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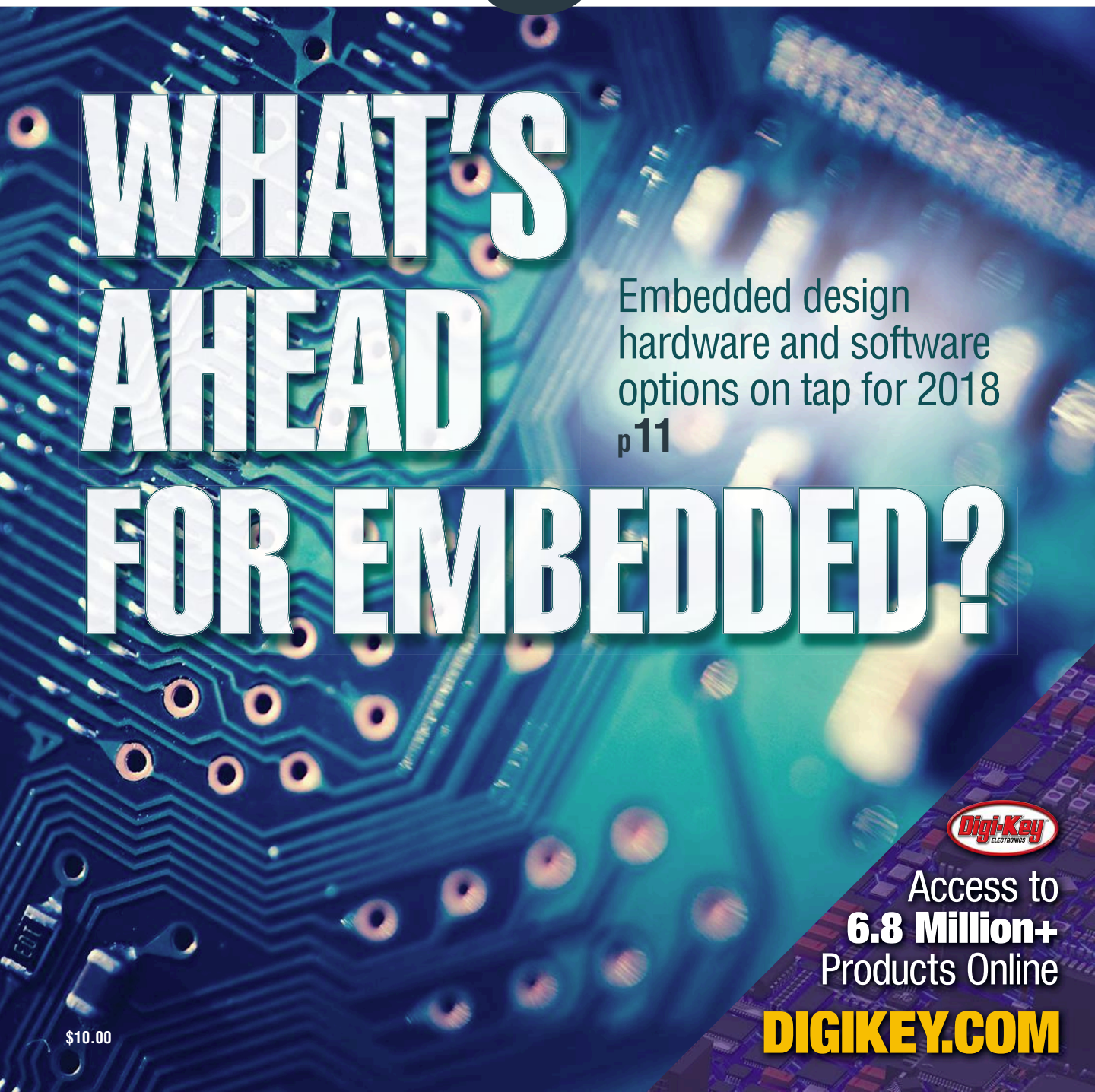

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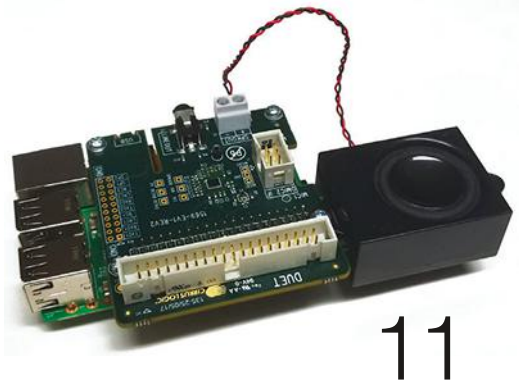

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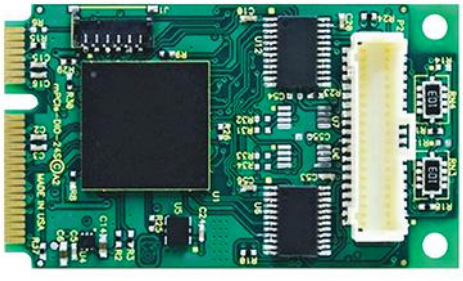

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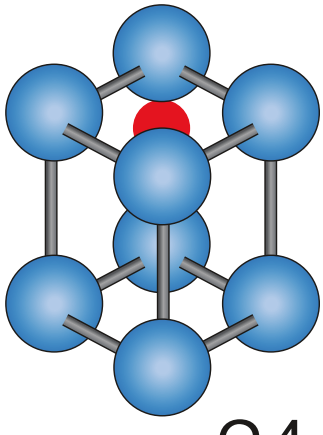

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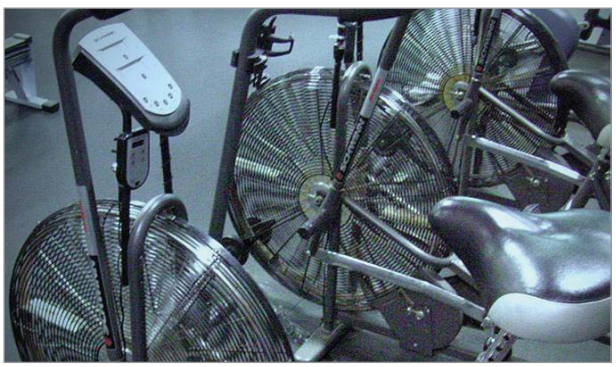


What's All This Usability Stuff, Anyhow?

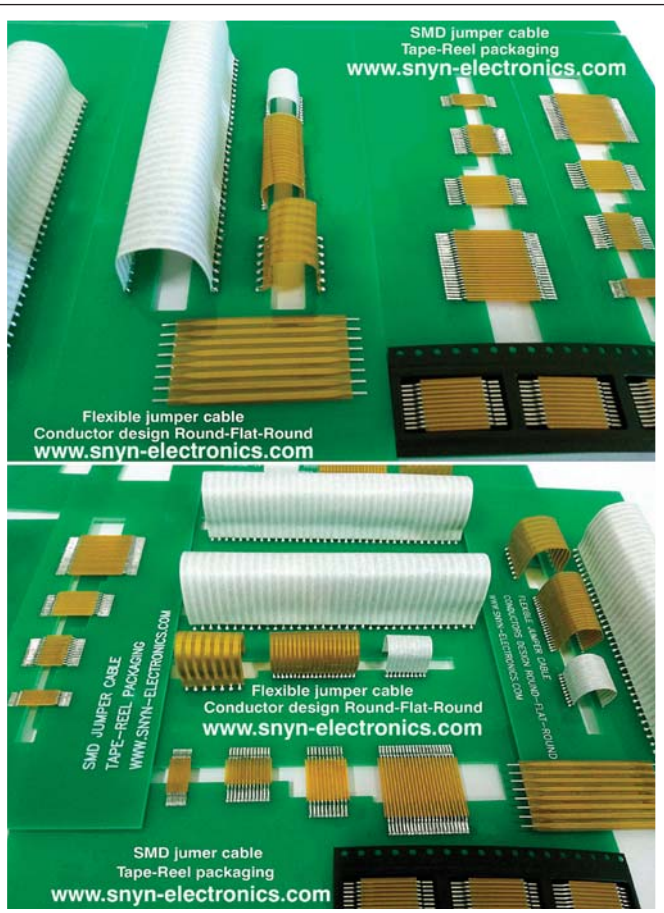
From head-scratching instructions and labels to near-impossible-to-read words to moronic mechanisms, it makes you wonder if a product's usability is last on the design checklist…or doesn't exist at all.

http://www.electronicdesign.com/analog/what-s-all-usability-stuff-anyhow

Artificial Intelligence Chips Could Spill Out of Data Centers, Onto Desks

No one knows what the future of artificial intelligence will look like and no one knows what computer architecture will take it there. For years, Nvidia has been trying to expand the market for its graphics chips, which are the current gold standard for training and running algorithms based on deep learning.

http://www.electronicdesign.com/industrial-automation/artificial-intelligence-chips-could-spill-out-data-centers-desks



Saved by the Sensor: Vehicle Awareness in the Self-Driving Age

At first inconceivable, self-driving cars are finally starting to make their way into the real world. In most robotic use cases today, an error can lead to a bad part, or perhaps an unswept floor. However, when driving a car, a computer must constantly make potentially life-threatening decisions.

http://www.electronicdesign.com/automotive/saved-sensor-vehicle-awareness-self-driving-age

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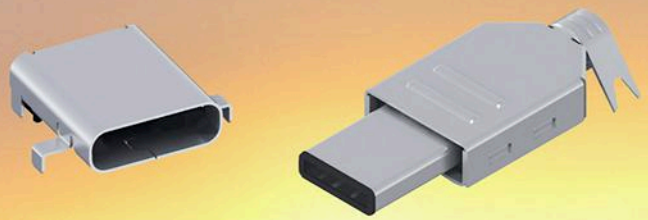

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Editorial

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Celebrating the 70th Anniversary of the Transistor

We recognize a device that overwhelmingly changed the electronics industry and our lives.

As of Dec. 23, 2017, the transistor was officially 70 years old. The invention of the transistor may have been the greatest technology development of the 20th century. It has given us the integrated circuit and its progeny computers, TVs, smartphones, and all the other electronic stuff we use every day. We probably all owe our jobs to the invention of the transistor. So let's take a moment to think about and celebrate this one monumental discovery.

The various historical records say that the transistor was invented Dec. 23, 1947 at AT&T's Bell Laboratories by scientists William Shockley, John Bardeen, and Walter Brattain. On that day, they demonstrated transistor amplification with a point contact transistor. That transistor type was difficult to make. Shockley followed up with the invention of the bipolar junction transistor (BJT). Practical transistors came about quickly and rapid developments thereafter eventually lead to the integrated circuit (IC) and of course the microprocessor. The rest is history as many of us have experienced it.

The first transistor ever conceived was actually a field effect transistor (FET), the brainchild of Julius Lilenfeld in 1926 that was quickly patented. Later Oskar Heil put forth the same idea in 1934. Neither man actually produced a working device. That's why the Bell Lab guys got all the credit, including a Nobel Prize in 1956. Shockley ultimately quit Bell Labs and moved to California to start a company making transistors. His company and the subsequent spin-offs started the semiconductor business. The transistor then begat the integrated circuit, which has given us everything electronic.

There have been many developments and patents in the meantime, too many to chronicle here. But the highlights of the transistor's history and related developments are briefly summarized in a timeline, available at *http://www.electronicdesign.com/power/celebrating-70th-anniversary-transistor.*

We have undoubtedly reached the physical limit for downsizing transistors. At the 5 nm manufacturing node, the gate size approaches that of the atoms and molecules. We simply cannot get any smaller thereby negating Moore's.

So what's next?

ROHM LAUNCHES INDUSTRY'S FIRST Dual-Mode Battery Charging IC

A GROWING NUMBER OF portable devices are adopting the USB Type-C Power Delivery (USBPD) standard that can charge up to 100W (20V/5A). To deliver the wide power supply range required by USBPD, a boost function must be added to a system to charge 2-cell (~8.4V) batteries from conventional 5V chargers. And if you want to enable the two different charging methods at the same time it further requires mounting charge ICs along with peripheral components as well as an MCU to control charge switching, all presenting a barrier to introduction.

But to show it can be done in a simpler manner while still supporting of the two predominant charging methods for the latest portable devices, ROHM has developed the BD99954, a Battery Management LSI for 1 to 4 cell Lithium-Ion secondary batteries and the first with dual-input control. Thus, it can autonomously select from two inputs—which one to get the supply—without intervention from an external controller, using instead an original built-in charging adapter function. Eliminating the MCU also removes the need to mount external peripheral components such as transistors and resistors typically necessary.

The BD99954 supports input voltages from 3.8V to 25V. This range encompasses the voltage range of 5V to 20V defined by USB PD (USB Power Delivery). Additionally, it also natively supports BC 1.2 (Battery Charging Specification v1.2) detection. This provides support for legacy USB AC Adaptors. The device does not natively support wireless charging but a wireless charging device can be connected to one of the inputs in order for the system to support wireless charging.

BD99954 also integrates a charging profile that monitors the charging state of the battery and limits the maximum current provided to the battery. This feature prevents the part from providing too much current to the battery, possibly damaging it. In addition, it can also monitor the temperature of the battery to reduce the charging current when the battery overheats.

BD99954GW is available in a 0.4mm pitch, 2.6mm x 3.0mm x 0.62mm wafer level CSP package designed for space-constraint equipment such as low-profile notebook PCs, tablets, and other applications. BD99954MWV comes in an 0.4mm pitch, 5.0mm x 5.0mm x 1.0mm QFN package. OEM quantities are available now.

To assist engineers ROHM also has introduced an evaluation kit for the BD99954 battery management system. Designated BD99954MWV-EVK-101 and featuring a GUI, users can access the battery charging profile and modify and read back the registers of the device.

The BD99954MWV EVK-101 board comes with a bill of materials, schematics, board layout, and application data. It features a Reverse Buck/Boost Option and an On-Board USB-to-I2C Communication Circuit. Its Input Operating Range is 3.8V to 25V. In addition, a user manual for the I2C control software is included to help program the BD99954MWV.

Operation is straightforward: make sure the BD99954 board is connected to your PC via USB cable and is powered on with a power supply. Once connected, click on the BD99954 I2C Control icon located on the desktop GUI or find the application in the Windows Start Menu to start the program. Upon starting the program and BD99954 board is being powered up with the appropriate voltage, the software will indicate on the top-right corner if the board is connected. ■

MURRAY SLOVICK, Contributing Editor

CEO OF TEXAS INSTRUMENTS to Step Down


Rich Templeton

TEXAS INSTRUMENTS SAID that its chief executive, Rich Templeton, is stepping down after more than 13 years in the captain's chair of the company he turned into the largest manufacturer of analog chips. The company has chosen Brian Crutcher, its chief operating officer, to replace him.

The switch from Templeton to Crutcher is scheduled to take place on July 1. Crutcher, who joined Texas Instruments in 1996, has been in charge of business operations and global manufacturing since he was promoted to chief operating officer last year. He previously presided over the company's analog and digital light processing businesses.

Choosing Crutcher seems meant to preserve the stability of Texas Instruments, the largest maker of analog chips that handle physical signals flowing inside everything from cars to the industrial machines that put them together.

Templeton is known for ushering Texas Instruments into analog. He was chief executive when, in 2011, Texas Instruments acquired National Semiconductor for $6.5 billion in cash. He also wound down the company's wireless operations, allowing it to plough cash into embedded and signal processing chips. ■

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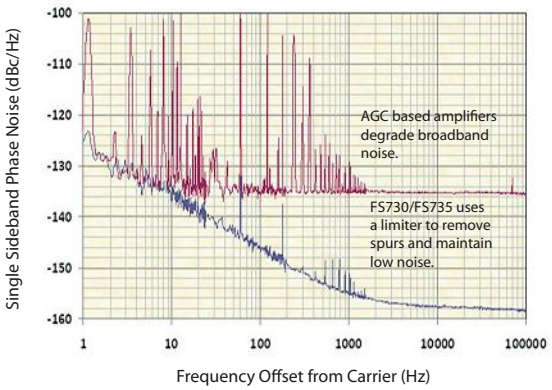

Additive phase noise in 10 MHz Distribution Amplifiers: Limiter vs. AGC Designs

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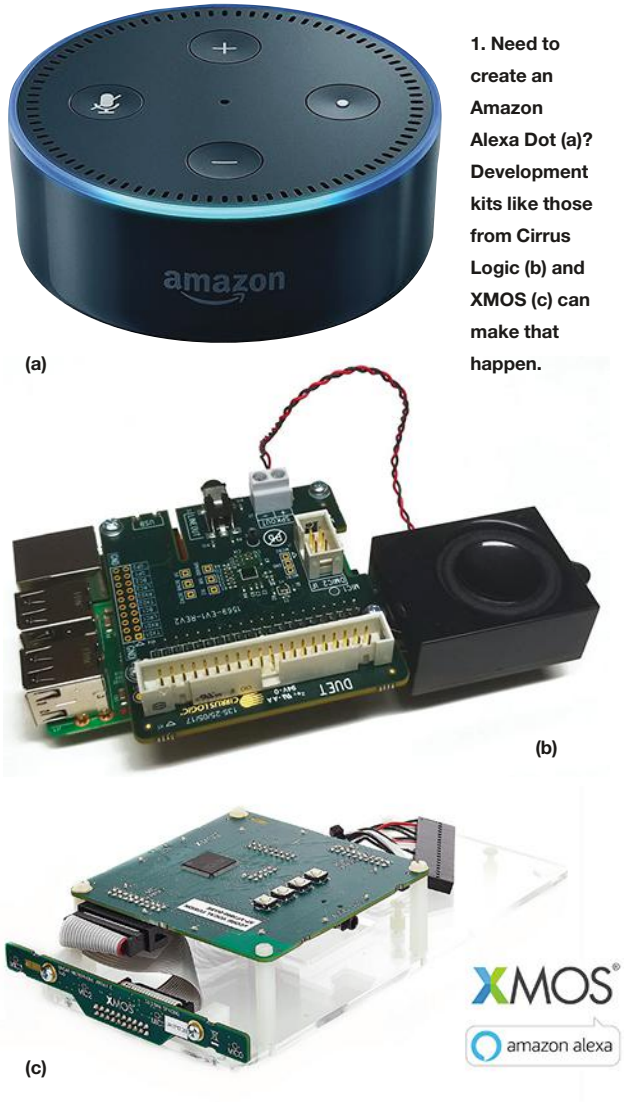
WILLIAM WONG | Technology Editor

Embedded Design Hardware and Software Options for 2018

Senior Technology Editor Bill Wong examines the future of embedded development with his annual forecast.

There has never been a more exciting, confusing, and challenging time to develop embedded products. The Internet of Things (IoT) is a given, but tools ranging from machine learning (ML), persistent storage (PS), and mesh networking are changing how developers look at a problem. Approaches that were impractical a few years ago are becoming readily available. That is not to say that these paths are not fraught with peril for the uneducated. Likewise, adopting the latest hardware and software should not mean ignoring other issues like privacy and security. Insecure systems can render the best-intentioned device or service untenable.



(a)

(b)

(c)

1. Need to create an Amazon Alexa Dot (a)? Development kits like those from Cirrus Logic (b) and XMOS (c) can make that happen.

CHANGING USER INTERFACES

Science and engineering fact continues to chase science fiction. Conversing with computers is no longer the exclusive domain of movies like "2001: A Space Odyssey."

A number of unrelated technologies have come together to make this possible including the internet, the IoT, artificial intelligence (AI), and machine learning, plus improvements in audio processing, MEMS microphones, and so on. The result is Amazon Alexa and its competitors like Google Home, Apple HomePod, and even Microsoft's Cortana.

Amazon has been in the lead working with partners to deliver hardware development kits that work with Alexa *(Fig. 1)*. Like most IoT solutions, it requires a collaboration with a number of partners. The noise reduction hardware and software are differentiating factors. Machine learning is being used at this level in addition to natural language processing in the cloud.

The challenge for companies is deciding what walled garden to work with. It is possible to have products that support multiple IoT frameworks, or even voice control systems like Alexa, but normally products will support one.

Voice interaction is not the only user interface that has benefitted from the use of artificial intelligence and other technology advancements. Stylus or pen-based input has improved on the hardware side and paired with tablets and giant smartphones. Editing of handwritten script, versus typed text, is possible using tools like MyScript's Interactive Ink and its Nebo app. The Digital Stationery Consortium's (DSC) is also working on a universal digital ink interchange format. DSC's format is based on Wacom's WILL technology.

Voice and script are affecting two other user interface technologies: augmented reality (AR) and virtual reality (VR). Advances on the hardware side will improve to user experience, but it is the software frameworks, integration, and advancements that will make AR and VR stand out this year. I expect AR to lead in non-gaming applications.

SECURITY, ACCELERATORS, AND EMBEDDED FPGAS

"Essentially, every electronic application now reaches out to the internet, and there are so many people with nothing better to do than to hack into someone else's good work to be mean or for profit, that it's imperative that designers build an adequate level of security into their products today," notes Tom Starnes, an analyst at Objective Analysis. "Unfortunately, security is a utility, the quality of which is hard to quantify, and isn't as fun as pimping up a User Interface. However, as engineers it is our duty to protect users of our creations from unseen danger."

Not a day goes by without a security breach being brought to light. PCs provided billions of targets to hackers and smartphones easily surpassed this. IoT devices will exceed smartphone deployments by orders or magnitude.

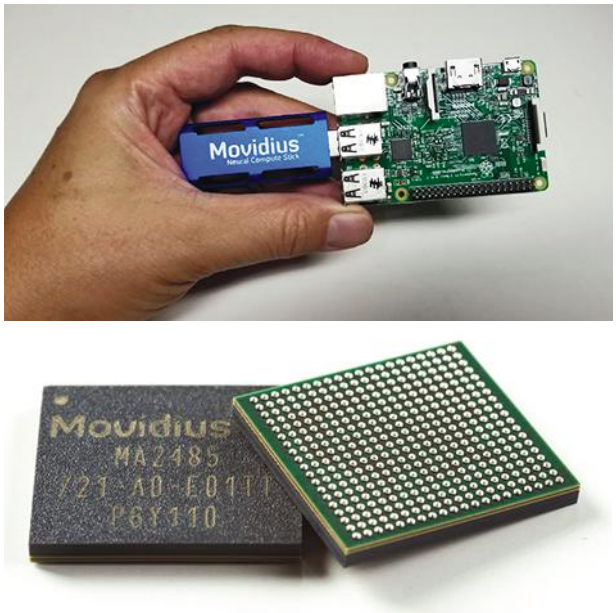
On the plus side, hardware vendors are focusing on including security hardware and firmware in standard products. Encryption hardware and secure key storage are more common now and are starting to be standard options within a microprocessor family. Look to dual, asymmetric core approaches to provide improved security as well as providing better power management.

