

Summary

Aircraft operators can increase their ability to make valid decisions regarding the use of PEDs, which may create EMI disturbances, by becoming aware of the most current information in these following areas: testing and analysis of PEDs and aircraft systems, resulting regulations and recommendations, operator actions for investigating and preventing PED events, and ongoing related activities at Boeing.

Some passengers may still use electronic devices without permission on board aircraft, including cellular phones that they shouldn't be attempting to engage. Pilots have reported anomalies with their navigation equipment that seem to correlate with use of personal electronics in the cabin.

This article recommends some key methods to minimize EMI interference in commercial aircraft. This will help promote safe air travel and foster greater passenger confidence in commercial air travel. ed

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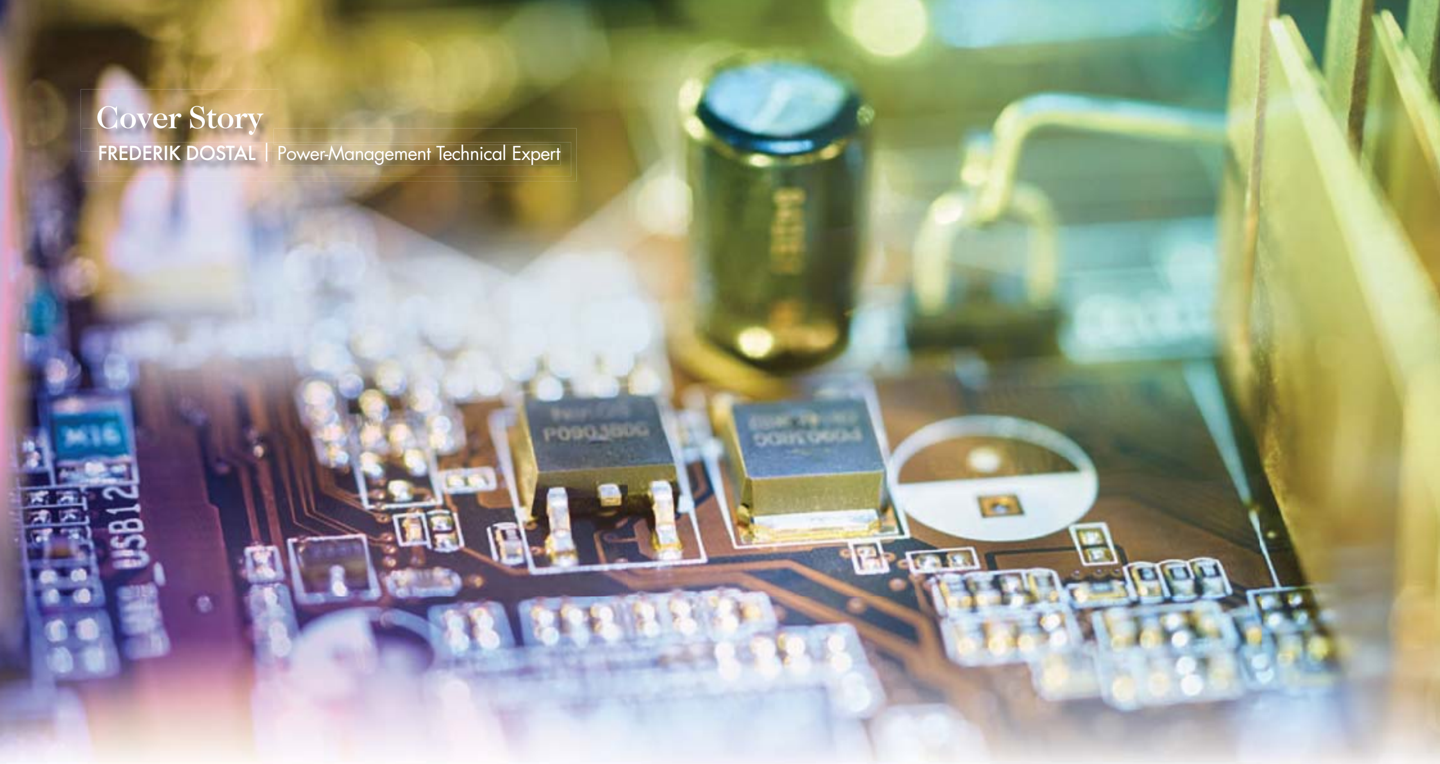


Cover Story

FREDERIK DOSTAL | Power-Management Technical Expert

How to Easily Design POWER SUPPLIES (PART 1)

The intent of this series is to shine the light on easy-to-understand concepts in power-supply design. Here we look at the LDO and the switch-mode power supply, as well as the most common non-isolated topologies used for SMPS.