Cortex-M23 and -M33 microcontrollers based on Arm's ARMv8-m architecture will be available this year. Arm's Platform Security Architecture (PSA) is a software complement to this. Unfortunately Intel's Management Engine (ME) woes highlight problems that can occur with embedded hardware and firmware.

Higher-end embedded systems will continue to see growth in the use of hypervisors and virtual machines. Embedded development tends to follow advances pushed by the enterprise where this technology has been used for decades.

Hardware acceleration to support neural networks, the backbone of the machine learning trend, will move from evaluation to production for many more developers. GPGPUs are being used in this space as well as hardware specifically designed for AI acceleration. Even DSPs are being tuned for AI like Cadence's Vision C5 DSP.

Intel's Movidius Myriad 2 VPU (video processing unit) is already being using in DJI drones to handle collision avoidance and recognizing user control gestures *(Fig. 2)*. It even works with the Raspberry Pi.



2. The Intel Movidius Myriad 2 VPU (video processing unit) is available on a USB 3.0 stick that works with a range of systems including the Raspberry Pi.

Developers will need to become more familiar with AI to determine what hardware and software requirements will be needed for training and deployment, since training typically requires more computation. There are many types of neural networks and different models. Some applications can benefit by simply using libraries or runtimes that take advantage of neural networks, while others may be much more complex programming, configuration, and training.

Also keep an eye out for embedded FPGAs and RISC-V. Embedded FPGAs (eFPGAs) are available from a number of vendors, and silicon foundries are supporting them. The eFPGAs have significantly reduced overhead compared to adding an FPGA chip to a design and provide a flexible way to incorporate proprietary designs.

RISC-V growth continues, but remains a minute fraction in terms of deployment compared to Arm, which dominates the space. On the other hand, its use is growing substantially. There are now a number of companies providing RISC-V IP and it runs on most FPGA platforms, including Microsemi's Mi-V environment. There are advantages to keeping it simple, stupid (KISS).

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The Storage Networking Industry Association's (SNIA) NVM programming model (NPM) will start having more impact as support for persistent memory model becomes more available in operating systems like Linux and Windows. Of course, having non-volatile DIMMs (NVDIMM) will be key to its success.

PERSISTENT STORAGE

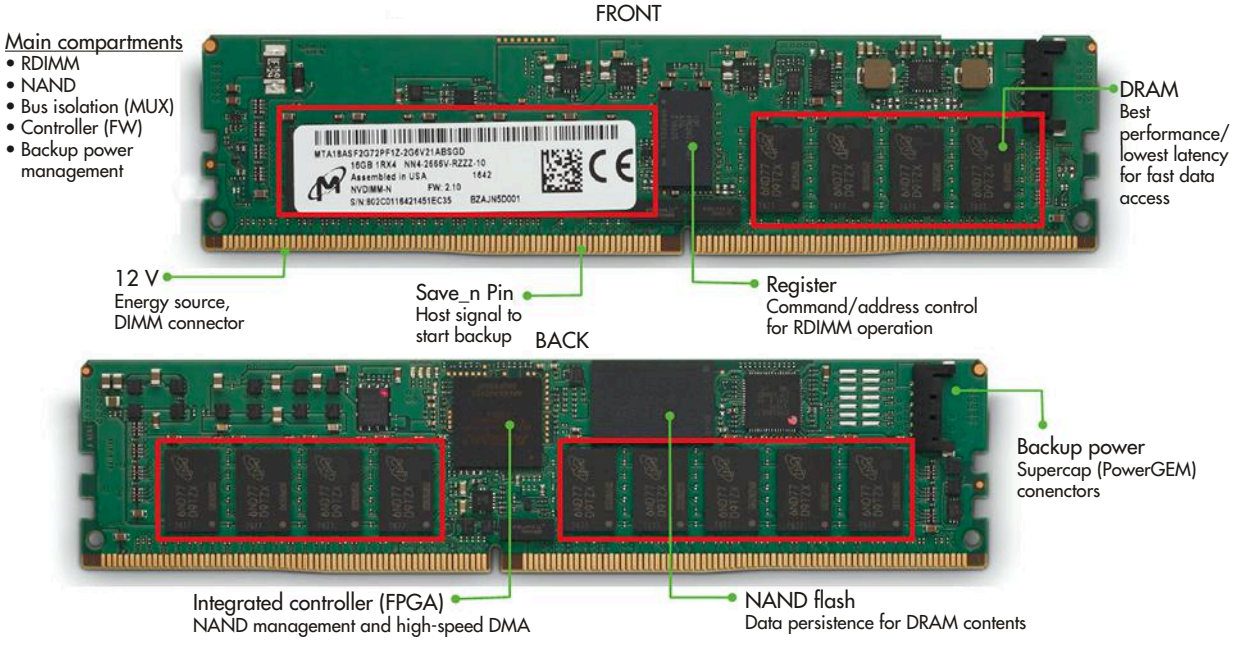
A change is in the wind for non-volatile memory (NVM) technologies as silicon foundries add support for storage technologies like Resistive RAM (ReRAM), Conductive Bridging RAM, and MRAM. This means microprocessors and system-on-chip (SoC) solutions can utilize non-flash NVM technologies that offer advantages such as speed and unlimited write lifetimes. Texas Instruments' MSP430 microprocessor family already has FRAM versions that offer significant advantages over flash-based solutions.

The Storage Networking Industry Association's (SNIA) NVM programming model (NPM) will start having more impact as support for persistent memory model becomes more available in operating systems like Linux and Windows. Of course, having non-volatile DIMMs (NVDIMM) will be key to its success.

"In 2018 Intel is due to introduce the Optane DIMM based on the company's 3D XPoint Memory," says Jim Handy, an analyst at Objective Analysis. "This should be a game-changer for any system based on DIMMs, since it will support much bigger memory sizes than DRAM at a lower price. It's nonvolatile, too, but there is no off-the-shelf software that supports that today, so this attribute will only be useful in systems built around proprietary software. Even so, we will see big changes in computer memory configurations starting next year."

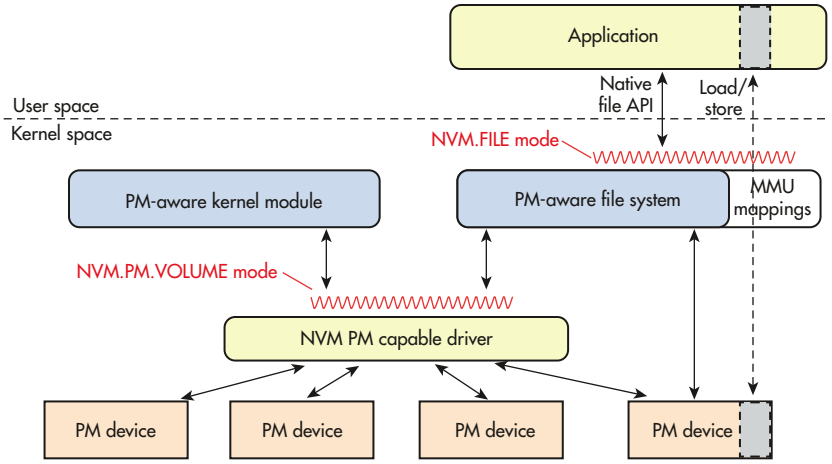
There are a number of vendors providing a range of NVDIMM solutions such as Micron's NVDIMM *(Fig. 3)*. It uses a combination of DRAM and flash memory combined with an FPGA controller and an external supercap. Diablo Technologies pioneered an all-flash NVDIMM device.

The biggest challenge is on the software side. SNIA's NPM includes support for direct application access of non-volatile, in-memory storage *(Fig. 4)*, unlike the conventional block-oriented disk storage or NVMe storage located on the PCI Express bus.



3. Micron's NVDIMM includes an FPGA controller, DRAM, and flash memory with a link to an external supercap. The controller copies DRAM contents to flash when power is lost and copies it back when power is restored.

Also keep an eye out for the ruler form factor designed to handle NVMe storage *(Fig. 5)*. It is complementary to the M.2 and U.2 form factors being used for NVMe storage. The system is designed to pack as much storage as possible into a 1U form factor.



4. Storage Networking Industry Association's (SNIA) programming model includes support for direct application access to in-memory NVM storage.

WILD WEST WIRELESS

Wireless connectivity has never been simple, but the number of options continues to grow. Even the venerable 802.11 standard has variations for 802.11a/b/g/n/ac. 802.11n/ac added in the 5 GHz band and multiple-input and multiple-output (MIMO) has now become ubiquitous. The latest trend is 802.11s mesh networking that continues to grow in importance.

Of course, wireless requires security and it is not immune from being compromised. The 2017 KRACK problem with WPA2 is only the tip of the iceberg. On the plus side, most attacks and problems can be fixed by a software upgrade, assuming the vendor provides it and the users install it.

Mesh networks continue to garner support throughout the wireless spectrum. The Bluetooth mesh standard has been established and is becoming more common as stacks become available. The Bluetooth mesh standard is independent of the new

Bluetooth 5.0 standard, so this functionality may find its way into older devices through software updates. Bluetooth 5.0 employs a random frequency-hopping scheme that decreases the chance of conflicts with a neighboring BLE device. It also works on longer-range connections with a tradeoff in speed.

The IoT craze has fueled interest in a range of wireless solutions with long-range, lower-power, point-to-point technologies like LoRaWAN, SigFox, and NB-IoT. They have a range on the order of a kilometer and can penetrate barriers (such as walls) with a tradeoff in speed. Of the three, SigFox has been around the longest, but LoRaWAN and NB-IoT are just taking off and have significant support. One advantage over mesh technologies is the lower software overhead allowing these protocols to be used on very lightweight microcontrollers. Each approach offers advantages and disadvantages that developers will need to take into account when choosing a technology.

These long-range, low-speed technologies complement mesh technologies like ZigBee, Z-Wave, and mesh Bluetooth that offer higher speeds but more limited range. Mesh technologies target applications with a large number of local devices to provide coverage over an area in excess of the area addressed by individual devices.

5. The ruler form factor is a hot swappable, non-volatile memory system with an NVMe interface.

WILLIAM WONG | Technology Editor

Shrinking SWaP to Achieve Smaller, Faster Systems

The relentless design goal of minimizing size, weight, and power (SWaP) will be bolstered by upcoming board systems that are equipped to meet those demands.

PC/104 and the ISA bus will never go away, but smaller-form-factor platforms like Diamond Systems' Zeta system *(Fig. 1)* are needed to minimize size, weight, and power (SWaP). They also must deliver the performance required for new applications from drones to the latest medical equipment.

The Zeta boards employ the compact COM Express Mini Type 10 form factor, allowing them to squeeze into small devices. The Mini-PCIe peripheral expansion is becoming more common on small motherboards and computer-on-modules (COMs) because it's being used for more than adding Wi-Fi to notebooks.

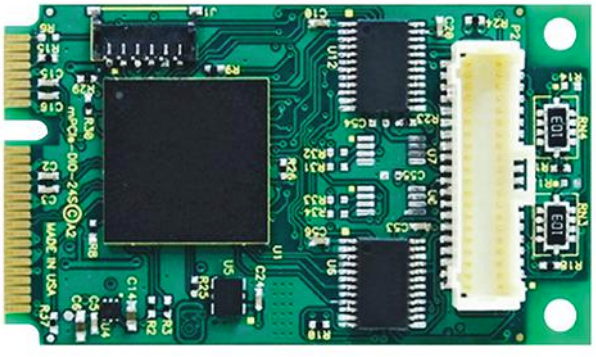
For example, Acces I/O's mPCIe-DIO-24 is a 24-channel digital I/O with a change-of-state (COS) Mini-PCIe card that would work with the Zeta board *(Fig. 2)*. Size and power requirements are minimized with an FPGA. Other Mini-PCIe cards often have microcontrollers to provide more functionality. In fact, the most challenging facet of Mini-PCIe peripheral cards concerns the connectors. The small size is possible using new, compact connectors and cabling.

Curtiss-Wright's Parvus DuraCOR XD1500 rugged mission computer is an example of how Mini-PCIe cards can be used. The computer hosts an Intel Xeon-D with up to three Mini-PCIe sockets for peripheral expansion.

Compact boards and tiny peripheral expansion options help to reduce size and power requirements, but not so much in terms of weight. Significant amounts of weight in board-level systems are often related to cooling requirements such as conduction cooling.

The VITA 48.8 air-flow cooling standard defines a systems approach that can cut the weight of a system almost in half versus a comparable conduction-cooled system *(Fig. 3)*.

1. Diamond Systems' Zeta board, which uses the COM Express Mini Type 10 form factor, includes features like Mini-PCIe peripheral expansion.



2. Acces I/O's mPCIe-DIO-24 is a 24-channel digital I/O with change-of-state Mini-PCIe card would fit right into the Zeta board.

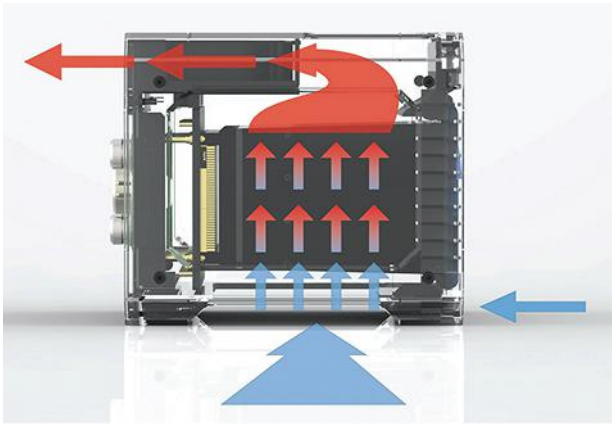
The standard uses conventional 3U and 6U VPX boards, but separates them to allow air flow between them instead of having a conduction system move the heat away from the boards. It eliminates a lot of metal, including channel locks, enabling systems to be built using lighter-weight materials such as 3D-printed plastic frames. This can have a significant impact on cost as well lead to more flexible design options.

Keep an eye out for systems with hardware designed to support machine-learning (ML) and artificial-intelligence (AI) applications. Platforms like Nvidia's Jetson TX2 accelerate ML and AI applications using the GPGPU built into the system. Even smaller AI/ML accelerators are showing up in chips like Intel's Movidius family.

Then there are platforms such as Movidius that target vision processing but can be used for other jobs as well. Intel's chips are already used in DJI's drones to provide obstacle avoidance and tracking, as well as recognizing gestures of users when the camera is aimed at them.

Chips like Movidius would fit nicely on a Mini-PCIe card. They're also small enough to be incorporated onto a motherboard. Quite a few of these platforms are becoming available, and there's even a RISC-V array of 64-bit ET-Maxion and ET-Minion cores in the works from Esperanto Technologies. The AI/ML platforms are designed to minimize SWaP while bringing significant performance improvements.

Modular, board-level systems remain the best way to quickly incorporate diverse processing and peripherals into an embedded solution. Commercial off-the-shelf (COTS) platforms are diverse and address a wide range of application requirements. Options abound for smaller, more powerful systems, and they can even address the latest trends in AI/ML. ed



3. VITA 48.8 defines an air-cooled system that's half the weight of a comparable conduction-cooled system.

White Paper

Find out how to overcome your biggest power system challenge

Power designers face many challenges. Vicor research has identified over a dozen challenges, but the biggest one discussed in this white paper is changes in specifications for the power system during development.


WHITE PAPER

VICOR

Spec Changes Top List of Power Designers' Challenges

Today, engineers are asked to find creative solutions to deliver more power from less space and with higher efficiencies. This makes power-system design an increasingly important part of developing technologically-advanced electronic equipment. Research by Vicor found that these engineers are facing a myriad of challenges meeting cost and schedule targets.

The research found that power-system developers around the globe perceive the biggest challenge to be changes in specifications for the power system during development. Although it may be surprising that this was the biggest problem, rather than technical challenges associated with meeting the system's requirements, in fact changing specifications make it even harder to deliver a project on time and on budget.

The following graph summarizes the responses given when power designers were asked to identify their biggest challenges.

What are the main problems you face with power system development?

VICOR PowerBench

Page 1

This concise white paper explores:

- Today's top power system design obstacles
- The causes of specification changes
- Solution to overcoming spec changes and other challenges

To download this white paper, simply go to

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MIGUEL MENDOZA | Senior Product Marketing Manager at Microchip Technology
www.microchip.com

Why Do Today's Server Applications Use 54-V BLDC Motors?

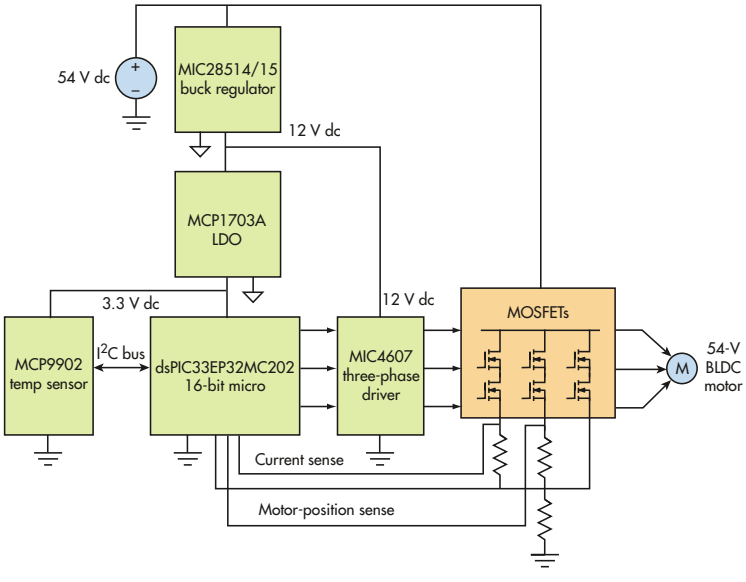
More server manufacturers are adopting 54-V brushless dc motors over traditional 12-V BLDCs to achieve significant savings on a couple of fronts.

Nearly everyone has heard the term "cloud-based computing," yet most of us who rely on being able to access important data from our computers and smartphones don't think much about where the data is actually stored. So what is cloud-based computing? Cloud-based computing refers to a mesh of remote servers that stores and moves data around the world so that we can access via Wi-Fi, local-area network (LAN), or a cellular network.

These remote servers act as a large storage device that consists of clusters of servers in a warehouse commonly referred to as a server farm. These server farms require a constant ambient temperature (optimal temperature range is between 68° and 71°F) to operate at their highest performance and to minimize any failure. They're typically cooled by central air conditioning or heated with central heating depending on their location, just like a typical office space.

The actual server racks use a series of fans that cool the electronic components inside them. As most of us have experienced, electronic equipment heats up as it's utilized, which eventually will affect the maximum performance of the equipment. To minimize the cost and size of heat sinks, the electronics are cooled by air flow using brushless dc (BLDC) fans to take advantage of the ambient temperature, which is kept constant by heating, ventilation, and air conditioning (HVAC) to cool the electronic components in the server rack.

Traditionally, server applications have used 12-V BLDC fans to cool the electronics in a cabinet. However, just like automotive applications, 54-V BLDC motors are being adapted for server applications for several reasons. This article discusses the two main reasons why server manufacturers are adopting 54V BLDC motors rather than traditional 12-V BLDC motors. It also breaks down the typical components required for 54-V motor-drive applications as well as some of the common motor-control algorithms.



1. This simplified block diagram of a 54V BLDC control circuitry identifies typical components used to drive a 54-V BLDC motor without compromising the proven motor-control algorithm.

TWO REASONS FOR SWITCHING TO 54-V BLDCS

Server manufacturers are adopting 54-V BLDC motors over traditional 12-V BLDC motors because it allows them to use one fourth of the current. In turn, motor manufacturers can use thinner copper wire. This also enables motor manufacturers to reduce the size of the motor and, therefore, the overall cost of the motor, because fewer raw materials are required to perform the same work load. Secondly, server manufacturers save on the cost of expensive cables—one cable can power four times the number of motors using

a 54-V BLDC motor compared to a 12-V BLDC using the same power bus gauge cable. For the same power, higher-voltage motors can use smaller cables or a narrower PCB track width.

For example, in a 450-W server, 32 W are consumed by the 12-V BLDC fans. The current required to power them can be calculated simply by the power equation (P= V × I, I = P/V, 32 W/12 V = 2.67 A). With 54-V BLDC fans, the current required will drop to about 0.67 A, assuming the power requirement is the same. This will allow the server engineer to use 26 American Wire Gauge (AWG) wire rather than the 20 AWG wire required to power 12-V BLDC fans.

With regard to PCB track widths, a server engineer can use 0.012-in. PCB track widths versus 0.1-in. PCB track widths when using 54-V BLDC fans instead of 12-V BLDC fans. That saves considerable board area when you add up all power bus traces in a server system.

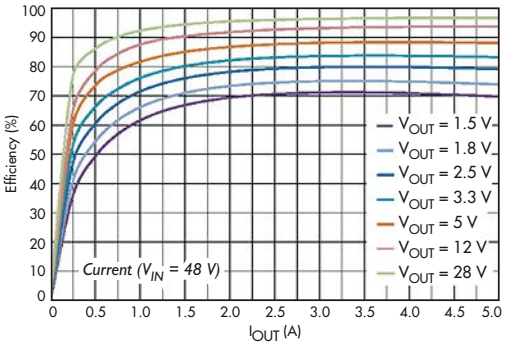
Another benefit for server manufacturers who adopt 54-V BLDC motors is the ability to run motors at higher speeds to move more air density while still using the same form factor of a traditional 12-V BLDC motor. This, however, would necessitate additional current to support the power requirement needed to increase the torque power of the motor.

For example, server manufacturers can use a 50-W BLDC motor over the traditional 32-W motor to achieve greater air flow. Adopting a 54-V BLDC motor would only require 0.93 A, which is considerably less current than is required by a 12-V BLDC motor—4.17 A—to drive a 50-W motor to achieve the same workload. On top of that, the 12-V BLDC would require large PCB traces and larger cables, which is cost-prohibitive. Using the 54-V bus voltage allows server manufacturers to run fans at a higher speed to increase the air-flow density while also reducing the cabling cost.