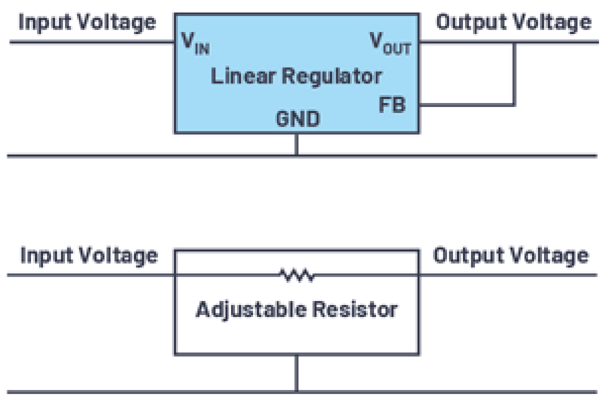
This series gives an overview of the possibilities for power-supply design. It addresses the basic and commonly used isolated and non-isolated power-supply topologies along with their advantages and disadvantages. Also covered are electromagnetic interference (EMI) and filtering considerations. This mini tutorial aims to provide a simplified understanding and renewed appreciation for the art of power-supply design.

Most electronic systems require some sort of voltage conversion between the voltage of the energy supply and the voltage of the circuitry that needs to be powered. As batteries lose charge, the voltage will drop. Some dc-dc conversion can ensure that much more of the stored energy in the battery is used to power the circuitry. Furthermore, for example, with a 110-V ac line, we can't power a semiconductor such as a microcontroller directly.

Since voltage converters, also named power supplies, are used in almost every electronic system, they have been optimized for different purposes over the years. Certainly, some of the usual targets for optimization are solution size, conversion efficiency, EMI, and cost.

The Simplest Power Supply: The LDO

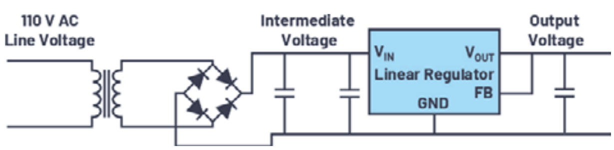
One of the simplest forms of a power supply is the low-dropout (LDO) regulator. LDOs are linear regulators as opposed to switching regulators. Linear regulators put a tunable resistor between the input voltage and the output voltage, which means the output voltage is fixed independent of how the input voltage changes and which load current is running through the device. *Figure 1* shows the basic principle of this simple voltage converter.



1. A linear regulator converts one voltage into another.

For many years, a typical power converter consisted of a 50- or 60-Hz transformer, connected to the power grid, with a certain windings ratio to generate a non-regulated output voltage—a few volts higher than the needed supply voltage in a system. Then, a linear regulator was used to convert this voltage to a well-regulated one as needed by the electronics. *Figure 2* shows the block diagram of this concept.

The problem with the basic setup in *Figure 2* is that the 50-/60-Hz transformer is relatively bulky and expensive. Moreover, the linear regulator dissipates quite a lot of heat, so the total system efficiency is low and getting rid of the generated heat is difficult with high system power.



2. Shown is a line transformer followed by a linear regulator.

Switch-Mode Power Supplies to the Rescue

To avoid the disadvantages of a power supply as shown in *Figure 2*, switch-mode power supplies (SMPS) were invented. They don't rely on 50- or 60-Hz ac voltage. SMPS take a dc voltage, sometimes rectified ac voltage, and generate a much higher-frequency ac voltage to use a much smaller transformer. In non-isolated systems, they can rectify the voltage with an LC filter to generate a dc output voltage.

The advantages of SMPS are small solution size and relatively low cost. The ac voltage being generated doesn't need to be a sine voltage waveform. A simple PWM signal shape will work just fine and is easy to generate with a PWM generator and a switch.

Up until the year 2000, bipolar transistors were the most commonly used switches. They would work well but had relatively slow switching transition speed. They weren't very power-efficient, limiting the switching frequency to 50 kHz or maybe 100 kHz.

Today, we use switching MOSFETs instead of bipolar transistors, allowing for much faster switching transitions. This, in turn, gives us lower switching losses, allowing for switching frequencies of up to 5 MHz. Such high switching frequencies enable the use of very small inductors and capacitors in the power stage.

Switching regulators bring many benefits. They generally deliver power-efficient voltage conversion, enable voltage step-up and step-down, and offer relatively compact and low-cost designs. The disadvantages are that they're not so simple to design and optimize, and they generate EMI from the switching transitions and the switching frequency. The availability of SMPS regulators, along with power-supply design tools such as LTpowerCAD and LTspice, have greatly simplified this difficult design process. With such tools, the circuit design process of a SMPS can be semi-automated.