CHALLENGES IN OPERATING FROM 54-V SUPPLY BUS

One issue does emerge when dealing with the electronics that drive a 54-V BLDC fan motor: Server engineers can't use the old 12-V hardware to drive 54-V motors. They're required to use electronic components with a higher operating voltage that are suitable for a 54-V power supply with plenty of margin. *Figure 1* shows a simplified block diagram of 54-V BLDC control circuitry, and identifies typical components used to drive a 54-V BLDC motor without compromising the proven motor-control algorithm.

Nonetheless, several hardware solutions on the market can help ease this transition. For example, Microchip's MIC28514 75V synchronous buck regulator offers a solution for the first stage of power conversion *(Fig. 2)*. With 5-A output-current capability, the device can power multiple BLDC systems from one 54-V supply rail. The MIC28514 converts the 54-V supply bus rail to a traditional 12-V power rail with better than 90% power efficiency. As a result, server engineers can continue to use the same motor-control algorithms and proven active components.



2. The plot shows typical power efficiency vs. output current using Microchip's MIC28514 75-V, 5-A synchronous buck regulator.

MOSFET drivers and MOSFET inverter circuitry will also have to be sized up to high-voltage MOSFETs, typically an 80-V power MOSFET for a 54-V BLDC application. However, the current requirement has been reduced to one-fourth that of 12-V systems, and the MOSFET on-resistance is much less important.

Microchip's MIC4607 is an 85-V, three-phase MOSFET driver with adaptive dead-time, anti-shoot-through, and overcurrent production.

LEVERAGING HIGH-VOLTAGE ELECTRONIC COMPONENTS

Other chip manufacturers have developed high-voltage integrated circuits similar to the MIC28514 75-V synchronous buck regulator, enabling customers to utilize 54-V BLDC motor technology without compromising the ability to use proven motor-control algorithms and other active components. These high-voltage devices make it feasible for server manufacturers to adopt 54-V power bus technology and, in turn, reduce overall system cost by utilizing smaller motors and less copper width on PCB boards and cabling. In addition, they have the ability to push more air with the same form factor due to increased voltage.

As cloud computing continues to grow in popularity and functionality, server manufacturers will have to adopt the best solutions for the best price to stay competitive in both cost and performance. ed

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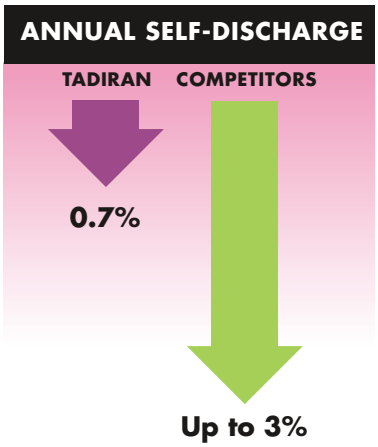

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JIM HANDY | Semiconductor Analyst, Objective Analysis

What's the Difference Between All Those Emerging Memory Technologies?

There are many memory technologies competing with flash. Find out what the options are and how they work.

Nothing has stayed "new" as long as emerging memory technologies. Whether they're MRAM, PCM, ReRAM, or FRAM (or the many other names these technologies go by), these names have been bandied about as the "Next Big Thing" for decades, yet they never have hit the mainstream.

Let's have a look at the leading ones, learn why they are considered necessary, and discover why they have taken as long as they have to become mainstream.

WHY THEY'RE NECESSARY

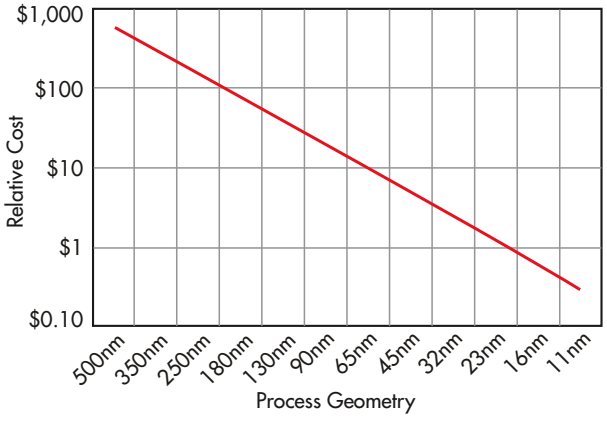
Chip costs are determined by two factors:

1. The cost of manufacturing a silicon wafer; and
2. The number of chips that can be produced on that wafer.

Semiconductor manufacturers have historically used process technology shrinks to increase the number of chips that can be produced on that wafer and drive down the costs out of their chips, migrating from a 35nm process to 25nm, then 20, and so on.

As a general rule the cost to process a silicon wafer is relatively constant, so the cost of a chip tends to decline in proportion to the process technology that is used to manufacture it *(Fig. 1)*. As the process technology shrinks (across the bottom axis of the chart), the cost of the chip should decrease in proportion (the vertical axis).

Memory manufacturers believe that there is a limit to how small a flash or DRAM process can be shrunk. This is called the "scaling limit," and is determined by the number of electrons that can be stored on a flash gate or DRAM capacitor, also called a "memory cell." As the process technology shrinks, the memory cell gets smaller and the number of electrons the cell can store declines to approach a lower limit of what can be accurately measured. Eventually the number of electrons on the memory cell will shrink to the point that it becomes extraordinarily difficult to determine whether or not there are actually any electrons on the cell at all.

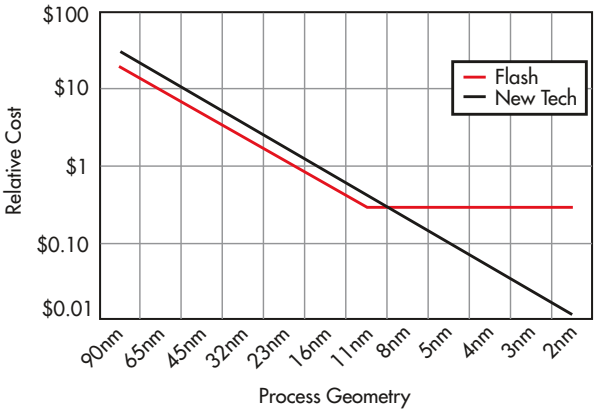


1. The relative cost of a chip is proportional to its process geometry. *(Source: Objective Analysis)*

A memory cell that has been shrunk to that point can no longer shrink in proportion to the process and that means that the die size (and cost) of the flash chip will remain the same even if the production process used to make it continues to scale.

Back in 2003, Intel announced at its Intel Developer Forum that flash memory could not be scaled beyond 65nm. The company then explained its plan to move to an emerging memory technology to continue to scale past 65nm. By 2004 the company encountered a breakthrough that allowed Intel to move farther down the road, projecting that flash could scale to a 35nm process, and that Intel expected to be able to shrink even beyond that process. Then, at the end of 2007, researchers at Toshiba found a way to produce basic planar flash using an 11nm process to prove that flash memory would continue to scale for another few years.

But Toshiba also had proven a year earlier that there was a path to continue to increase the number of bits on a chip even past this point by tipping the entire structure on its side, thus creating 3D NAND. This approach further postponed the end of NAND flash, extending its life, and delaying any mass adoption of any alternative technology.



2. The end of flash scaling would open opportunities for an alternative. *(Source: Objective Analysis, January 2008)*

Even though the flash and DRAM businesses have enjoyed these breakthroughs, NAND and DRAM makers continue to expend significant research efforts to develop alternative technologies. From their perspective the scaling limit of today's technologies, although frequently extended, will inevitably come upon us, forcing them to adopt some alternative technology.

Here's how chip makers expect for this to play out. *Figure 2* is a rendition of *Fig. 1* meant to illustrate the relative costs of flash versus some alternative technology. The chart was actually created in 2008, nearly 10 years ago, well before 3D NAND flash was expected to extend flash technology. In the chart, wafer costs for the "New Tech" memory technology have been arbitrarily set to be 50% higher than that of standard flash. Although it's unclear how much a new technology will actually add to the cost of a wafer in volume production, it is certain that it will increase the cost. The 50% figure fits our needs for the purpose of illustration.

This model assumed that the scaling limit for flash technology would be 10nm, which, at that time, was in keeping with Toshiba's December 2007 announcement that was previously mentioned. (In actuality, production NAND flash stopped scaling at 15nm.)

The chart *(Fig. 2)* clearly shows that flash will lose its cost advantage over the new technology once flash loses its ability to scale. Although the new technology has a higher wafer cost, its ability to scale allows it to scale costs below flash's to become the more cost-effective technology for future generations of memory. A similar chart can be drawn for DRAM.

This crossover's timing will depend on two factors:

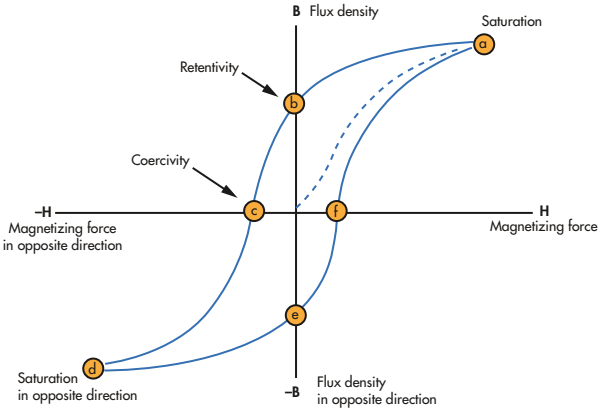
1. The actual point at which a pure silicon flash technology loses its ability to cost-reduce; and
2. The wafer processing cost difference between a pure silicon wafer and the wafer required for the new technology.

This juncture has been anticipated for over two decades, but is continually postponed. Ask any chip executive, though, and they will express certainty that a scaling limit will indeed occur, and that limit will drive the adoption of a new memory technology.

Let's have a look at the leading alternative memory technologies.

FRAM

The Ferroelectric RAM, usually called FRAM or FeRAM, is mislabeled since it involves no iron (chemical symbol: "Fe"). Despite the technology's name, older FRAM technologies are based on something called a Perovskite crystal. The technology gained its name from the fact that certain materials exhibit hysteresis similar to that of magnetic materials. Hysteresis is the basis for magnetic recording, and is diagrammed in *Fig. 3*.



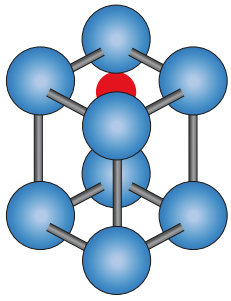
3. Hysteresis (shown above) is the basis for magnetic recording. *(Source: NDT Resource Center)*

In a magnetic system a magnetizing force "H" is applied (horizontal axis) to push the flux density "B" (vertical axis) to be either north or south. As the force moves to the right on the chart from (0,0) the flux density of the magnet rises to some level where it saturates. When the field is removed (returning back to the center of the horizontal axis) the flux remains (marked "Retentivity"), and the bit is magnetized. The curve's vertical axis intercept represents this remaining magnetism. Reversing this process drives the left-hand side of the curve, and causes the vertical axis to be intercepted in the opposite direction.

Ferroelectric memories behave much the same way, but the horizontal axis is replaced by the voltage across a material, and the vertical axis is used to indicate the charge.

In the past this has been accomplished through the use of certain very unique materials known as PZT and SBT. The storage mechanism consists of one atom in the middle of the PZT or SBT crystal which can be moved by a positive current to the top of the cell (the red sphere in *Fig. 4*) or by a negative current to the bottom to indicate a 1 or a 0. Once moved, the atom stays where it is until moved again, so the technology is nonvolatile.

The biggest drawback that has stood in the way of the technology's success has been that neither of the materials used, SBT or PZT, behaved very nicely in a semiconductor fabrication plant. PZT is lead zirconium titanate, and lead ions are very mobile—they wander all over the chip (and the entire fab) rather than stay where they can do their job. Lead contamination is a big concern in semiconductor fabs. This limited the technologies' popularity.



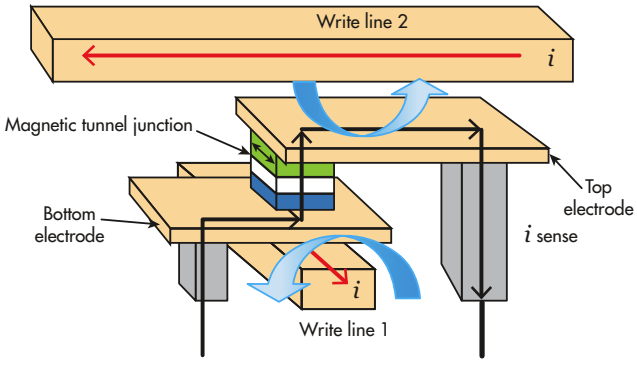
4. Here is a ferroelectric PZT molecule. *(Source: Objective Analysis)*

Recently ferroelectric-style hysteresis has been identified in hafnium oxide (HfO_2), a material that is widely used in standard semiconductor processes known as Hi-k dielectrics. This is a more manageable material, and it is already used in high volume in leading wafer fabrication plants, giving it a very promising outlook for future memory technologies.

MRAM

As opposed to the FRAM, an MRAM actually does use magnetism to store bits. This makes some people worry that bits will be disturbed by external magnetic fields, but these bits are flipped by energy that is applied in very close proximity to the magnet, so the local field is extraordinarily dense compared to most externally applied fields. In other words, it would take a big effort to cause any trouble.

Early MRAMs, now called "Toggle MRAMs" would magnetize and demagnetize bits by passing write currents through write lines above and below the bit cell. These currents created a magnetic field around the write lines that, combined, were strong enough to magnetize the "soft" magnetic layer represented by the green plate in *Fig. 5*. The blue plate, called the "hard" magnetic layer, was insensitive to this field and remained magnetized in the original direction set at the factory. Reversing the currents reversed the soft layer's magnetic moment from north to south.

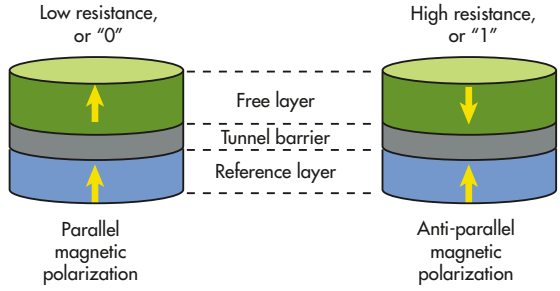


5. Above, a toggle MRAM. *(Source: Freescale Semiconductor)*

During manufacture a magnetic tunnel junction (MTJ) was formed between the hard and soft magnetic layers. If the two layers are both magnetized in the same direction the MTJ's resistance is low, but if the two layers are magnetized in opposite directions then the MTJ has a high resistance.

Toggle MRAMs run into a problem as the bit cell is scaled: The current required to flip the bit doesn't shrink as the write lines get smaller, so the current density increases to the point where the wire will melt.

The solution to this problem came from the disk-drive industry, which was already using spin torque transfer (STT, also called "spin transfer torque" in some circles) to reduce the size of the bits on HDDs. With STT the programming current actually passes through the magnet rather than through write lines adjacent to the bit. STT is the basis for more advanced MRAM cells, and a further development of STT called "perpendicular STT" promises to take MRAMs to tiny processes envisioned for future chip technologies *(Fig. 6)*.



6. Above is a perpendicular spin transfer torque MRAM cell. *(Source: Spin Transfer Technologies)*

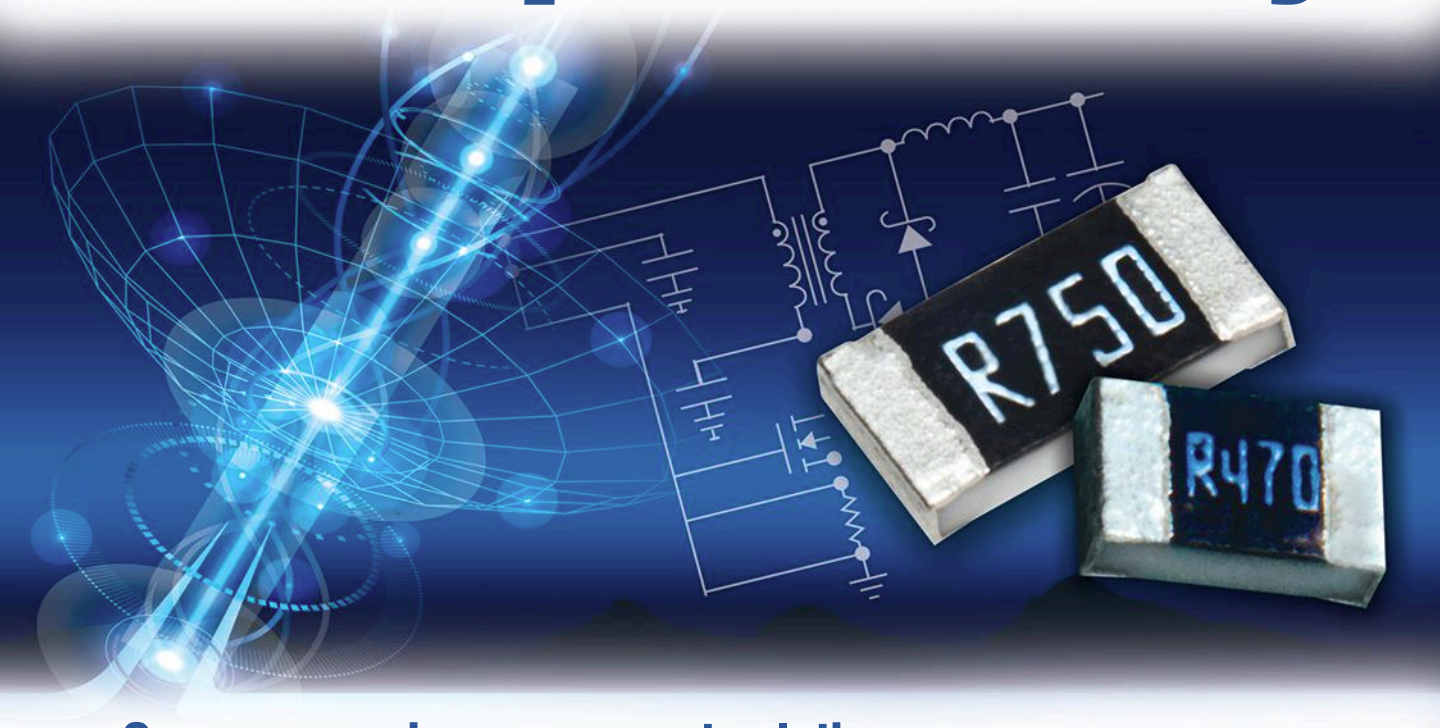
Because the materials needed to manufacture MRAM are already used in very high production volumes to make silicon-based HDD heads, their maturity is high and their interaction with silicon is very well understood. This is a strong advantage for MRAM technology.

Today MRAM is available in volume from Everspin, with other companies like Spin Transfer Technologies and Avalanche closing the gap. All of these companies are fabless. Everspin's fab partner Globalfoundries is aggressively promoting the Everspin MRAM technology as a replacement for NOR flash in ASICs and MCUs for 14 nm and tighter process geometries.

All major memory chip makers appear to have ongoing MRAM development efforts, but most are being relatively quiet about them. They're participating in MRAM development to prepare for the inevitable end to DRAM scaling, which seems to continually be postponed.

IBM has also done some notable research on MRAMs, with the most intriguing technology being its "Racetrack Memory." In this technology *(Fig. 7)*, a ribbon of magnetic material is patterned onto the walls and bottom of a trench, and is treated

From Concept to Reality



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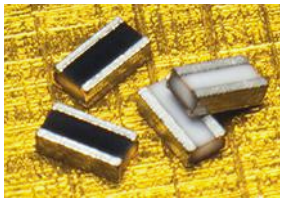
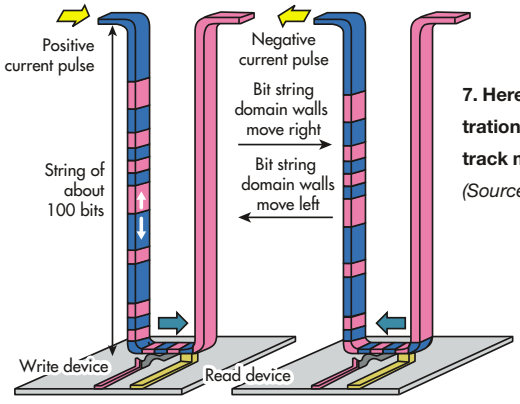


Wide Terminal Current Sense Resistors (WK73R1J)



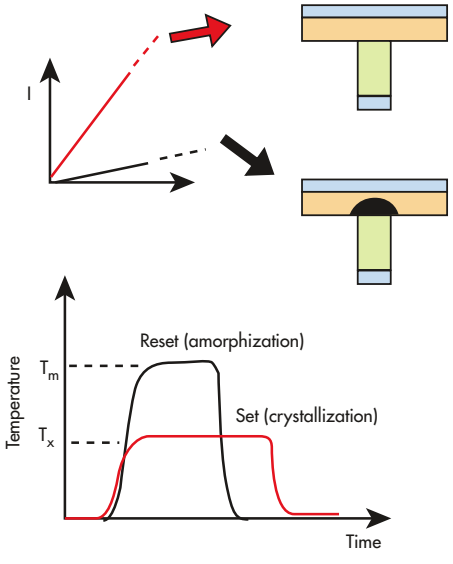
7. Here is an illustration of race-track memory. *(Source: IBM)*

somewhat like a magnetic tape. Read and write head structures are placed at the base of the ribbon to read and record data that runs along the length of the ribbon. When a current is passed through the ribbon, the magnetized domain walls move left or right along the current path and pass over the heads.

PCM

Perhaps the most notable attribute of Phase-Change Memory (PCM) is its legacy: Gordon Moore and Ron Neale co-authored an article in *Electronics Magazine* in early 1970 detailing a 256-bit PCM they had developed.

PCM works by changing the phase of a special kind of glass ($Ge_2Sb_2Te_5$) within the bit cell. When a programming current flows through the cell *(Fig. 8)*, it heats up. A higher heating current that is removed early causes the glass to solidify into an amorphous, nonconductive state. Slower heating at a lower initial temperature solidifies the glass in a conductive crystalline structure. Technically the amorphous state is still a liquid, and technically a crystal is necessarily a solid, so the two states of the cell, crystalline and amorphous, represent two of the three phases of matter: solid, liquid, and gas. This is the basis for the name "Phase Change Memory."



8. PCM works by changing the phase of a special kind of glass ($Ge_2Sb_2Te_5$) within the bit cell. *(Source: Intel Corp.)*

Although Intel and Micron argued at its 2015 introduction that their new 3D XPoint Memory was not a phase change memory, reverse-engineering of actual devices indicates otherwise.

One of the nicer aspects of PCM is the fact that the current runs in only one direction, making the selector much easier to design. A simple diode is all that's needed (more on this later).

RRAM

Here's where nomenclature gets tricky. Resistive RAM, known as RRAM or ReRAM, is an umbrella term for any memory whose bit state is defined as a higher or lower resistance. This differs from NAND and NOR flash, as well as EPROM and EEPROM, all of whose states are defined by a shift in a transistor's threshold voltage. It also differs from DRAM, whose state consists of a charge (or lack of charge) on a capacitor, or SRAM, whose state is the status of a flip-flop: Is the right-hand or the left-hand transistor turned on, since they can't both be on at the same time?

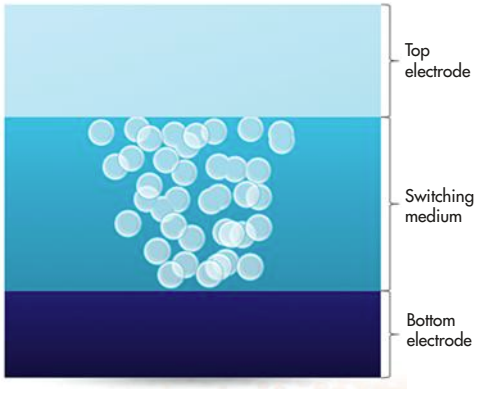
It happens that MRAM's mechanism involves a change in resistance, so a liberal interpretation of RRAM could include MRAM, and for similar reasons PCM could be called an RRAM.

Typically, though, the industry refers to other technologies as RRAM, mainly oxygen vacancy memory (OxRAM, below) and conductive bridging memory (CBRAM, further down.)

OxRAM

The oxygen displacement memory (OxRAM) is based on a material similar to that used in PCM. This material, called chalcogenide glass, can be coupled with other materials that will remove oxygen ions when a current flows in one direction, and replace them when the current flows in the other direction. Normally this glass is an insulator, but glass with "oxygen vacancies" is conductive.

A number of different companies have research efforts in this area, including Rambus (through its acquisition of Unity Semiconductor), Western Digital (via its Contour Semiconductor acquisition), HP, 4Ds, and Weebit Nano. Crossbar is making serious progress in this effort with active sampling of prototypes.



9. Crossbar's design has been called "self-selecting" thanks to an attribute that eliminates the need for a selector device on the cell. *(Source: Crossbar Technology)*

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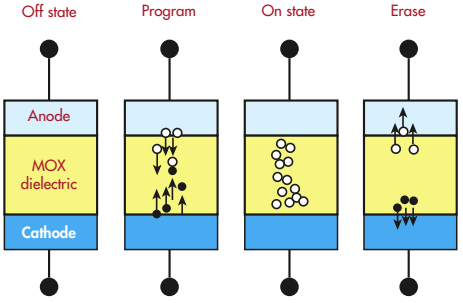
Crossbar's design *(Fig. 9)* has been called "self-selecting" thanks to an attribute that eliminates the need for a selector device on the cell. An un-programmed cell has no oxygen vacancies and does not conduct current. By passing a higher current in the right direction a conductive path is formed that almost bridges the gap, but not quite. When a small Read current is passed through the device in the same direction, the final gap is bridged and the bit becomes fully conductive.

A small reverse read current (leaked from another cell) fails to bridge the gap, to prevent the "Sneak Paths" explained below. A larger reverse current removes the conductive path altogether. One overhyped rendition of this an OxRAM was HP's "Memristor." Although the company made out that this was a revolutionary change and was unlike any technology that had preceded it, close inspection revealed that it was yet another name for an oxygen vacancy memory.

CBRAM

Like the OxRAM just described, a Conductive Bridging RAM (CBRAM) is based on a chalcogenide glass, but its set/reset mechanism differs: Rather than building a conductive path through oxygen vacancies, the CBRAM moves silver ions from the cell's anode into the glass to create a conductive path *(Fig. 10)*. A reverse current moves these silver ions back into the anode.



10. The CBRAM moves silver ions from the cell's anode into the glass to create a conductive path. *(Source: Adesto Technologies)*

The only company actively involved in CBRAMs at this point is Adesto Technologies, whose device was initially developed at Arizona State University.

NRAM

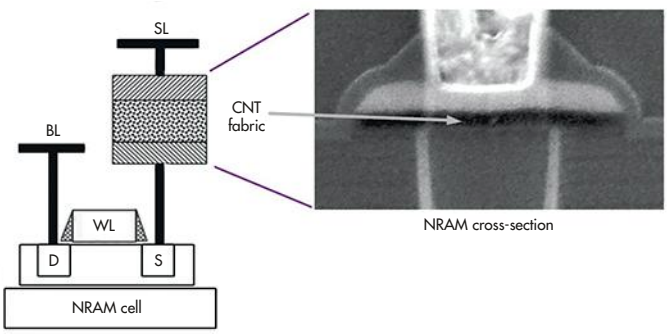
The Nantero NRAM is a very different form of cell that uses a pad or "fabric" of carbon nanotubes (CNTs) in a silicon well to store bits *(Fig. 11)*.

When a current flows through the cell in one direction these nanotubes compress into a highly-conductive state. When the current is reversed the nanotubes expand and become less conductive. Programmed bits remain in their compressed state after current is removed thanks to van der Waals forces, a phenomenon that causes things to stick together once they

come into intimate contact. This is a very strong force and is a challenge to overcome in many mechanical systems, but in the case of the NRAM it is a desirable attribute.

Nantero has licensed Fujitsu to produce its NRAM technology, which is a very good sign: Fujitsu was the highest-volume producer of Ramtron's FRAM technology in the previous two decades, having chosen this technology because of its very low write energy requirements. Fujitsu's approval of the NRAM process is a very positive sign.

11. The Nantero NRAM uses a pad or "fabric" of carbon nanotubes (CNTs) in a silicon well to store bits. *(Source: Nantero)*



NRAM cell with CMOS select transistor and CNT resistive change memory element shown in SEM cross-section.

BULK SWITCHING

Some companies argue that there's a statistical chance that "filamentary memories" can have bad bits, and that the likelihood that a bit will reliably program drops as the production process shrinks. The memories that do not count on filaments include PCM, MRAM, NRAM, and 4DS' rendition of OxRAM. To our knowledge all the others use filaments to form the conductive path between either end of the bit cell.

SELECTOR DEVICES

One very important part of all of these memories is the choice of selector devices. Since none of these new technologies depends on the use of transistors for sensing, they can be built as diode arrays with the memory cell above or below the diode. This brings space savings to the device, since diodes are smaller than transistors.

The selector needs to have a very high ratio of on to off resistance, since a crosspoint can leak currents from unselected cells. An entire article could be dedicated to these "sneak paths" so we won't go into that in detail here. Suffice it to say that R&D labs are placing a phenomenal focus on selectors, as is evidenced by the fact that, for the past few years the IEEE's IEDM conference has included roughly as many selector papers as memory cell papers.

Certain companies claim to have an advantage in this realm: Crossbar's cell is "self-selecting," so the selector is inherently a part of the cell. PCM, including the Intel-Micron 3D XPoint Memory, is unique in that it is programmed and erased with currents flowing in the same direction. This means that the selector can be a simple diode, whereas other selectors are bidirectional devices.

The selector device is about as important as the memory cell itself, as it can make or break the memory. In the future we anticipate continuing focus on this critical technology.

KILOPASS VLT

This article would be incomplete if it omitted one more technology. Kilopass has recently started to promote its VLT (Vertical Layered Thyristor) technology, shown in *Fig. 12*, as a replacement for SRAM and DRAM. The greatest difference between VLT and every other technology in this article is that VLT is not a nonvolatile memory. Instead, it's a DRAM replacement that requires no refreshing and that promises to scale well beyond any limit that DRAM may face.

The bit consists of nothing more than the basic thyristor and requires no DRAM capacitor. A selector is not required either, since the device passes current in only one direction when turned on. The bitline ties directly to the cathode and the wordline to the anode.

Not only should VLT scale well, but the company says that it also can be stacked, an option that appears today to be impossible with DRAM. Since it's an all-silicon technology and is based upon existing process technology it could have strong advantages over other technologies as a DRAM replacement.

DO SOME APPLICATIONS HAVE PREFERENCES?

I am often asked which memory technology has the best prospects for success, and which applications are better matched to which technology. My short reply is that none of these technologies is particularly better suited for an application than is any other, and that cost is the one overriding factor that will determine their success.

A glowing example can be found with today's mainstream technologies: NAND vs. NOR vs. DRAM vs. SRAM. Each of these technologies competes against the others in many applications, even though they are extremely different from one another. Code can be executed directly out of NOR but not from NAND, but NAND is substantially less costly, and NAND/DRAM combinations have successfully taken the bulk of the cell phone market from a combination of NOR flash and SRAM. Server users have found that they can often cost-reduce their systems by reducing DRAM and increasing the

Design Note

36V, 2A LED Driver with 5000:1 PWM Dimming Meets CISPR 25 Class 5 EMI Limits with Silent Switcher Architecture

Kyle Lawrence

Introduction

The LED backlights in automotive heads-up displays, infotainment systems, and dashboard lighting must be bright enough to compete with direct sunlight streaming into a car during the day, yet capable of reducing brightness by several orders of magnitude to avoid blinding a driver at night. Generic LED drivers struggle to achieve such high dimming ratios.

The LT3932 synchronous step-down LED driver with integrated 36V, 2A switches features high ratio PWM dimming. The LT3932 houses its high efficiency integrated power switches inside a small 4mm × 5mm QFN package, and can be run at up to 2MHz switching frequency for a compact, high bandwidth design. When high dimming ratio capability is not needed, and simplicity is paramount, its internal PWM generator can be used to produce 128:1 PWM dimming controlled by a simple DC voltage. With built-in fault protection to handle open and short LEDs, and spread spectrum frequency modulation to aid in reducing EMI, the LT3932 meets the demanding requirements of automotive and industrial LED lighting applications (Figure 1).

High PWM Dimming Ratio

With the LT3932 operating at a dimming frequency of 100Hz and a switching frequency of 2MHz, a high current LED design can achieve 5000:1 PWM dimming with well regulated LED current. Furthermore, PWM and analog dimming can be combined to push dimming ratios to 20,000:1. For applications requiring PWM dimming ratios surpassing 5000:1, the LT3932-1, a variant of LT3932, enables higher dimming performance with no part-defined limitation of minimum PWM on-time vs switching frequency.

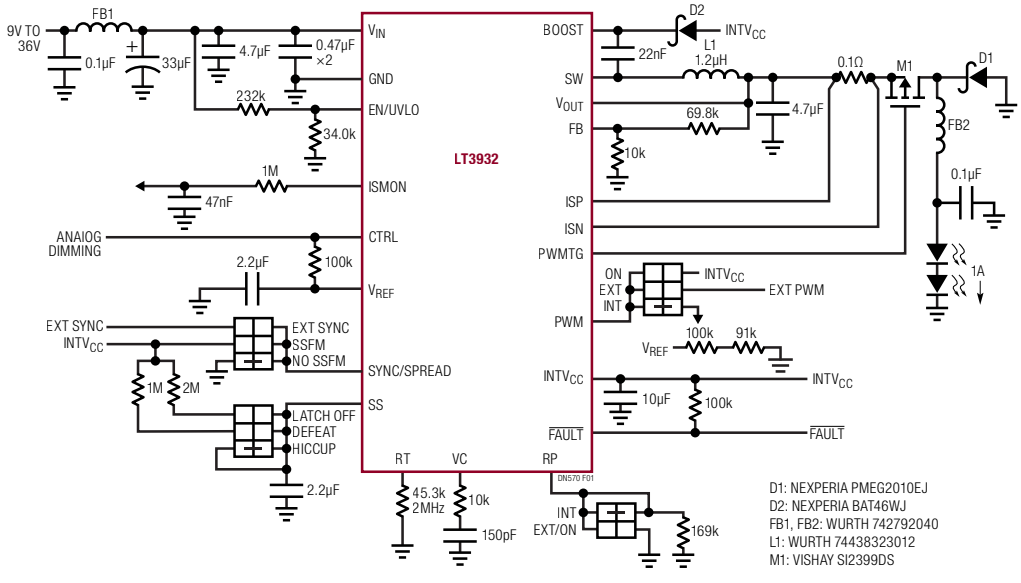


Figure 1. 2MHz Automotive LED Driver Features Low EMI and Internally Generated PWM Dimming with 90% Peak Efficiency Over the Input Range (~91% Efficient without EMI Filters)

With the latest in-car automotive displays requiring minimum dimming ratios of 10,000:1, the LT3932/-1 makes it easy to meet otherwise daunting dimming specs.

Low EMI Silent Switcher

The extreme LED dimming requirements in automobile applications can make it difficult to meet CISPR EMI standards without adding costly noise-mitigating components and complexity. The LT3932 makes it possible to achieve both a high dimming ratio and low EMI by incorporating a number of built-in EMI-minimizing features:

- EMI is minimized by its Silent Switcher® architecture for low EMI hot loops.
- Built-in spread spectrum frequency modulation (SSFM) helps to reduce both conducted and radiated EMI.
- The slew rate of the LT3932 is controlled to optimize efficiency while maintaining low noise performance.

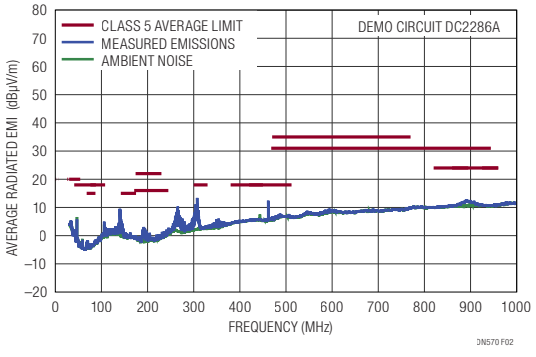


Figure 2. The LT3932 Figure 1 Circuit Passes CISPR 25 Class 5 Radiated Average EMI

The efficacy of the LT3932's low EMI technology is shown in Figure 2—a radiated EMI scan of the production demo circuit for the LT3932 (DC2286A). It passes CISPR 25 Class 5 average limits, as well as peak limits.

Machine Vision Applications

Modern industrial assembly line production utilizes machine-assisted automated optical inspection to ensure that the fast moving parts on an assembly line meet defined specifications. Defective parts that fail optical inspection are tagged and automatically removed from the assembly line, ensuring part-to-part consistency. The high speed cameras used on these types of assembly lines require a photoflash system capable of consistently reproducing a fixed on-time

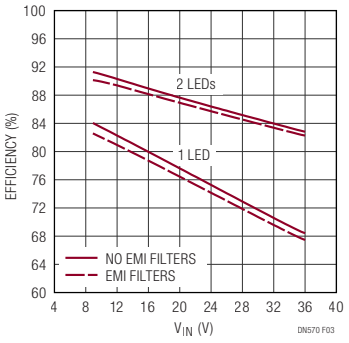


Figure 3. Figure 1 Efficiency Remains High While Driving 1A LEDs at 2MHz f_{SW}, Even with Low EMI Filters

pulse of light with a variable off-time defined by the speed of the assembly line, as well as the spacing of the parts.

The LT3932 can reproduce a fixed on-time pulse of LED current with an indefinite off-time by maintaining its output charge while PWM is held low—no additional circuitry is required. Figure 4 shows two fixed-length on-time pulses of LED current produced by the LT3932, separated by one hour of off-time, demonstrating the LED driver's ability to maintain its output charge during arbitrarily long PWM off-times. By preserving the state of the output, the LT3932 produces consistently shaped current pulses, regardless of the PWM off-time.

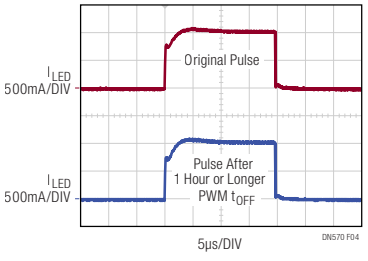


Figure 4. The LT3932 Faithfully Reproduces Current Pulses Regardless of PWM Off-Time—Important for Machine Imaging Applications that Demand Lighting Fidelity Over Time

Conclusion

The LT3932 enables compact, high current LED driver designs with excellent dimming performance. It includes a number of built-in features to simplify the design process of high performance automotive and industrial LED driver applications.

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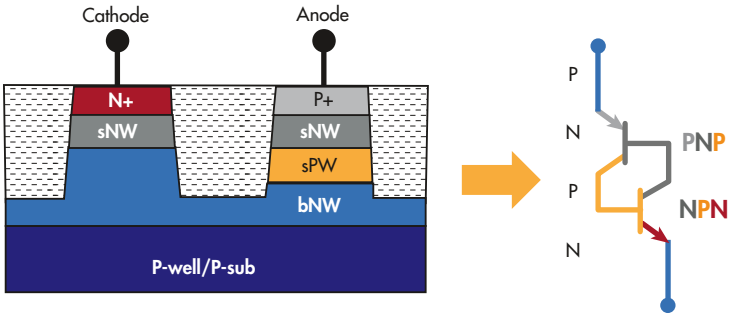

12. Kilopass has recently started to promote its VLT (Vertical Layered Thyristor) technology, as a replacement for SRAM and DRAM. *(Source: Kilopass)*

use of NAND-based SSDs to achieve the same performance. NOR and SRAM win out for reasons of speed or economy when the size of the memory is small enough that a cheaper NOR flash or SRAM can replace a significantly larger (and slightly more expensive) NAND or DRAM.

Decisions of which technology to use most often are based on the total cost of the system and the performance it must achieve. At the moment all of the emerging memory technologies defined above are challenged to approach the cost of entrenched alternatives. As volume shipments increase that situation should change.

WHICH WILL WIN?

Objective Analysis expects for the memory that races down the cost curve the fastest will stand the greatest chance of winning the bulk of the market.

Intel is forcing its 3D XPoint Memory down the cost curve by manufacturing significant volumes at a loss. The company can afford to do this because it believes that 3D XPoint is required to support the company's higher-performance CPUs. Any money that Intel loses on 3D XPoint sales will be recovered through the sale of more costly processors.

Other technologies don't have this advantage, and must be sold at a profit to make any sense. This is a chicken-and-egg problem: To reach high volumes any emerging memory must sell at competitive prices, but costs will prohibit that until high volumes are reached.

If DRAM and NAND flash do finally hit their scaling limits, then these technologies can become cost competitive after a couple of scaling nodes have been missed, as was shown in *Fig. 2*, but until that time they will be relegated to those niches that can tolerate their higher costs in return for some indispensable technical advantage.

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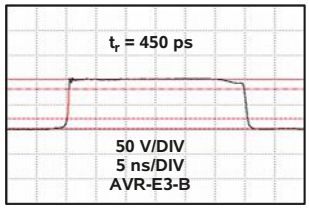

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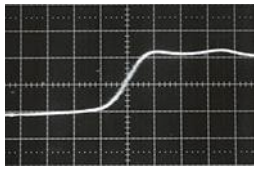

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20 V	200 ps	10 MHz	AVMR-2D-B
15 V	100 ps	25 MHz	AVM-2-C
15 V	150 ps	200 MHz	AVN-3-C
10 V	100 ps	1 MHz	AVP-AV-1-B
10 V	50 ps	1 MHz	AVP-3SA-C
5 V	40 ps	1 MHz	AVP-2SA-C

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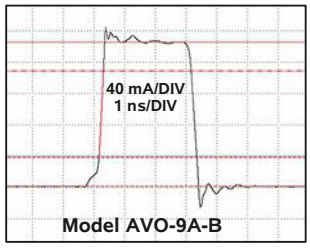

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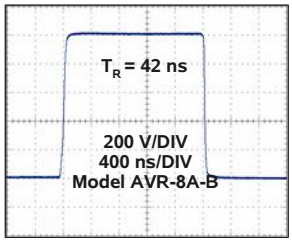

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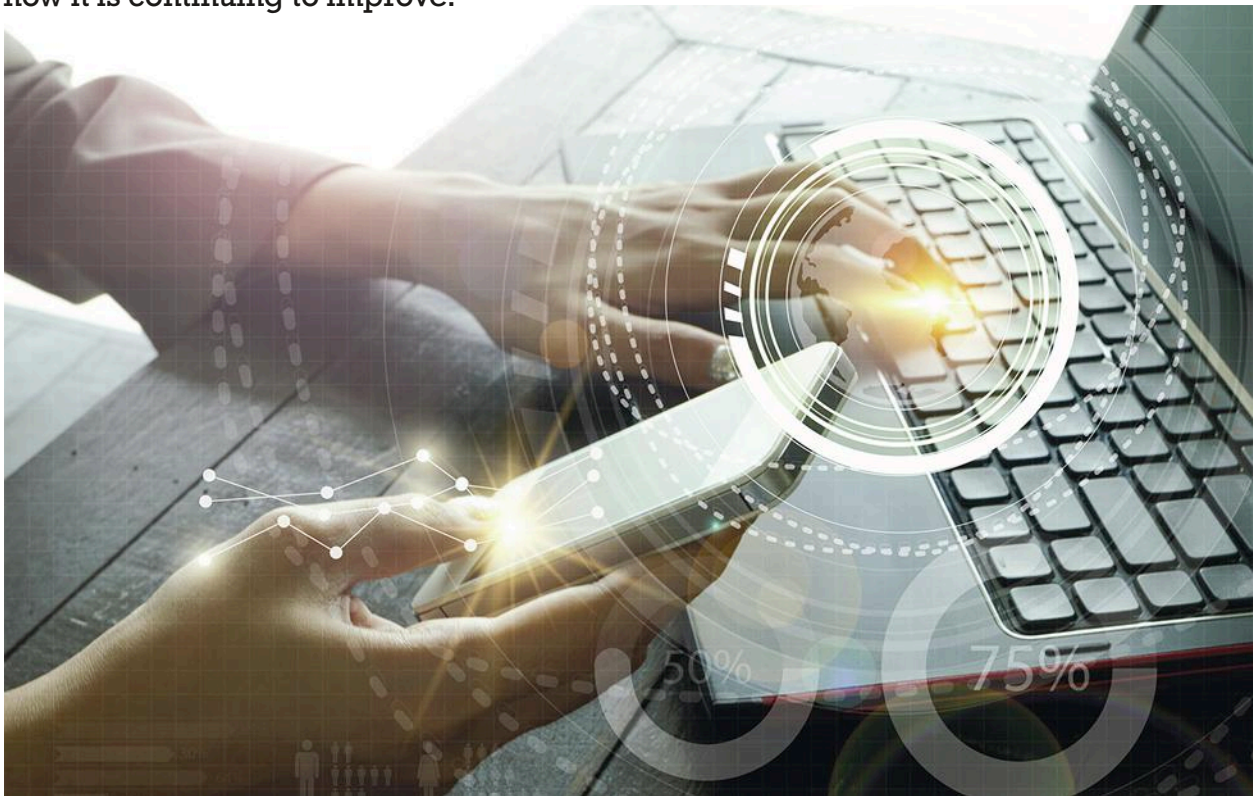
LOU FRENZEL | Contributing Editor

Wireless Technology: The Existential Necessity of Life

We take a look at the technology *behind* the technologies like LTE, 5G, and Wi-Fi and how it is continuing to improve.