Isolation in Power Supplies

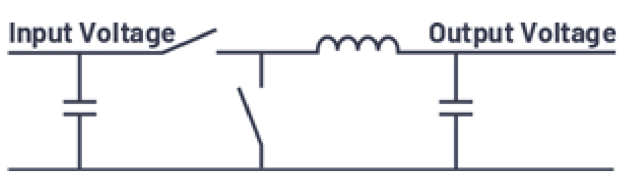
When designing a power supply, the first question should be whether or not galvanic isolation is required. Galvanic isolation is used for multiple reasons. It can make circuits safer; allows for floating system operation; and prevents noisy ground currents from spreading through different electronic devices in one circuitry. The two most common isolated topologies are the flyback and forward converters. However, for higher power, other isolated topologies are employed, such as push-pull, half-bridge, and full-bridge.

If galvanic isolation isn't required, then in most cases a non-isolated topology is used. Isolated topologies always require a transformer, which tends to be expensive, bulky, and often difficult to get off-the-shelf with the exact requirements of a custom power supply.

Most Common Topologies When Isolation Isn't Required

Buck

The most common non-isolated SMPS topology is the buck converter. It's also known as the step-down converter. It accepts a positive input voltage and generates an output voltage lower than



3. Concept of a simple buck step-down converter.

the input voltage. The buck converter is one of the three most basic SMPS topologies that only require two switches, an inductor, and two capacitors.

Figure 3 shows the basic principle of the buck-converter topology. The high-side switch pulses a current from the input and generates a switch-node voltage alternating between the input voltage and ground voltage. The LC filter takes that pulsed voltage on the switch node and generates a dc output voltage. Depending on the duty cycle of the PWM signal controlling the high-side switch, a different level of dc output voltage is generated. This dc-dc buck converter is very power efficient, relatively easy to build, and requires few components.

> **The buck converter is one of the three most basic SMPS topologies that only require two switches, an inductor, and two capacitors.**

The buck converter pulses current on the input side, while the output side has continuous current coming from the inductor. This is the reason why a buck regulator is very noisy on the input side and not so noisy on the output side. Understanding this is important when low-noise systems must be designed.

Boost

Besides the buck topology, the second basic topology is the boost, or step-up, topology *(Fig. 4)*. It uses the same five basic power components as the buck converter, but rearranged, so that the inductor is placed on the input side and the high-side switch is placed on the output side. The boost topology is used to step up a certain input voltage to an output voltage that's higher than the input voltage.

When selecting a boost converter, it's important to note that boost converters always specify the maximum rated switch current and not the maximum output current in their datasheets. In a buck converter, the maximum switch current is directly related to the maximum achievable output current, independent of voltage ratio between the input and output voltage. In a boost regulator, the voltage ratio directly affects the possible maximum output current based on a fixed maximum switch current. When selecting a suitable boost regulator IC, you need to not only know the desired output current, but also the input and output voltage of the design in development.

A boost converter is very low noise on the input side because the inductor in line with the input connection prevents rapid changes in current flow. However, on the output side, this topology is quite noisy. We only see pulsed current flow through the outside switch, and thus output ripple is more of a concern compared to the buck topology.

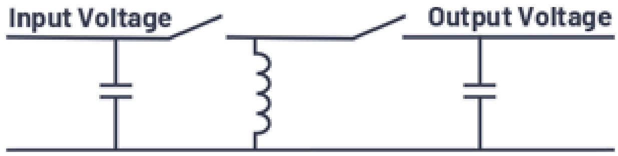
4. Concept of a simple boost step-up converter.

Buck-Boost

The third basic topology, only consisting of the five basic components, is the inverting buck-boost converter *(Fig. 5)*. The name is derived from the fact that this converter takes a positive input voltage and converts it into a negative output voltage. Besides this, the input voltage may be higher or lower than the absolute of the inverted output voltage. For example, –12 V output voltage may be generated out of 5 V or 24 V on the input. This is possible without making any special circuit modifications.

In the inverting buck-boost topology, the inductor is connected from the switch node to ground. The input side as well as the output side of the converter see pulsed current flow, making this topology relatively noisy on both sides. In low-noise applications, this nature is compensated by adding additional input and output filtering.

One quite positive aspect of the inverting buck-boost topology is the fact that any buck switching regulator IC may be used for such a converter. It's as simple as attaching the output voltage of the buck circuit to system ground. The buck IC circuit ground will become the adjusted negative voltage. This trait leads to a very large selection of switching-regulator ICs on the market. ed



5. Concept of a simple inverting buck-boost converter.

FOR PARTS 2 AND 3, which cover specialized topologies, common isolated topologies, and advanced isolated topologies, go to https://www.electronicdesign.com/power-management/whitepaper/21173589/analog-devices-how-to-easily-design-power-supplies.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Ad Index

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No Time to Die...Driving

(Continued from page 40)

back to the shop turned these two-wheel-drive cars into four-wheel-drive monsters that also were equipped with auto-inflating air bags sufficient to keep the cars afloat should the ice they were driving over prove insufficient support for these new, weighty autos.