Wireless technology dominates our lives these days, yet most of us do not notice until it isn't there. We take our smartphones and Wi-Fi connections for granted and simply expect them to work. Wireless services have become like electricity. How can we live without them? Here is a look at the dominant wireless technologies like LTE, 5G, and Wi-Fi and how they are continuing to improve.

WIRELESS UPDATE

The wireless technologies we all use daily are cellular LTE and Wi-Fi. LTE is gradually morphing into 5G and Wi-Fi continues to get better. The common theme behind the recent and coming improvements is faster data rates and increased capacity. Video demand is the primary reason for the need for more speed. Wireless standards continue to meet that expectation.

Wi-Fi. The IEEE 802.11 working group and the Wi-Fi Alliance over the years have given us a continuous upgrade path for our wireless LANs. New standards are always in the works and WLANs continue to get faster and serve more users. Many users have still not upgraded from the breakthrough 802.11n version that first incorporated MIMO. The next logical upgrade step is 802.11ac. This version called Wave 1 uses the 5 GHz band only and makes use of three spectral streams, 20/40/80 MHz channels, and 256QAM to achieve data rates to 1.3 Gb/s. The Wave 2 version of 802.11ac uses four spatial streams, channel bonding, and up to 160 MHz bandwidth, and introduces multi-user MIMO. This serves more users and boosts data rate to a peak of 1.7 Gb/s.

Now the 802.11ax standard has come along to provide an even more aggressive upgrade. This standard has not been finally ratified but, as usual, chip companies have already

implemented it. Final approval is expected in 2019. 11ax uses either 2.4 or 5 GHz channels, switches from OFDM to OFDMA, adds 1024QAM with FDD, and uses narrower subcarriers. OFDMA permits multi-user MIMO, so it adds capacity as well as greater speed. Speeds peak at 7 Gb/s under ideal conditions. This standard also supports mesh networking.

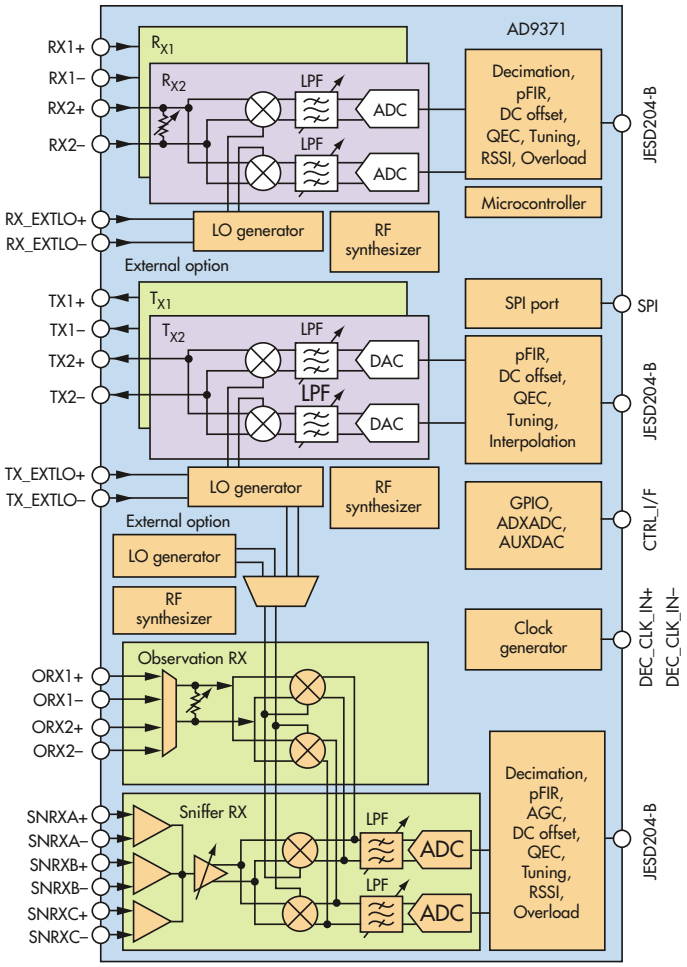
Broadcom's new Max WiFi devices (BCM43684, BCM43694, BCM 4375) for 11ax promise to improve download speeds by four times, upload speeds by six times, better coverage by four times, and battery life by seven times over the current 802.11ac. Chip company Quantenna Communications' new QSR10R-AX chip packages three 4×4 MIMO 11ax radios on a chip, making it easier to implement mesh access points (APs).

A somewhat forgotten technology is WiGig or the 802.11ad standard that uses the 60 GHz band. Speeds to 7 Gb/s are possible, but the range is restricted to about 10 meters with line-of-site coverage and no wall penetration. It uses a phased array with beamforming to achieve its coverage. WiGig has been around for several years now but not been widely deployed. Wireless virtual reality headsets are said to be one possible application.

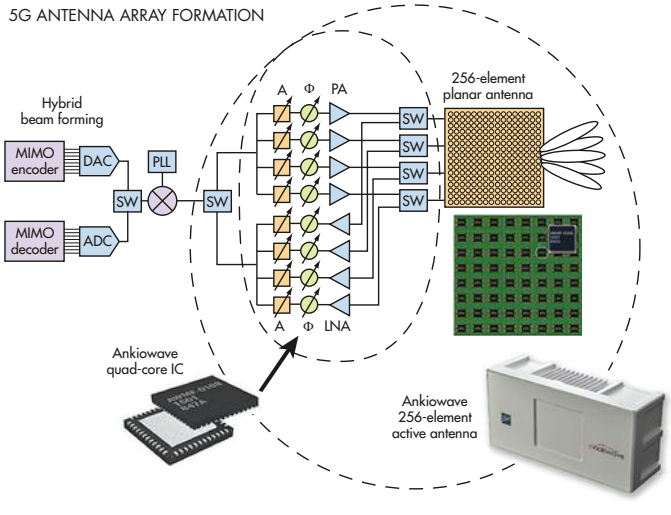
A new wireless LAN technology on the horizon is visible light communications. Also known as LiFi, this developing LAN technology uses visible light as the carrier. The data stream modulates standard LEDs in light fixtures. Data rates as high as several hundred Mb/s have been demonstrated but lower rates are more typical. One form of implementation is an LED light bar, designed to replace fluorescent tubes, that incorporates the LiFi circuitry. The range is short and there is no wall penetration making this type of LAN very secure. Dongles containing a photodetector are currently used on laptops or other computers to link to the network.

LTE. Long Term Evolution is our current 4G worldwide cellular standard. Like other good wireless standards it has been continuously improved through a series of upgrade Releases by the Third Generation Partnership Project (3GPP). Virtually all major carriers implement it and follow the upgrade path. Currently many carriers are incorporating the LTE Advanced version as defined by 3GPP Release 10. LTE-A adds carrier aggregation (CA) and higher-level 8×8 MIMO. CA allows operators to combine up to five 20 MHz channels (contiguous or non-contiguous) into one channel as a way to boost data rate. Along with higher MIMO, the potential maximum data rate is 1 Gb/s. The next upgrade is to Release 13, LTE-Advanced Pro that permits up to 32 CA, making LTE speeds even faster. It makes one wonder why we need 5G. LTE will be with us for decades to come, even when 5G arrives.

And let's not forget that LTE is increasingly being used for some IoT/M2M applications, thanks to the new LTE-M and NB-IoT standards. New LTE-M (Cat 1) modules are available from Link Labs and Gemalto.



1. Analog Devices' AD9371 dual transceiver operates up to 6 GHz and is finding a home in some 5G products.



2. The Anokiwave AWA-0134 contains PAs, LNAs, phase shifters, attenuators, and switches that simplify phased-array construction to meet MIMO and beamforming requirements.

5G. The Third Generation Partnership Project (3GPP) is still working on 5G, but concurrently companies are testing 5G New Radio (NR) equipment. And we should see a first draft (Release 15) during 2018.

The goals for 5G are a user capacity of x100 existing LTE capability, downlink data rates up to 10 Gb/s, and a latency of less than 10 ms. Here are the highlights of the proposed 5G standard to meet these goals.

- **Spectrum.** The major carriers will use their below-6 GHz spectrum licenses. The 3.5 GHz Citizens Broadband Radio Service (CBRS) now used by the military may see some 5G usage on a shared basis. The major trend is to build out a network in the millimeter wave bands. In the United States, the 28 GHz and 39 GHz bands will be the new operational space. AT&T, T-Mobile, and Verizon have committed to this spectrum.
- **Small Cells.** A dense collection of small cells will supplement traditional LTE basestations. These miniature cell sites will attach to light poles, the sides of buildings, and on other structures. Getting permissions to install the small cells is turning out to be a major problem and will no doubt slow implementation of full 5G networks. Providing power and backhaul are related issues.
- **Modulation.** Some form of OFDMA with different subcarrier bandwidths from LTE's current 15 kHz to 30-240 kHz. Adaptive modulation to 256QAM.
- **Duplexing.** Time division duplexing (TDD) rather than frequency division duplexing (FDD) that requires twice the spectrum.
- **Coding.** New channel coding includes low-density parity check (LDPC) for data and polar coding for control.
- **Antennas.** Massive, multi-user MIMO and agile beamforming antennas.

MULTIPLE ANTENNAS ARE THE SOLUTION

Wi-Fi, LTE, and 5G all have one thing in common. Their increases in data rate and user capacity have come primarily from advanced antenna techniques. With spectrum limited and most technologies up against Shannon's law, it would seem that data rates should have topped out long ago. Antenna technology like MIMO, phased arrays, and agile beamforming and steering have made it possible to continue to boost data rates while accommodating more users with the same or less spectrum.

MIMO. Multiple input, multiple output is a system of multiple transmitters, receivers, and antennas for boosting data rate and adding reliability to a wireless system. Data is divided

into separate serial streams that modulate transmitters on the same frequency band. Spatial diversity creates different signal paths with unique spectral characteristics that allow multiple receivers and advanced signal-processing techniques to separate and reproduce the data streams. The result is an increase in data rate by a factor of the number of paths created.

An enhancement to MIMO is multiple-user MIMO or MU-MIMO. This permits two or more simultaneous data streams to serve different users. Different antennas are assigned to each user so they get maximum data rates. MU-MIMO is still not widely implemented but the most recent standards 802.11ac/ax have adopted it. Both AP/routers and mobile terminals must support the technology for it to be useful.

MIMO is the key technology for all new Wi-Fi, LTE, and 5G products. But it has also initiated the need for fast, low-cost testing solutions. Over-the-air (OTA) testing is a must.

Phased Arrays. Another antenna technology that makes the modern wireless systems possible is the phased array. This is a matrix of multiple antennas such as tiny dipoles or patches spaced by at least one half wavelength and driven by multiple transmitters. By controlling the phase and amplitudes of the signals applied to the antennas, it is possible to combine the beams of each antenna so that the electromagnetic waves mix in an additive or subtractive way. The result is narrow beams that focus the signal and provide gain. In addition to this beamforming, control of the signals to the antennas can make the beam steerable in azimuth, elevation, or both.

On the receive side, the multi-element array feeds the signals to LNAs and individual phase shifters. The resulting signals are combined to form the composite signal. Agile beamforming and steering let the antenna focus on individual clients.

Multiple companies are now addressing the phased array. Analog Devices' AD9371 dual RF transceiver is making it easier to build phased arrays with beamforming. This IC shown in *Fig. 1* on page 36 includes two transmitters and two receivers that operate at frequencies up to 6 GHz. It supports FDD and TDD operation. When combined with the phase shifters and amplifiers/attenuators, this transceiver provides most of the circuitry to build large MIMO and beamforming phased arrays.

A fully integrated phased-array device is Anokiwave's AWA-0134, a 256-element electronically scanned antenna for 5G applications *(Fig. 2 on page 36)*. The IC operates in the 28 GHz band and contains four each sets of power amplifiers (PAs), low noise amplifiers (LNAs), plus related phase shifters, attenuators, and switches; 64 of these chips go to operate the 256-element array. Anokiwave has a family of chips that support four radiating elements with 5-bit phase control and 5-bit gain control. ICs are available for the 26, 28, and 39 GHz 5G bands.Ethertronics recently announced its next-generation Wi-Fi Active Steering platform, based on the EC477 Active Steering Processor and the EC624 Active Steering Antenna Switch. This solution doubles throughput, range, and efficiency for high-performance 802.11ax/802.11ac systems and has been optimized for current Wi-Fi access point and client solutions. The technology implemented in the EC477/EC624 family provides support for up to 8x8 MIMO in 802.11 applications as well as performance and scalability for next-generation 802.11ax applications.

Movandi, a venture-backed startup, has a new RFIC front-end called BeamX that integrates RF, antenna, beamforming, and control algorithms into a modular 5G millimeter wave solution targeted for Customer Premises Equipment (CPE), small-cell, and base-station applications. Movandi has 28 and 39 GHz versions.

Now, what is the design solution for integrating 5G mmWave antennas into a handset with existing antennas for LTE cellular with MIMO, Wi-Fi, Bluetooth, and GPS? ED

WILLIAM WONG | Embedded/Systems/Software Editor
bill.wong@informa.com

Improving Code Quality in the New Year

Are you going to reduce bugs and improve security and code quality in 2018?

I don't intentionally put bugs into my code. Do you? Probably not, but having coded for decades I know that those nasty critters sneak in whether we like it or not.

I spent a good deal of time coding in assembler. It was easy to make errors because a programmer needed to do most of the checking. Moving to a high-level language improved the development process, but C traded off some common bugs for others—like using a single equal sign (=) instead of a double equal sign (==), causing an assignment when I intended to do a comparison in an IF statement. Sometimes the code would work because the value being assigned matched the result of what the comparison should have resulted in.

Programmers often dismiss these kinds of bugs as trivial, which they are, but they are ones that can result in problems that are hard to find and fix—ones that cause major headaches when the code is in the field.

There are many tools and methodologies that can improve the development process, like static analysis tools or code reviews. The difference between the two is that the former uses a computer while the latter involves human beings, although machine learning is starting to tackle code reviews. Still, while many will probably not be offended by having another person review their code, they may scoff at having the computer do it. Unfortunately, the computer is a lot better at tracking down those nitpicking bugs like in the above assignment/comparison example. Our *Electronic Design* Embedded Survey indicated that many (but not most) are using static analysis tools.

Now it is true that many C/C++ compilers can check and warn about such problems, but only if the developers take advantage of this and enable those options. Likewise, most static analysis programs are much more sophisticated. They can find more complicated problems, from identifying dead code to detecting semantic errors the compiler cannot.

Languages have been devised that address some common errors like memory management. Java is one example of a language that has garbage collection support as part of its specification. One can argue about the usefulness of this feature in embedded applications, but it is only one way to approach the problem.

Another language that looks to address memory management is Rust, which is new but growing in popularity. It uses the manually managed storage approach common in C and C++ while placing restrictions on the use of pointers and allocation procedures. Unfortunately, there are no commercial Rust compilers at this point, which makes its use moot for many embedded applications.

SPARK, a provable subset of Ada, takes the idea of static analysis to the extreme. The problem with applying static analysis to C and C++, versus SPARK, is that the languages were not designed to allow developers to indicate the intent of their code. Likewise, many of the techniques available are deficient from a static analysis point of view, making it difficult at best for a static analysis tool to determine a programmer's intent.

Ada 2012 included the concept of contracts. This allows a developer to indicate what kinds of arguments can be accepted and what kinds of actions/results will occur. Contracts can set up to emit code for this type of checking, but with SPARK these contracts can be used to analyze the code. The analysis can determine whether the code will actually do what the developer desires. T

Most programmers will be unlikely to switch programming languages at this point, but picking up SPARK and Ada is a relatively easy chore for C and C++ programmers. There are many advantages to switching besides contracts, but starting to use static analysis tools with C and C++ will be a major step forward for most companies, as reducing bugs is important for safety and security too.

There are a number of vendors that provide static analysis tools, including Adacore, Rogue Wave Software/Klockwork, Grammatech, LDRA, Parasoft, Programming Research, and Synopsys. There are also some open-source tools, including cppcheck and the Eclipse Codan (CODe Analysis) project. Most of these tools will support the majority of MISRA C/C++ rules. ed

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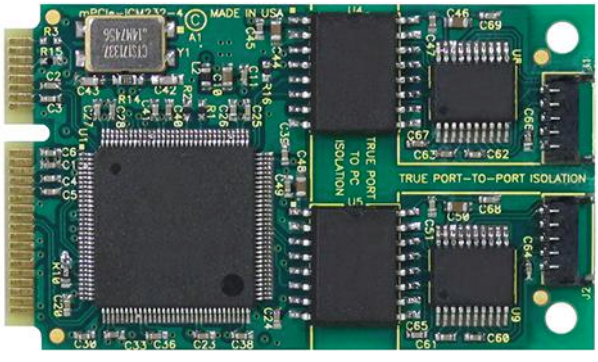

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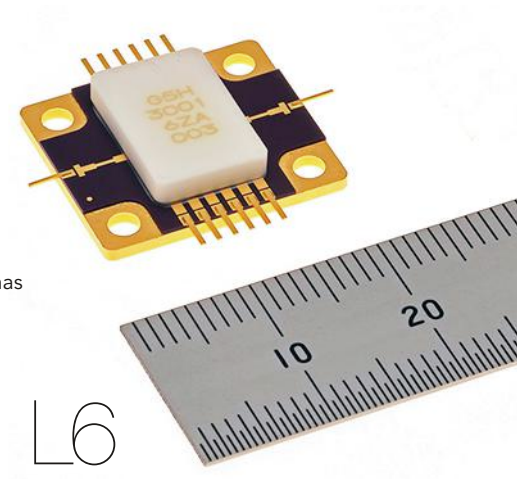

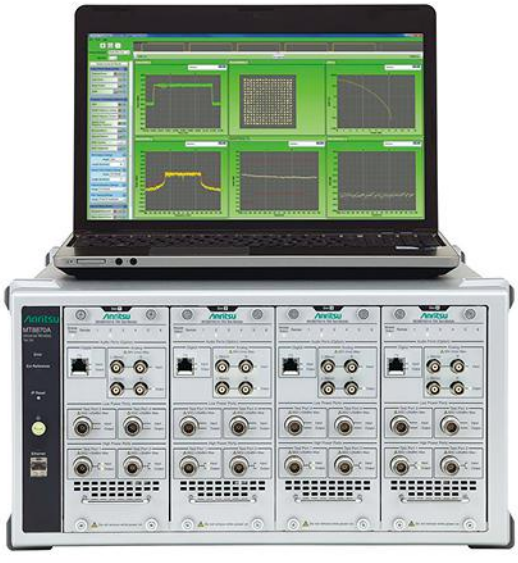

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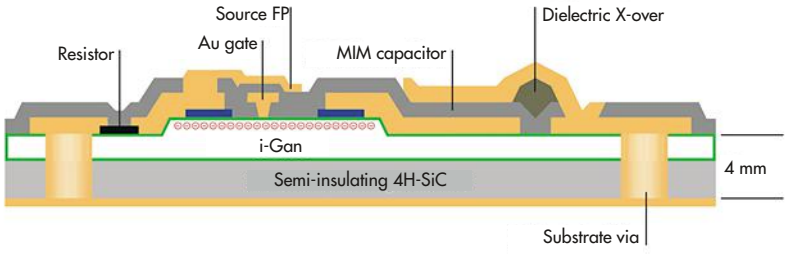
MURRAY SLOVICK | Contributing Editor

Making the Jump to Wide Bandgap Power

What was once only the potential for significant power electronics advances has now become a workaday reality, as SiC and GaN enable operation at higher voltages, temperatures, and switching frequencies while raising efficiency.

Silicon's 20th century dominance in power electronics applications has been eroding for some time now. As engineers extract dwindling amounts of additional performance from silicon ICs, they are looking to wide-bandgap (WBG) materials to develop next-generation power electronics. Examples include silicon carbide (SiC) and gallium nitride (GaN). Materials that have a wide bandgap are inherently applicable in high-power electronics, as they have a higher breakdown voltage and are able to run at higher temperatures when compared to materials with narrow bandgaps, such as silicon.



1. Shown are the GaN HEMT MMIC semiconductor process components from Wolfspeed. On the subject of frequency bands per amplifier, the company's literature says, and we kid you not, that it has "more bands than Woodstock."

SiC and GaN also offer the potential for smaller, more robust power devices, which switch faster and are more energy-efficient than Si-based devices. SiC and GaN products, in demand for electric-car and mobile-device applications, perform much better than Si in reducing on-state resistance and shrinking package size. This results in faster charging, lower power consumption, and more efficient energy conversion. Generally speaking, SiC power semiconductor devices are being specified for applications with high power capacity (in excess of 600 V) and GaN for applications involving medium to low-power capacities.

Silicon carbide has become an attractive alternative to Si in applications requiring efficient high-voltage, high-frequency power conversions. SiC power devices operate at higher switching speeds and higher temperatures with lower losses than conventional silicon. In addition, SiC allows inverters and other energy-conversion systems to be built with improved power density and energy efficiency at lower cost. Almost all the OEMs and Tier-1s are using or testing SiC devices in electric and hybrid electric vehicles (EVs and HEVs).

Similarly, GaN possesses high breakdown voltage and low conduction resistance characteristics, thereby enabling high-speed switching and miniaturization. Unlike conventional Si transistors, which require bigger chip areas to reduce on-resistance, GaN devices have smaller sizes (and lower parasitic capacitance) for high-speed switching. Miniaturization is possible in part because of the smaller passive components needed.

Let's now look at recent developments in SiC and GaN one at a time.

GaN

According to a new report from MarketsandMarkets, "Gallium Nitride Semiconductor Device Market—Global Forecast to 2023," the GaN semiconductor device market is expected to reach $22.47 billion by 2023. It will chalk up a CAGR of 4.6% between 2017 and 2023. In 2016, optoelectronic devices held the largest market share. (GaN LEDs are widely used in laptops and notebooks, televisions, and signs). Yet the market for GaN-based inverters for motor drives is expected to grow significantly during the forecast period. Indeed, another market research firm, Yole Développement, is even more optimistic. While the power-supply segment will remain the biggest application for GaN, it suggests that the data-center market is adopting GaN solutions as well—driving a 114% CAGR for power supplies through to 2022.

The advantages of high-voltage GaN field-effect transistors (FETs) are best seen when used in power electronics systems including power supplies, servo motors, and photovoltaic inverters. Yaskawa Electric Corp.'s Σ-7 F is the first servo motor to use high-voltage (HV) GaN, in this case provided by Transphorm (and precipitated by a $15 million investment in Transphorm from Yaskawa Electric). The AEC-Q101-qualified, 650-V GaN semiconductors enabled Yaskawa to develop an integrated servo motor half the size of a similar design using Si technology. The key achievement here is that the Σ-7 F integrates the servo amplifier with the servo motor itself. According to Yaskawa, the topology will be deployed across its full Σ-7 F product line, which currently includes three servo motors ranging from 100 to 400 W.

By integrating the driver in the same package, as Texas Instruments has done with its TIDA-00915 reference design, it's possible to reduce parasitic inductances and optimize switching performance. This approach reduces power loss, allowing the designer to downsize the heat sink. Such space savings are beneficial for compact servo drives and motor-integrated drives. Operating the inverter at a high switching frequency of 100 kHz reduces the current ripple, which improves torque ripple when used with low-inductance motors. The three-phase inverter design for driving 200-V AC servo motors (with 2 kWPEAK) is built around six of TI's LMG3410 600-V, 12-A GaN power modules. They allow switching up to five times faster than silicon FETs, while achieving efficiency levels said to be greater than 98% at 100 kHz and 99% at 24 kHz pulse width modulation (PWM).

Designed to help engineers evaluate USB power-delivery (PD) adapters and dongle solutions featuring power and data, Navitas Semiconductor has developed what is reportedly the smallest 65-W USB-PD laptop adapter. It minimized the size, weight, and cost of transformers, filters, and heatsinks through the use of AllGaN Power ICs. The part delivers 65 W in only 2.7 in.3 and weighs only 60 g. By contrast, existing silicon-based designs can require 6 to 7 in.3 and weigh over 300 g. The new reference design uses its GaN power ICs in an active-clamp-flyback (ACF) topology running 3x to 4x faster and with 40% lower loss than typical adapter designs. The firm says that its AllGaN 650-V platform process design kit (PDK) monolithically integrates GaN power FETs with logic and analog circuits, enabling smaller, high-energy-efficiency and lower-cost power for mobile, consumer, enterprise, and new energy markets.

A promising approach to long-distance, high-capacity wireless communications is to utilize the 75 to 110 GHz W-band and increase output with a transmission power amplifier. Fujitsu has succeeded in developing a power amplifier for use in W-band transmissions that offers both high output power and high efficiency, improving transistor performance through the reduction of electrical current leakage and internal GaN high-electron-mobility-transistor (HEMT) resistance. The company has achieved 4.5 W per millimeter of gate width, which is said to be the world's highest output density in the W-band. In addition, it has confirmed a 26% reduction in energy consumption compared to conventional technology.

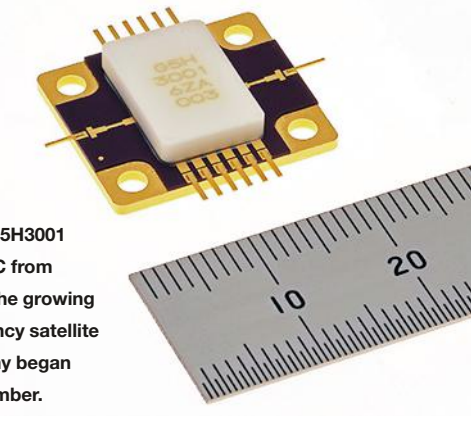
The latest GaN-on-SiC HEMTs from Cree's Wolfspeed *(Fig. 1)* comprise a series of 28-V RF power devices that can operate to 8 GHz. The new devices were developed using Wolfspeed's 0.25-µm GaN-on-SiC process. They are designed with the same package footprint as the previous-generation 0.4-µm devices, making it easy for RF design engineers to use them as drop-in replacements. The new GaN HEMTs are said to deliver 33% higher frequency operation to 8 GHz (from 6 GHz) as well as a 5% to 10% boost in operating efficiency compared to Wolfspeed's earlier-generation devices. The higher efficiency and bandwidth capability make these devices well-suited for a range of RF power amplifier applications including military communications systems, radar equipment, electronic warfare (EW), and electronic countermeasures (ECMs).

With the continuing development of GaN HEMTs, new topologies and control methods are challenging classic power-supply architectures. In soft switching applications, for instance, GaN HEMTs have the potential for very high switching frequencies. In contrast, silicon-based counterparts are limited to low and moderate switching frequencies. An example is satellite networks, which are used for high-speed communication during natural disasters and in areas where ground networks are difficult to construct. Currently, they are implemented mainly in the C-band (4 to 8 GHz) and Ku-band (12 to 18 GHz).

Higher frequencies are increasingly being explored, however. In response, Mitsubishi Electric has launched a Ka-band (26 to 40 GHz), 8-W GaN HEMT monolithic microwave integrated circuit (MMIC) amplifier for satellite earth stations *(Fig. 2)*. Its new GaN-HEMT MMIC, which offers low distortion and an output power rating of 8 W, boasts a small footprint that will help to downsize power transmitters. Features include one-chip integration of amplifier transistor circuits, matching circuits, and a built-in distortion-reducing linearizer.

SiC

Today, SiC technology's added value is widely understood and accepted by the power electronics commu-



2. Solutions like the MGFG5H3001 Ka-band GaN-HEMT MMIC from Mitsubishi will help meet the growing demand for higher-frequency satellite deployments. The company began shipping samples in November.

(Continued on page L22)

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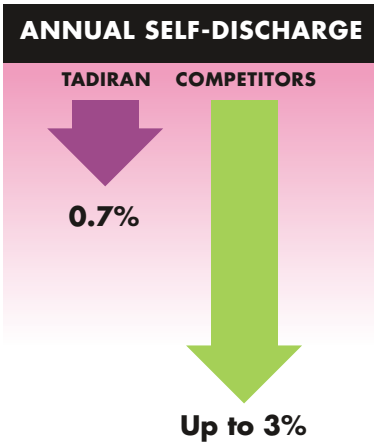

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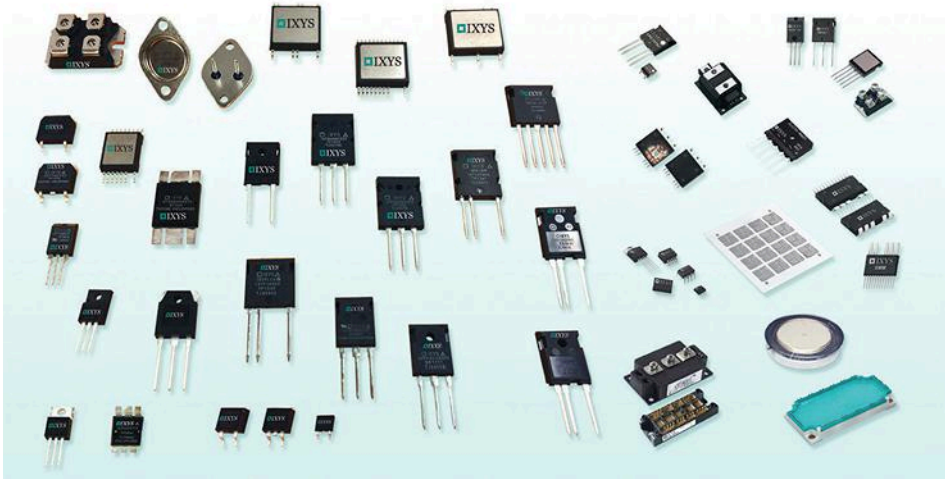

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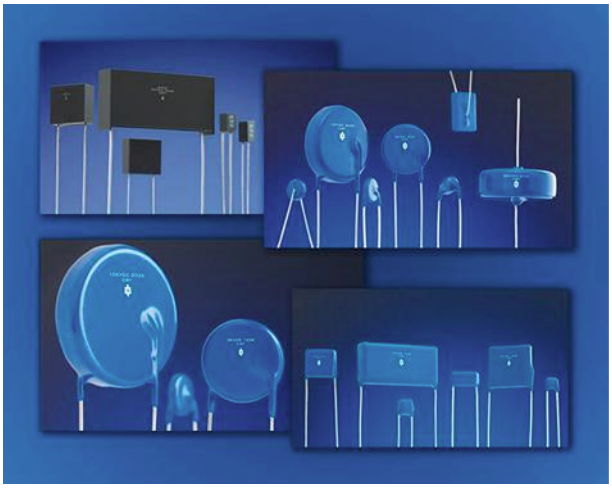

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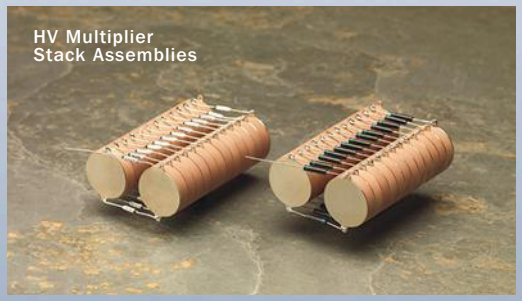

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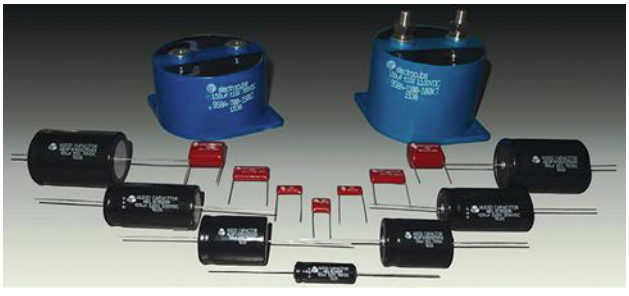

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Nova Electric was founded in 1966 and purchased as a division by Technology Dynamics Inc. in 1990. The company designs and manufactures rugged True Online UPS Systems, Pure Sinewave DC-AC Inverters, and Solid-State Frequency Converters from 120W to 500+KW. In addition, related products such as custom EMI filters, standalone transformers, and bypass switches are also offered. These products are designed for use in severe-environment and military applications (such as shelters, shipboard, submarine, HMMWV, vehicular communications systems, and military-related installations). Nova Electric also sells to commercial utilities, mines, steel mills, and airports. Nova's products are in fact COTS-based, and use some industrial grade commercial components—however, they are ruggedized to withstand American and NATO shock, vibration, humidity, and EMI military specifications such as MIL-STD-461, MIL-STD-810, MIL-S-901, MIL-STD-167, and MIL-STD-1399.

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Nova resides in a 35,000-sq.-ft. facility in Bergenfield, NJ. It employs 100 workers, among them 20 engineering personnel. The company has an extensive line of off-the-shelf Inverters, UPS, and Frequency Converters, but for the most part it designs power systems to customer specifications.

Nova is able to design military products in record time due to its in-depth understanding of the military standards, and the fact that it has its own sheet metal and transformer departments. As such the company is completely vertically integrated.

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(Continued from page L7)

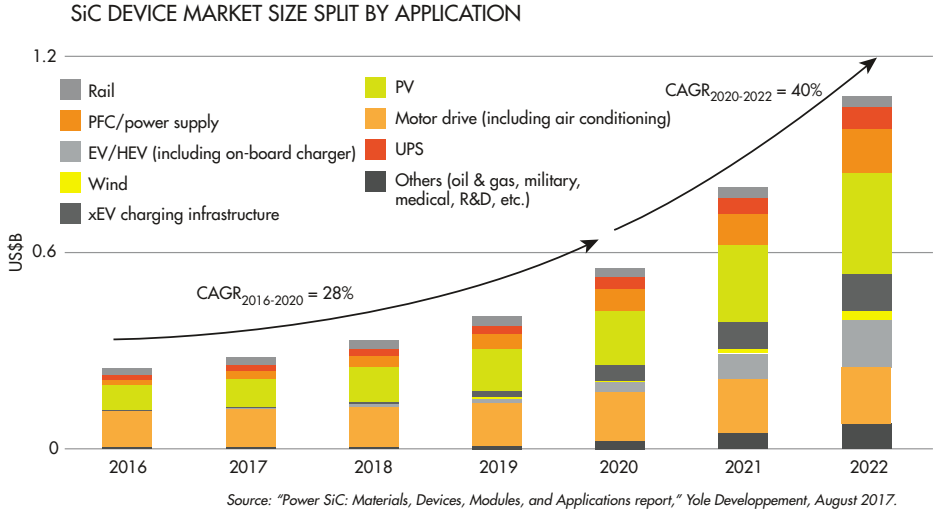
nity. Yole's analysts peg CAGR at 28% through 2022 *(Fig. 3)*. Part of the appeal of SiC comes from its physical properties. For example, where silicon has a breakdown electric field of 0.3 MV/cm, SiC can withstand up to 2.8 MV/cm. Its internal resistance is 100 times smaller than that of silicon. As a result, applications can handle the same level of current using a smaller chip and, in turn, smaller systems.

Recently, Rohm developed an all-SiC, 1200-V, 600-A power module integrating SiC Schottky barrier diodes (SBDs) and MOSFETs. The module achieves a rated current of 600 A by utilizing a new package featuring a revised internal structure and optimized heat radiation design. In doing so, it enables support for higher-power applications. This half-bridge module is suitable for the following applications: motor drive, inverter, converter, photovoltaics, wind-power generation, and induction heating equipment. Compared to IGBTs, the SiC MOSFET offers much faster switching. At a chip temperature of 150°C, Rohm claims that the part offers a 64% reduction in switching losses. A new package has a flatter baseplate that decreases contact resistance by 57% and inductance by 23% (compared to earlier products) by optimizing the placement of the SiC device inside the package. According to the company, the "G Type" package decreases switching loss by 24% under the same surge-voltage drive conditions.

The Infineon 650-V G6, as the name implies, represents the sixth generation of the company's CoolSiC Schottky diodes. These devices are built upon the characteristics of its G5 series, but feature a new layout, cell structure, and proprietary Schottky metal system. The G6 diodes are designed to complement Infineon's 600-V and 650-V CoolMOS 7 families. Aimed at current and future applications in server and PC power, telecom power, and photovoltaic inverters, the CoolSiC 650-V G6 boasts an industry benchmark V F (1.25 V), and a Q c x V F figure of merit (FOM), which is 17% lower than the previous generation, according to Infineon. In addition, the new G6 diode leverages two of silicon carbide's strong characteristics: temperature-independent switching behavior and no reverse recovery charge.

SiC Schottky diodes have approximately 40 times lower reverse leakage current than PN silicon Schottky diodes. Littelfuse, which got into the SiC game through its acquisition of Monolith Semiconductor, has come out with a new generation of 1200-V SiC Schottky diodes with current ratings from 5 to 40 A. With negligible reverse recovery, the LSIC2SD120 Series—the Monolith/Littelfuse partnership's first product introduction--reduces switching losses (compared to Si bipolar diodes) to boost system efficiency. The switching behavior of the diodes is temperature-independent and the operating junction temperature is 175°C. These aspects enable a larger design margin and reduced thermal management requirements. Target applications are EV charging stations, solar inverters, and switch-mode power supplies.

Using its second-generation SiC MOSFET technology, STMicroelectronics has introduced a 650-V, 22-mΩ (typically at 150 °C) SiC power device. The main features of this product include low on-resistance per unit area and better switching performance. The variation of both RDS(on) and switching losses are said by ST to be almost independent from junction temperature. When employed in the EV/HEV main inverter, the company reports that the part increases efficiency by up to 3% compared with an equivalent IGBT solution. This translates into longer battery life and a lighter power unit. ST's SiC MOSFETs also feature what the company claims is the industry's highest junction-temperature rating of 200°C.



Source: "Power SiC: Materials, Devices, Modules, and Applications report," Yole Developpement, August 2017.

3. Yole Developpement analysts pull no punches. In 2016, they said the SiC power business was "concrete and real, with a promising outlook." This year, they added,"The trend has not changed in 2017 and even more, the SiC industry is going further."

GAINING MOMENTUM

Efficiency, power density, and the reduction of system cost are key drivers behind the use of the WBG materials SiC and GaN. While some application areas tend to be early adopters for new technology (if benefits outweigh risks), many others are now following as these materials move into more mainstream applications. As additional suppliers enter the market, increased production will drive down costs. Those cost benefits—taken together with quality and reliability gains—will push the rapidly maturing SiC- and GaN-based topologies to the tipping point, even in cost-sensitive applications.

TOM STARNES | Objective Analysis, Chief Analyst, Processors

IoT Security: Getting Well-Deserved Attention

With growing numbers of ways to circumvent established preventative measures, staying on top of security is a never-ending task.

There is no doubt that security concerns are heightening in the quickly-growing Internet of Things (IoT) world. The public is reminded almost daily that the internet can be compromised with an array of consequences, much of which they don't really understand. Yet, consumers unwittingly encourage hacking by putting so much of themselves on the grand network, with their incessant use of smartphones and social networks, let alone buying some of those IoT devices or just driving around in modern automobiles. Business faces much greater risk, threat, and financial impact from security breaches, yet simply cannot operate without the digital electronics that expose them to it.

The electronic products and digital services that we normally use are revered for the functions they perform and maybe how easy they are to use or how cost-effective they are. The system designers see their creations that way, too. How reliable and secure those systems and that software may be is difficult to assess and tends to be pretty low on the priority list, spiking up only when a problem suddenly becomes traumatic.

Users have trusted that the engineers and programmers have created very useful products and services, regardless of whether they understand the underlying complexities of how they work, but that they are safe as well. Government agencies may establish regulations to assure a certain level of safety, but the digital world spins much faster than policy advances. Also, governments can be part of the problem and a newfound nationalism is throwing suspicion on other governments' motivations as well.

Ultimately, the designers of our modern electronic systems and digital services must continue in their role of responsibility for building the best products they can while being good stewards for their safety and security. Unfortunately, there are growing numbers of people intent on devising new ways to circumvent established preventative measures, so staying on top of security is a never-ending task.

The path forward to security in the highly connected Internet of Things (IoT) world is still being blazed. It is good to periodically review how different approaches to security have progressed.

Intel, CISCO, and Amazon may have schemes for the internet side of things, but Arm and many semiconductor companies are executing on strategies to tighten up security on the "things" side as well. The IoT is and will be well-served by Arm-based products, so Arm's efforts in security are important, if only from a holistic view. There are many semiconductor providers with an interest and a hand in IoT security, but a representative company like Microchip can give insight where the rubber meets the road.

BEARING ARMS IN DEFENSE

Security was a predominant theme at the recent Arm TechCon in Santa Clara, Calif., where Arm Ltd. highlighted its new Platform Security Architecture (PSA). With the Arm processor architecture being used by essentially every microprocessor (MPU) vendor and many microcontroller (MCU) vendors in the industry, any reasonable program promoted by Arm is sure to quickly gather a large following. Arm processors' defacto position in mobile phones, tablets, and what eventually became the IoT has given Arm a healthy heads-up of the issues of security.

Arm has posted a "Security Manifesto" with a handful of luminaries highlighting security issues, giving cues from other systems (including human and biological), and calling on equipment makers and service providers to take threats to

(Continued on page L28)

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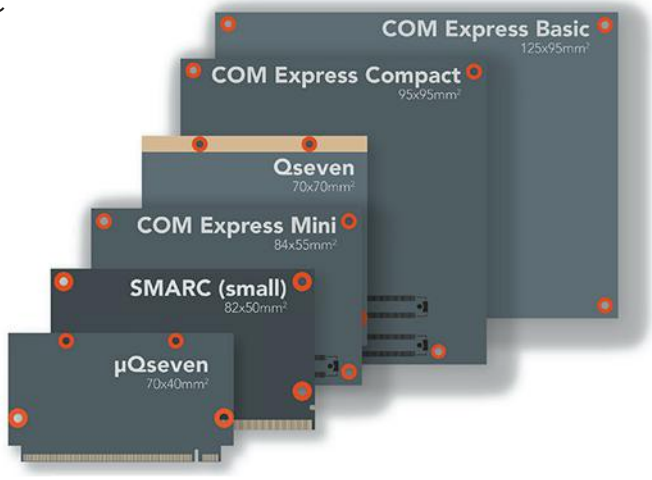

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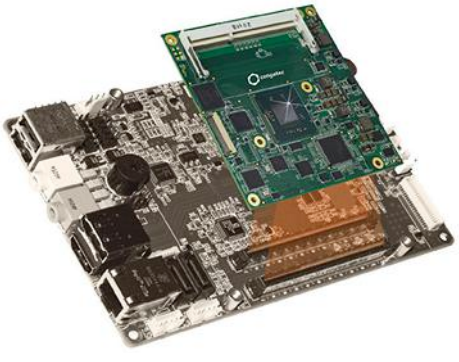
- Quicker Time To Market
- Reduced Development Costs
- Scalable Product Ranges
- Fast Reaction to Market Trends

EMBEDDED IN YOUR SUCCESS

CONGATEC IS COMMITTED to customer success and ensures support through every step of your project. Leave the embedded core to us so you can focus your engineering resources on your team's core competencies.

Thanks to a well-equipped toolkit comprised of reference designs, schematics, application notes, drivers, board support packages, and module-specific BIOS, congatec delivers a smooth learning curve for designers utilizing Computer-on-Modules.



All of our boards also come equipped with congatec's Embedded BIOS/UEFI platform. With this platform the most common BIOS modifications can be handled directly by the designer to suit their application needs, allowing for quicker time to market. When more complex customization is required, a congatec BIOS engineer is on hand to provide the help needed resulting in the perfect fit formula for the application.