Another idea Chris had was used in *GoldenEye*, where the chase scene was originally intended to be a motorcycle chase. Instead, Bond gets to drive a tank, which provided some new options such as going through obstacles rather than around.

While the results on screen are amazing, the actual creation is challenging and can be dangerous, so don't try these stunts at home—especially when six high-speed vehicles must be choreographed. Adding CGI to the mix can enhance a scene, crop out things the director doesn't want in the scene, as well as add virtual items to the video. Quite a few of the scenes in *No Time to Die* are more CGI than live. However, when it comes to the cars, what you see is what you get. ed

2. Daniel Craig did some of the stunt driving in the Aston Martin DB5.

3. The new 007, Nomi, drives a new Aston Martin DBS Superleggera.

4. A variety of Land Rover Series III vehicles were needed. These included remote-controlled versions for safety purposes, since crashing a car with people inside isn't a great way to work.

BILL WONG | Senior Content Director

NO TIME TO DIE... DRIVING

1. Chris Corbould (left) is the Special Effects Supervisor for the movie "No Time to Die."

Editor Bill Wong talks about car movie magic with "*No Time to Die*" Special Effects Supervisor, Chris Corbould.

I admit it. I've been a Bond fanatic ever since I saw *Doctor No* when it was first released. The gadgets were amazing as were the cars. Aston Martins have played a central role in a host of Bond films, with fast car chases doing seemingly impossible stunts. The latest incarnation is *No Time To Die*, and I had a chance to talk with the film's Special Effects Supervisor, Chris Corbould *(Fig. 1)*. He has worked on numerous movies, including many Bond films.

These days, computer-generated imagery (CGI) is the norm. especially with sci-fi and action films. However, sometimes old-fashioned stunt driving and special effects are what's needed, and this new film has a mix, including half-a-dozen cars and vehicles where stunt driving and real effects dominate. A quick synopsis of the film:

"In *No Time To Die,* Bond has left active service and is enjoying a tranquil life in Jamaica. His peace is short-lived when his old friend Felix Leiter from the CIA turns up asking for help. The mission to rescue a kidnapped scientist turns out to be far more treacherous than expected, leading Bond onto the trail of a mysterious villain armed with dangerous new technology."

The scene filmed in Matera, Italy has a tricked-out Aston Martin DB5 driven in full battle mode, literally, by Daniel Craig as James Bond *(Fig. 2)*. The DB5 is equipped with dual M134 mini-guns, bulletproof glass, and smokescreen generators. Eight carbon-body, stunt versions were made for the movie, with Mark Higgins doing some of the stunt driving. If you have a few million, there's a run of about 25 new Aston Martin Continuation DB5s being built.

The car first appeared in *Goldfinger* and one was destroyed in the movie *Skyfall*. It also has appeared in *Thunderball, GoldenEye, Tomorrow Never Dies, Casino Royale,* and *Spectre*. Sean Connery and Pierce Brosnan were at the wheel in addition to Daniel Craig.

Nomi, the new 007, gets to ride in an Aston Martin DBS Superleggera *(Fig. 3)*. You need to watch the movie to see this car in action as well as the Aston Martin V8 Vantage that Bonds rolls through London, England.

The Land Rover Series III scenes *(Fig. 4)* filmed in Jamaica highlight some of the changes that have been made possible with the latest automotive technology ranging from self-driving cars to remote-control drones. On the plus side, hooking into a car's control system is much easier today versus the fully mechanical cars of yore.

These days, it's possible to mount a pod on the roof of a car with a driver that's really controlling the vehicle. Cameras in the car with the actors can film the action without having to use technologies like green screens to put scenes in the background. Shooting the entire scene live, while the car is moving, causes momentum and centrifugal force to affect the actors.

The pods also can be remote-controlled when necessary, and various techniques that provide feedback to the real driver have been used, such as virtual-reality goggles. It's not bad for exercises like racing drones, but it can be a bit different when trying to muscle around a Land Rover. As it turns out, having a driver in a second car, with its own driver, following or running next to the car being controlled, often works better because the remote driver can feel the road effects.

Revamping cars was nothing new for Chris. For example, the ice lake chase scene in *Die Another Day* really needed four-wheel drive for safety and effects. However, the Jaguar and Aston Martin cars did not come with that option. A trek

(Continued on page 39)


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