Getting started is easy with congatec's Computer-on-Module starter kits and reference designs. congatec's Technical Solutions Center has experienced support engineers available to help kick start the project, as well as to see it through to market release.

COMPUTER-ON-MODULE CONCEPT:

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- Standardized modules combined with an application-specific carrier board form an individualized device
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- Wide range of modules from different manufacturers

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COM Express Type 10
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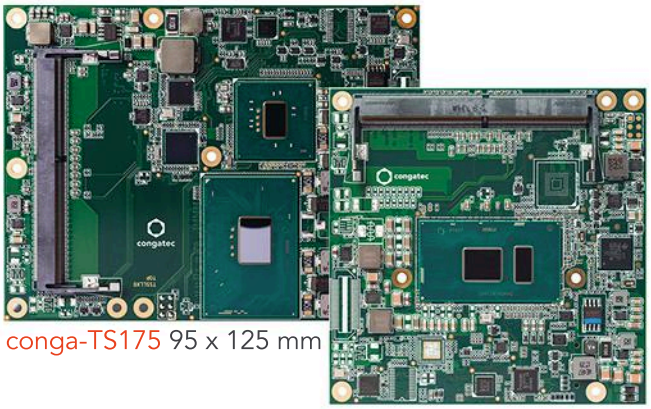
Low-power draw modules for industrial extended temperature range are a perfect fit for handheld and rugged mobile applications and IoT gateways.

conga-MA5 55 x 84 mm

conga-MA5 with Intel® Atom™, Celeron® and Pentium® processors feature up to 8 GB dual channel DDR3L RAM and Intel® Gen9 Graphics.

COM Express Type 6
Performance Class

Widely scalable modules for applications ranging from industrial, medical, infotainment and IoT. COM Express Type 6 bridges the gap from the lowest level requirements to the highest end server and number crunching applications.



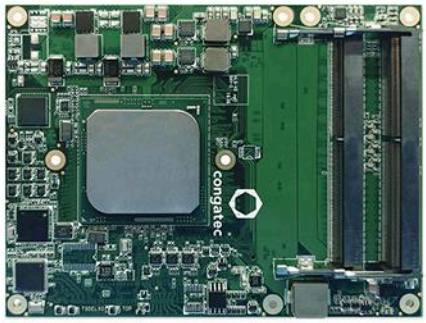
conga-TS175 95 x 125 mm

conga-TC175 95 x 95 mm

Both modules with Gen7 Intel® Core™ processors feature Intel® Gen9 HD Graphics and Intel® Optane™ memory. conga-TS175 also available with Intel® Xeon® processor.

COM Express Type 7
Server Class

Server-on-Modules for industrial automation, storage and networking, base stations as well as cloud, edge and fog servers for IoT and Industry 4.0 applications.



conga-B7XD 95 x 125 mm

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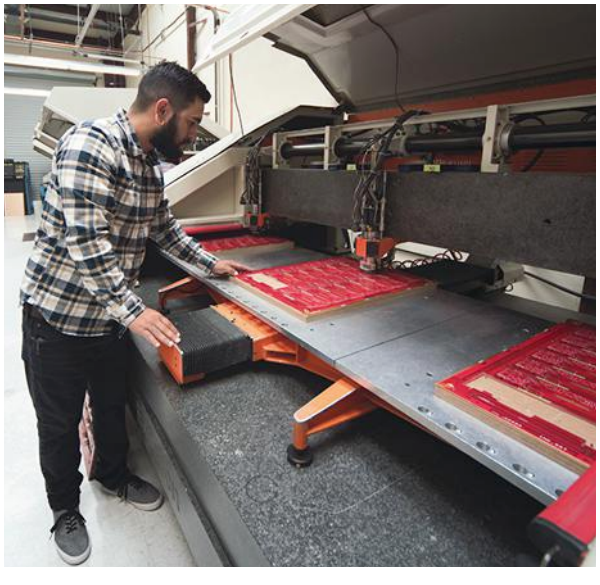
10. Over 20 Years of Experience
11. PCB Design Services



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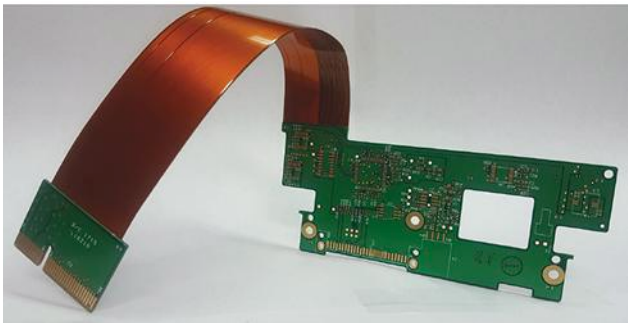

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- copper and overall design thicknesses
- and much more.

ROYAL FLEX CIRCUITS

(Continued from page L23)

cyber security seriously and to provide a safe environment in which connected digital equipment can operate. Arm, rightfully, sees security as a responsibility of such businesses. However, specifics are limited and Arm believes "industry bodies" will pull together actual standards.

PLATFORM SECURITY ARCHITECTURE

A centerpiece in Arm's security position is the Platform Security Architecture (PSA), better addressing the security challenges all the way down to the smaller, cost- and performance-constrained critical components of systems—MCUs. Of course, the highest volume of processors is in MCUs, so it is vital that data flowing up from and managed by these workhorses is not compromised and that MCUs do not become access points by which the larger system, or even unrelated systems, can be attacked or infiltrated.

However, the PSA also addresses higher-performance systems and even initially specifying support for the Arm v8-A architectural profile, as well as Arm v8-M, which could be adopted to the Arm v7-M and v6-M. PSA material is littered with exotic terms, acronyms, and explanations that take some getting used to—or leave it all to the security wizards—something the concept was supposedly trying to avoid.

There are three main parts to the PSA. These are given as follows:

- Threat models and security analysis, derived from a range of typical IoT use cases
- Architecture specifications for firmware and hardware
- An open-source reference implementation of the firmware architecture implementation *(source: Arm, Ltd)*

The first is a set of models or use cases that typify many applications with an analysis of the security threats they may face and the potential consequences of an attack. This may be used to judge or qualify the protection that a given application affords. The models feed issues and urgency to the protective specs being developed.

A Device Security Model *(Fig. 1)* describes the architecture. The implementation of such specs push all the way down to assuring that the silicon manufacturing processes are secure. This sounds like just any ol' fab may not be qualified for producing tamper-proof security. When security is truly important, everything must be treated as suspect and as a potential weak link until demonstrated otherwise. Not only must initial device keys and attributes be secure, but later firmware updates, crypto certificates, and maintenance and calibration changes must be authenticated.

The PSA also lays out the elements that reside in secure partitions of the system (in the Secure Processing Environment) under hardware enforcement by the Secure Partition Manager, which probably makes the old memory management unit (memory protection unit in Arm parlance) look pretty rudimentary and narrowly focused.

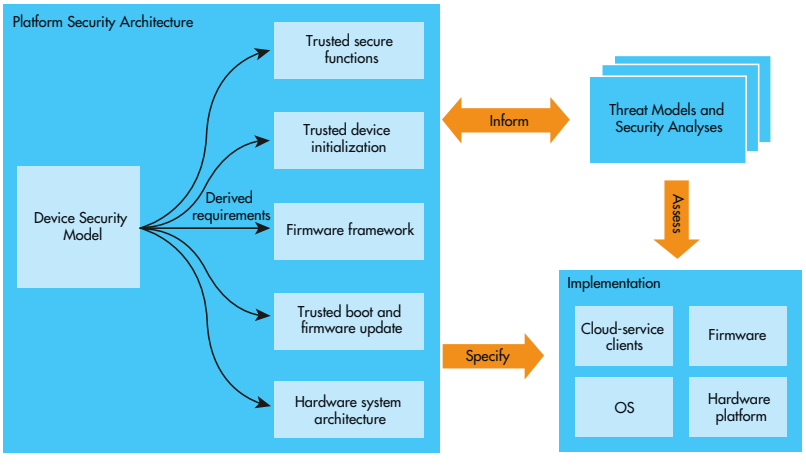
The PSA builds from Arm's earlier TrustZone, Trusted Execution Environment, Trusted Boot, Root of Trust, SecureCores, and other protection elements.

Arm sees chip designers cordoning off security "enclaves" containing the most critical security elements as part of a larger silicon die. Arm is developing its own such intellectual property (IP) to be tagged CryptoIsland-300. That may sound like the place where John McAfee is fighting with his neighbors and hiding under the sand from satellite cameras, but the sand making up Arm's islands will be much more highly refined, intended to have rigid security on par with that found on SmartCards (chip-enabled bank cards and ID cards).

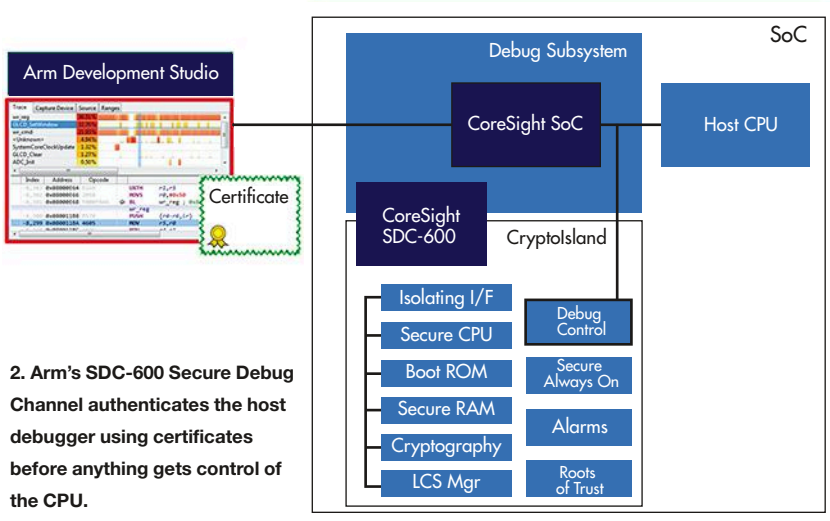
CryptoIsland details quickly become mind-boggling and complex. However, they also should reaffirm humanity's trust in things like our bank cards. Many features described on these CryptoIslands remind this analyst of all the precautions, lessons, technologies, processes, and solutions that semiconductor vendors have learned over decades in securing memory, processors, and chip cards from natural (alpha particles) and semiconductor-scaling-induced quality and failure problems, as well as code-, circuit-, IP-, and design-stealing protection practices.

Arm also offers a Secure Debug Channel, the SDC-600 IP*(Fig. 2)*, which authenticates prodding into the silicon hardware under the guise of a debugger.

The third part of the initial PSA will address firmware (largely code) strategies including partitioning into secure and nonsecure spaces with a Firmware Framework that eases reuse of code across various MCU cores and reliable updates.



1. The PSA consists of three parts: the Threat Models and Security Analyses, an architecture specifications for firmware and hardware, and an open-source reference implementation.



2. Arm's SDC-600 Secure Debug Channel authenticates the host debugger using certificates before anything gets control of the CPU.

Overall, the Platform Security Architecture is a work in progress, but lays out the greater structure that partners, chip vendors, OEMs, programmers, development-tool third parties, and application developers can gather around, work together on, and align their products and software to. It is an evolving program just now seeing the light of day, though it has obviously had a lot work put into it. Perhaps close partners have a much better understanding of how the concepts will play out in practice—silicon implementation, OS integration, coding techniques, system integration, and how well the PSA will work up the value chain—or is it the internet/Ethernet/wireless mesh—to the servers, databases, and cloud services.

As with all such schemes, it will take a long time for large-scale implementation to prove out. With more creative attacks being attempted every day, this will be a never-ending race. But at least Arm has the ear of the bulk of processor vendors and the third parties behind them, including and especially on those with customers building "things," diverse as they are, so Arm's PSA should have enough interested parties to steer it to success in securing the IoT.

Arm expects the PSA to lower the cost and time for its partners to design a secure system while lowering the risks of attack, hopefully using techniques that others in the industry also use, leading to an overall much-safer internet (of things). Perhaps, more realistically, application developers can more easily design a system that is an optimally secure system, providing *sufficient* security without costing too much to design, pilfering too much processor performance, or requiring too many additional resources (circuitry, memory, coding, delay…).

MICROCHIP PAY-AS-YOU-GO SECURITY

One of the leading microcontroller suppliers is Microchip Technology, which has a more feet-on-the-street approach to serving security needs, probably more typical of semiconductor vendors. In spite of its $4 billion size, Microchip's business is almost wholly associated with MCUs. Most of its MCUs use its proprietary PIC architecture, although Microchip took a unique path in its 32-bit offering by utilizing the MIPS architecture (which seems to now be nearly a proprietary architecture). Microchip did pick up the proprietary AVR architecture and the ubiquitous Arm architecture when it bought Atmel.

Alongside the MCUs, Microchip has acquired and developed assorted networking and radio components with numerous communications peripherals on its MCUs. Associated with networking and especially RF, the company has picked up security components as well.

For security support, Microchip offers a selection of components to serve a variety of designers with widely different or changing needs. As it does for its MCU customers, Microchip provides easily accessible tools to help even less security-savvy customers to build in the level of security they need.

The security components are primarily add-ons that support the MCU, limiting the incremental expense to only those applications that need the security benefit. In conjunction with all of those MCU architectures, this makes good sense since every cent counts in small systems and Microchip is known for squeezing every penny of cost out of its products.

RIGHTS, PRIVACY, SECURITY: A FINE LINE

Society has a struggle, debating and pushing the line of who has which rights, what is private, and when has security been compromised. Individuals, organizations, corporations, countries, and even softer concepts play into the discussion like culture, morals, deceit, and what is right. The arguments arise, develop, reconcile, and rehash over time. Often money is the ultimate resolution, but that has moral considerations, too.

Without trying to settle where lines of rights, freedom, and privacy should be drawn, security is about enforcing those lines. That enforcement has a cost, but security must be incorporated into our evolving inventions or they will fail from its absence. There will continue to be a learning process because the attackers will not stop trying. But one must determine a strategy, execute a rational plan, review real-world results, and make adjustments in order to advance to higher security.

The number of electronic devices and digital services in the world today, the interconnectivity of those devices, services, and humans, the sheer volume of network traffic, and the dependence of modern society on all those inventions pushes the importance of security in our digital world to where it cannot be ignored. ED

AUTOMOTIVE

MURRAY SLOVICK | Contributing Editor

Advances in Intelligent Vehicle Technology Keep Rolling On

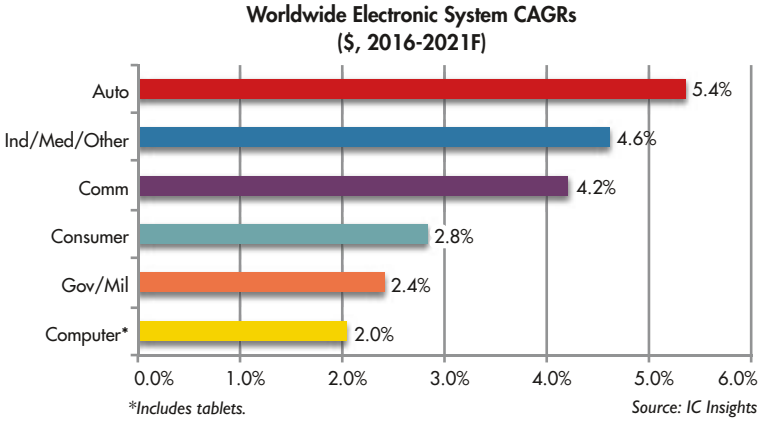
As carmakers and Tier 1s develop basic building blocks for the autonomous cars of the future, drivers are getting a glimpse of what's to come.

In an industry that once lagged in electronics adoption, today's automobile is at the forefront of the electronics technology curve. Much of what we're seeing today is bridging the gap between traditional automobiles and the self-driving car yet to come. According to data presented in the 2018 edition of the IC Market Drivers study from IC Insights, automotive-electronic system sales are forecast to rise by a compound annual growth rate (CAGR) of 5.4% through 2021, which is the highest among major end-use system categories studied by the Scottsdale, Ariz., research firm *(Fig. 1)*. (Industrial electronic systems was next at 4.6% CAGR, followed by communication systems at 4.2% and consumer electronics systems at 2.8%.)

At the heart of the hit parade are car companies and Tier 1s. They are partnering with tech giants like Google and Uber as well as prominent startups to develop the next-generation autonomous vehicles that will alter our roads and highways. Now common aboard the vehicles currently in showrooms are (SAE) Level 1 features, such as adaptive cruise control, automatic emergency braking, automated parking, and active lane control. Luxury brands including Volvo, BMW, and Mercedes-Benz have begun to showcase Level 2 features like automated steering and speed control. Level 3 cars from Tesla, Cadillac, and Audi offer partial autonomy, but still require driver intervention. Level 4 will be fully autonomous but can be driven by humans, while Level 5 vehicles will be designed to eliminate the driver completely.

Ponder this: GM's Cadillac Division is now selling its CT6 sedan with a driver-assistance system called Super Cruise *(Fig. 2)*. It uses a radar sensor, cameras, GPS positioning, and a digital map to handle all of the braking, accelerating, and steering on divided, limited-access highways—places where it does not contend with intersections, traffic lights, and pedestrians. Super Cruise is General Motors' answer to Tesla's Autopilot, the best known of the semiautonomous driving systems that have arrived in the past two years. Neither system is fully autonomous, as both require drivers to remain alert and prepared to take control at any time.

Unlike Autopilot, Super Cruise does not require you to keep your hands on the steering wheel. A camera mounted on the steering column monitors the driver's eyes and head. When Super Cruise is engaged, a thin light strip on the top of the steering wheel appears green. If the driver looks away longer than once every three seconds or so, it flashes to bring his/her attention back on the highway. If the driver fails to do so, the light strip turns red and the driver's seat vibrates, alerting the driver to take control.



1. Automotive electronic system growth is the highest among major end-use categories studied by the research firm IC Insights.

2. Cadillac's Super Cruise, offered on its 2018 CT6 sedan, permits hands-off driving but warns the driver if he/she diverts attention. *(Source: Cadillac)*

SMART SUVs NAVIGATE OFF ROADWAY

Different requirements affect sport utility vehicles, as intelligent, connected SUVs are not expected to operate exclusively on regular roads. In November, Ford Global Technologies was granted a patent for an off-road autonomous driving system that can evaluate an environmental obstacle, like a ditch or a boulder field, and traverse the obstacle without manual input. Ford's patent outlines a system utilizing on-board cameras, radar, ultrasonic and height sensors, LIDAR, topographic maps, and rain and road-condition detectors.

The system initially performs two key tasks. First, it decides if it could safely navigate an off-road challenge. If so, it next determines whether it could do so with passengers in the vehicle. If the system suspects a rollover risk beyond a certain safety threshold, passengers would be instructed to exit the vehicle. It would then try to maneuver the route on its own while the passengers and driver followed along on foot. A remote-control override ensures that the vehicle won't leave anyone behind. The system would command variables, such as an active suspension, differentials, body mounts, and individual wheel position, via settings like "rock crawling," to get around or through the obstacle.

LIGHTING THE WAY

Situational awareness is key to the operation of intelligent vehicles. The 2018 Audi A8L fuses sensor data from a forward-looking camera, a 145-deg. forward-looking laser scanner, four corner-mounted short-range radar units, and a longer-range grille-mounted radar sensor as well as short-range ultrasonic sensors. The laser scanner involves a stationary laser beam aimed at a spinning wheel with flat mirrors on it. The face of each mirror directs the beam through its 145-deg. forward arc.

To illuminate the environment around its cars, Audi has achieved full type approval to sell laser high-beam lights in the U.S. It is, however, restricted to a range that extends just slightly past the LED high-beam pattern. In contrast, the laser doubles the high-beam range in Europe. The 405-nm blue laser beam reflects off a material that turns the light white. *(Fig. 3)*.

Similarly, BMW's adaptive LaserLight headlights do not project lasers onto the road, but fire laser light through a series of mirrors. Those mirrors are located within the headlamp assembly. As a result, the light is reflected and focused into a lens filled with yellow phosphorus. Once the light interacts with the yellow phosphorous, a white light is created that's 10 times brighter and more intense than traditional Xenon or LED headlamps. The system is said to improve high-beam output by a factor of two, meaning you can see twice as far down the road or up to 600 m, according to the company.

Laserlight high-beams are also designed to prevent oncoming traffic from being blinded. So there's no need to turn off the lights when oncoming traffic is approaching. LaserLight uses a camera and a selective beam system that detects oncoming vehicles or those that are overtaking the BMW and automatically dims the beam. Because the system is GPS-enabled, it can anticipate and better light turns in the road.

3. The European version of the Audi laser light doubles the range of the high beam. *(Source: Audi)*

ALL CARS CONNECTED

Among the basic building blocks for intelligent cars of the future are wireless technologies like vehicle-to-everything (V2X) communications. Continental AG has announced its intention to use Qualcomm's C-V2X Reference Design with the integrated Qualcomm 9150 C-V2X chipset in connected car systems being built for field trials. Its goal is to test connected car systems with regard to range, reliability, traffic density, and latency in addition to defining automated-driving use cases. Designed to enhance device-to-device communications, C-V2X technologies complement and extend existing cellular capabilities, enabling direct communications without requiring the involvement of the cellular network.

(Continued on page L34)

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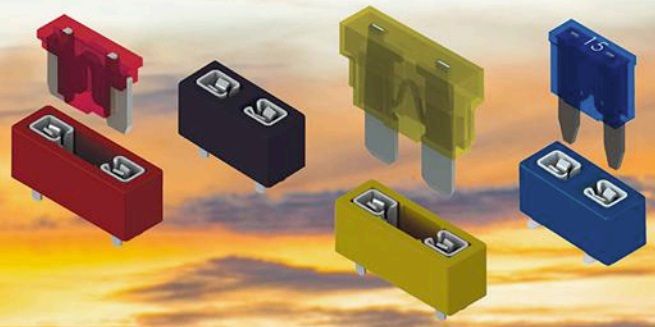

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(Continued from page L31)

Volkswagen will bring its own dedicated V2V technology to market in 2019 utilizing public wireless LAN (pWLAN) as a communication channel. The technology allows cars to share information within a range of about 500 m. This makes it possible for cars and transport infrastructure to give drivers accident warnings and a heads-up on risky scenarios like traffic and road conditions.

A MORE FUEL-EFFICIENT MEANS OF PROPULSION

Historically, every time it seems fossil fuel is on the ropes, the automotive industry pushes technological innovation one step further. This time, however, it does appear that the shift to electric vehicles and alternate fuels, such as hydrogen, is going to have government backing. For instance, France, Great Britain, the Netherlands, and Norway have all said they plan to ban the sale of gas and diesel cars in the coming decades. More importantly, China—the world's largest car market—and India plan to join them.

On a corporate level, Volvo said it would cease production of gas-only vehicles by 2019. Daimler AG, the parent company of Mercedes-Benz, announced plans to offer electrified versions of all of its cars by 2022. GM is working toward an all-electric, zero-emissions future that starts with two new, fully electric models next year and at least 18 more by 2023. For its part, Volkswagen said it would electrify its entire 300-car lineup by 2030.

In the commercial truck space, Tesla has unveiled a prototype for a battery-powered, short-haul electric "semi" truck. It features the company's Autopilot system, which can maintain a set speed and automatically slow down in traffic and keep the vehicle in its lane. Tesla says the semi will consume less than 2 kwH per mile and have a range of up to 500 miles (804 km) on an electric charge—even with a full 80,000-lb. (36,287-kg) load.

According to Tesla, it will cost less than a diesel semi considering fuel savings, lower maintenance, and other factors. Production will begin in 2019. Global annual electrified powertrain medium and heavy-duty truck sales are expected to grow from about 31,000 vehicles in 2016 to nearly 332,000 by 2026, according to Navigant Research.

4. Toyota's Sora bus has 10 tanks containing 600 liters of hydrogen.
(Source: Toyota)

At the Tokyo Motor Show this past October, Toyota debuted two concept vehicles powered by hydrogen fuel cells. The Sora fuel cell bus (Sora is an acronym for Sky, Ocean, River, Air—the earth's water cycle) is aimed for production in 2018, with more than 100 of them to be used in the Tokyo metropolitan area ahead of the 2020 Olympic and Paralympic Games *(Fig. 4)*.

Sora's powertrain consists of two 114-kW fuel-cell stacks and dual drive motors outputting 113 kW and 355 Nm of torque each (equivalent to 152 hp and 262 lb.-ft. of torque). A relatively small nickel-metal-hydride (NiMH) battery is also on board, as are a total of 10 hydrogen tanks with a total capacity of 600 liters.

The other fuel-cell-powered Toyota concept vehicle is dubbed "Fine-Comfort Ride." This crossover-type vehicle runs on hydrogen with a range of 1,000 km (620 miles) per charge. It can be refueled in about three minutes. The "Fine Comfort" name relates to six captain's chairs that all swivel toward the middle. They adjust to their user's posture and seating position in a manner similar to a business-class airplane seat.

THE NEXT STEP

We can no longer pretend that a tectonic shift in how we interact with automobiles isn't on the horizon. 2017 brought motorists "hands-off" assisted-driving services in which drivers are still largely in control. Thus equipped, intelligent cars can activate automatic braking and lane-keeping functions while providing assistance in traffic jams on expressways and in parking maneuvers. While this technology is being widely accepted by the public, the next step—the fully autonomous car—continues to generate skepticism.

According to a 2017 study by American International Group, Americans are highly polarized as to whether to accept or reject self-driving vehicles on the road. In the survey, 41% of respondents said they are uncomfortable with the idea of sharing the road with driverless vehicles. Yet 42% are generally okay with it. A plurality (39%) believes driverless vehicles will operate more safely than the average human driver, though a substantial group—27%—felt they would not.

A major stumbling block to acceptance is the perceived security of the vehicles. Fully 75% of respondents expressed concern that fully driverless vehicles—and even autos with autonomous features (emergency braking, lane departure avoidance, etc.)—are susceptible to hackers taking control. Clearly, there is work that still needs to be done. ed

CABE ATWELL | Contributing Editor

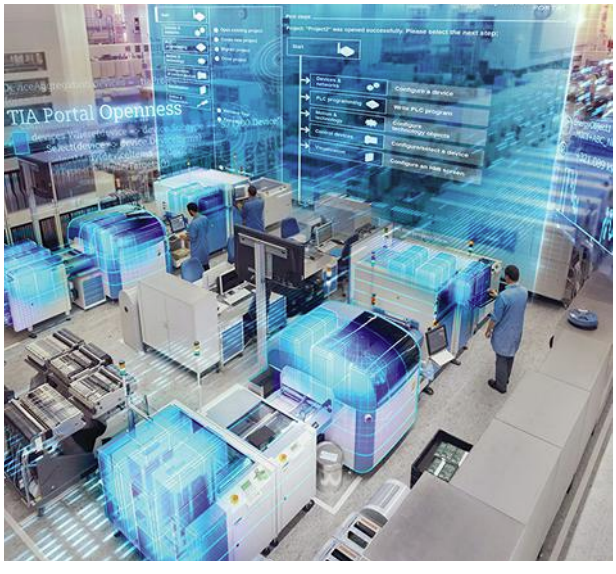
Turning to Machine Learning for Industrial Automation Applications

We look at companies using machine learning in their industrial automation and manufacturing facilities and what results it's generating for those businesses.

At its core, machine learning studies the construction of algorithms and learns from them to make predictions on data by building models from sample inputs. If we further break it down, machine learning borrows heavily from computational statistics (prediction modeling using computers) and mathematical optimization, which provides methods, theory and application data to those models. In essence, it creates its own data models based on algorithms and then uses them to predict defined patterns within a range of data sets.

Machine-learning algorithms can be broken down into five types: supervised, unsupervised, semi-supervised, active, and reinforcement, all of which act just like they sound. Supervised algorithms are programmed and implemented by humans to provide both input and output as well as furnishing feedback on predictive accuracy during training. Machine learning will then use what it has learned and apply it to introduced data sets. Unsupervised requires no training and relies on "deep learning" (an aspect of AI that automates predictive analytics) to analyze data, which it uses to predict data sets. Semi-supervised is provided with incomplete algorithms or training sets and learns by completing the missing components. Reinforcement learning provides feedback to the program as it completes actions in a dynamic environment and extrapolates predictive data sets by learning from said actions.

There are a considerable number of algorithmic approaches to machine learning, and that number continues to grow given that AI, Deep Neural Networks (DNNs), and machine learning (all part of the same family) are still in their infancy. While volumes of information are written for each, they were all created for specific applications. For example, reinforcement learning can be found in self-driving vehicles and computer opponents in video games while decision-tree learning is used extensively for mining big data.



1. Siemens MindSphere helps to optimize automation systems and facilities. *(Courtesy of Siemens)*

That being said, machine learning has a surprising number of applications that move beyond self-driving vehicles and video games, including the medical industry (helps physicians make a more informed diagnosis), the financial industry (portfolio management, stock trading, fraud detection, etc.), and retail/customer service (pinpoint customer behaviors for advertisements), to name just a few. While those examples are perhaps more commonly known for those with little knowledge of machine learning, it may be surprising to see that those AI

(Continued on page L42)

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Altech Corporation is an established United States-based supplier of components and devices used in industrial control, instrumentation, and automation applications. Altech is an ISO 9001:2000-certied manufacturer and distributor of electrical, electronic, and electromechanical components.

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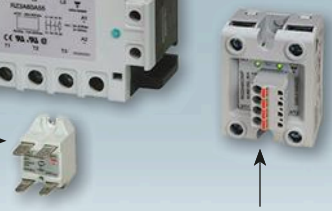

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A complete line of UL Ground Fault Equipment Protection (GFEP) devices from Altech Corp.® – including an industry "first" – introduce ideal solutions to help prevent costly production shutdowns due to AC and DC pulsating ground faults, as well as overloads and (with some models) short circuits. The technology lineup – unmatched in the industry – offers three highly engineered series of devices delivering multiple capabilities and promoting reliable protection and operation of equipment wherever and whenever ground faults may occur. In all three series, ground fault sensitivity levels range from 10 mA – 500 mA.

The UL 489 Branch Circuit Breaker with Ground Fault Relay (GFL Series) represents an industry "first" by combining a Ground Fault Equipment Protector with a UL 489 Branch Circuit Protector, which eliminates a need for upstream circuit protection. This device is available in 1 pole+N, 2 pole, and 2 pole+N configurations at 120/240V AC and 240V AC. Rated current is 5A-40A and rated Short Circuit Interrupt Capacity is 10kA. Three trip curves (B, C, and D) can be specified.

The UL 1053 Ground Fault Sensing and Relaying device (GF Series) provides residual current protection for circuits with loads up to 63A. This model is designed with 2 and 4 poles at 277V AC and 480Y/277V AC, rated current of 25A, 40A, and 63A, and rated Short Circuit Withstand Capacity of 10kA. This device represents an ideal retrofit GFEP where standard overload and short circuit protection is already being provided (or will be provided) by other means.

The UL 1077 Ground Fault Relay with Overload Protection (GFR Series) serves as a combined Equipment Ground Fault Relay and Supplementary Protector (RCBO). The device can be supplied with 2 and 4 poles at 277V AC and 480Y/277V AC and with a rated current of 5A-40A. Rated Short Circuit Withstand Capacity is 10kA and three trip curves (B, C, and D) are offered.

These three series are the latest additions to Altech's UL listed product range dedicated to meet the most demanding conditions and applications across industries. Altech further provides comprehensive product support and the capability to develop customized solutions to meet particular requirements.

THE ALTECH ADVANTAGE

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- Rated Frequency 50/60Hz
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The Most Complete Lineup of UL Ground Fault Equipment Protection

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Ground Fault Sensing & Relaying Equipment
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UL 1053

Ground Fault Sensing and Relaying Device

- 1 Pole + N and 3 Pole + N versions
- 277V AC and 480Y/277V AC
- Rated Current 25, 40 and 63A
- Residual Current Sensitivity 10, 30, 100 and 300mA
- Rated Short Circuit Withstand Capacity 10kA
- Rated Frequency 50/60Hz

c UL us
Ground Fault Sensing & Relaying Equipment
E483493

UL 1077

Ground Fault Relay with Overload Protection

- 1 Pole + N and 3 Pole + N versions
- 277V AC and 480Y/277V AC
- Rated Current 5 - 40A
- Residual Current Sensitivity 10, 30, 100 and 300mA
- Rated Short Circuit Withstand Capacity 10kA
- Rated Frequency 50/60Hz
- Overload Trip Curves B, C and D

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(Continued from page L35)

algorithms are finding their way into the manufacturing industry, providing everything from increased production capacity to more efficient plant operations and everything in between.

Preventative maintenance/repair, condition monitoring (machine efficiency), and optimizing supply chains can all be had with integrated machine-learning algorithms. Manufacturers are also starting to integrate AI programs into their automation processes and the inclusion of other advanced technologies (IoT, modular/adaptive hardware, distributed intelligence, etc.), is helping manufacturers gain a foothold in the 21st century's Industry 4.0 revolution. According to a report from TrendForce, smart manufacturing is expected to undergo significant growth in the next three to five years and estimates the manufacturing market will bring in $200 billion this year alone—and is expected to grow to $350 billion by 2020, a growth rate of 12.5%.

If manufacturers want to remain competitive, they will have to eventually (if they haven't already) incorporate these new technologies into their plant infrastructure or modernize their legacy systems, a key component of which is industrial automation. With consumers growing more conservative in their product views (quality and customization), being able to change production systems in a short amount of time is crucial, and advanced hardware and software help provide that path without the need for retooling or systemwide reprogramming. Machine learning in this area and all aspects of industrial automation can be beneficial—it can monitor and help perform maintenance on production machinery, reprogram industrial PCs (distributed intelligence) for new product production, and optimize the efficiency of plant operations over the entire supply chain.

While there is a host of manufacturers incorporating machine learning into their production platforms, there are currently four businesses leading the way in this area with the different ways they are utilizing the technology. In this article, we'll look at how these companies are using machine learning in their industrial automation and manufacturing facilities and what results it's generating for those businesses, beginning with the well-known German conglomerate Siemens.

MINDSPHERE: FROM PRODUCTION DESIGN TO MAINTENANCE

Siemens has been using neural networks to monitor its steel plant operations and improved efficiency since the 1990s and currently employs around 200 employees to advance machine learning in the coming years. One of the company's more exciting technologies that utilize AI for automation and other systems is its MindSphere open-IoT OS, which lets it monitor, record, and analyze nearly every facet of manufacturing—from production design to maintenance.

"Our industrial operating system MindSphere also benefits from intelligent data analyses—with regard to predictive maintenance, for example, as well as through its ability to optimize the operation of systems and facilities. The software's ability to analyze operating data and sensor measurements, allows it to spot anomalies in facilities and automation systems," explains Siemens AG Chief Technology Officer Roland Busch. Siemens can use the AI platform on legacy systems by attaching sensors and communication nodes to older motors and transmission systems to provide data to MindSphere, which can analyze the information and draw conclusions on their optimum performance, making predictive maintenance possible.

The OS is so successful that the company uses it for other industries, including electrical power grids (classify and localize disruptions), railway trains (predictive maintenance utilizing vehicle's operating data), and wind parks (optimize wind turbine position based on weather data). Siemens hopes to integrate the MindSphere system in the near future for a new product known as ClickToMake—a production-as-a-service platform or a type of point-and-click vision of a self-configuration factory.

AT GE, SPOTTING POTENTIAL PROBLEMS

GE has followed suit, developing its own machine-learning industrial automation operating software. Similar to Siemens' MindSphere, GE's Brilliant Manufacturing Suite is a production-wide system that tracks, monitors, and processes everything in the manufacturing cycle to find possible problems and inefficiencies before they become prevalent. According to GE, the premise of the software suite is to spot potential problems and provide possible solutions.

The system is powered by GE's Predix software platform, which is an IIoT software package that garners data from sensors and monitors production hardware for potential problems. The company has already spent around $1 billion developing the Brilliant Manufacturing Suite, $200 million of which went to building the Brilliant Factory (back in 2015) in India, claiming it improved equipment effectiveness by 18%. In total,

2. GE's Brilliant Manufacturing Suite provides monitoring and predictive maintenance for manufacturing production platforms. *(Courtesy of GE)*

GE has established seven factories outfitted with the Brilliant Manufacturing Suite, which has boosted its production efficiency across the board.

MACHINE LEARNING FOR ROBOTS

Chinese-owned German manufacturer KUKA is one of the world's largest industrial robot and factory automation manufacturers and produced its first industrial robot back in 1973. The company has since taken an interest in machine learning, most notably for human-robot collaboration in manufacturing, where safety is paramount. While some industrial robots rely on sensors and predefined force pressures for safety measures, KUKA uses machine learning to achieve the same goal.

The company's flagship LBR-iiwa industrial robot, for example, learns from its surroundings and movement repetition via simulations—position the robotic arm in a virtual environment and it will plot those positions in the real world using coordinates. According to Project Manager Jakob Berghofer, "The LBR iiwa is sensitive, compliant, safe, precise, and flexible, and is equipped with mechanical systems and drive technology for industrial operation. This makes it possible to automate delicate and complex assembly tasks in which the use of robots was previously inconceivable."

Not only does KUKA employ these robots in its manufacturing plants, but others have also taken notice and have incorporated them into theirs, including BMW, which has recently added them to its Munich facility production line, working side by side with their human counterparts. It's only a matter of time before others follow suit and incorporate machine-learning robots into their factories.

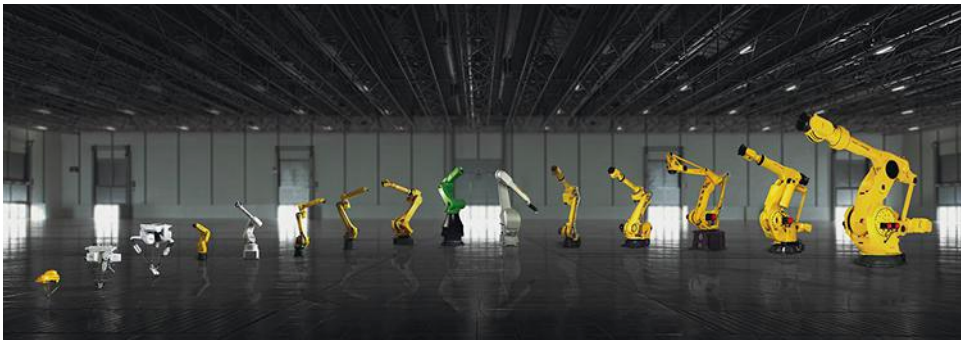
Japanese industrial robotics company Fanuc utilizes machine learning to perform manufacturing tasks in a similar fashion as KUKA, albeit using a different method or algorithm. The company collaborated with prominent Japanese AI developer Preferred Networks to develop industrial manufacturing robots that can learn on their own with minimal input. More accurately, they learn using a deep reinforcement learning platform to train itself over time. For example, you show the robot what task you would like it to perform, and it will take video of that job and try to duplicate it through repetition until the task is achieved with a high accuracy.

The successful development of smart robots has other companies taking an interest in Fanuc's endeavors. The robotics company contracted with Cisco and Rockwell Automation last year to develop and deploy the machine collaboration platform FIELD (Fanuc Intelligent Edge Link and Drive) for smart automation manufacturing. In essence, FIELD brings data analytics to intelligent robotic applications for a new level of efficiency through predictive analysis.

3. KUKA's LBR-iiwa industrial robot uses machine learning for increased safety for human/robot collaboration. *(Courtesy of KUKA)*

A short time later, GPU manufacturer Nvidia took notice and offered up its chip technology to enhance the FIELD platform with a shorter learning time for manufacturing robots. The idea is if it takes a robot eight hours to learn specific tasks, then eight robots could learn it in just one hour. Fanuc hopes that the latest developments will help power the factories of the future.

These companies are leading the forefront of development when it comes to machine learning in industrial automation, and while these developments are just baby steps into a much larger world, they are significant and paint a picture of the future where Industry 4.0 is the standard in manufacturing. The IoT, cognitive computing/AI, the cloud, sensor suites, and robotics are all just modular parts that makeup what modern manufacturing is becoming. The technology is already being implemented in most modern factories in some form or another, helping manufacturers to remain competitive in an ever-changing world with ever-changing technology. ed



4. Fanuc utilizes Preferred Networks' machine-learning algorithm to perform new tasks. *(Courtesy of Fanuc)*

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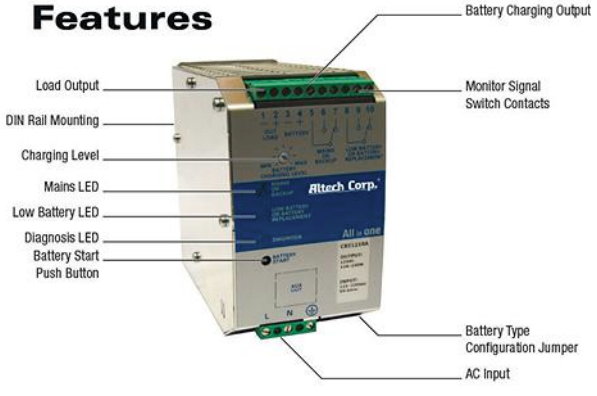
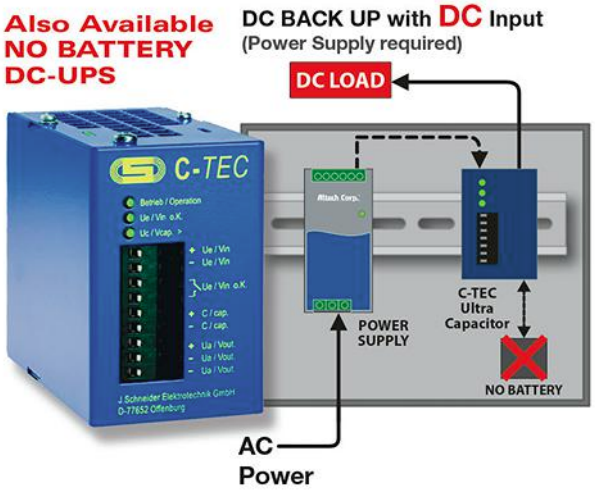
The CBI UPS (Uninterruptible Power Supply) device is available in 12VDC, 24VDC, and 48VDC output versions for pairing with conventional battery types including open lead acid, sealed lead acid, lead gel, and Ni-Cd (as an option). The device features three charging levels (Recovery, Boost, or Trickle), allows for adjustment of charging current (from 20% to 100% of output current), and automatically and ideally distributes available power among load and battery. High efficiency up to 91% is achieved through switching technology.

The device's battery-charging function is microprocessor-controlled and uses algorithms to detect a battery's condition and then choose the appropriate charging mode. Real-time diagnostics enable easy battery diagnosis and fault identification (displayed by LED) to protect against potentially occurring faults, such as short circuit, inverted polarity, overload, or disconnection of the battery. If the CBI device ever becomes disconnected from the main power source, the battery will serve to supply the load until battery voltage reaches 1.5 V per cell, preventing deep battery discharge.

The CBI device performs over a wide temperature range from -40ºC to 70ºC (-40ºF to 158ºF) and is housed in a compact and rugged metal case offered in three sizes. The device can be DIN-rail mounted using a built-in a bracket.





This power solution builds upon and expands Altech's extensive line of dedicated CB battery chargers, which feature the same advanced automatic diagnostics, charging level options, and protection against potential faults. All Altech power solutions meet relevant safety and EMC product standards.

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PATRICK MANNION | Contributing Editor

IoT and 5G Test Will Make or Break Leaders

IoT and 5G test is challenging the status quo for leadership as cost, flexibility, ease of use, performance, and time-to-market acceleration demands increase.

Technology historians may well look back on 2017 and 2018 as having sparked a golden age of test and measurement innovation, restructuring, and leader remaking. While all good companies are both predicting and responding to customer needs, the industry is well into a hyper-test environment with extreme pressure toward lower cost on one end, while pushing the outer limits of system performance on the other. Of course, both must be accomplished while accommodating ease of use and shortening "time to insight."

How equipment vendors and users respond to the conflicting dynamics in the next few years will affect who stays at the top of a test and measurement industry that MarketandMarkets expects will grow at a CAGR of 3.55% from $23.51 billion in 2017 to $28.98 billion in 2023. The end applications driving this growth include healthcare, IT and telecommunications, and automotive. However, the specific mix of trends and technologies that are stressing both equipment vendors and users include the Internet of Things (IoT), the accelerating shift to 5G, the massive amount of testing required for "the connected car" and autonomous vehicles.

Further upstream, in the datacenter, where all the generated data eventually comes to rest, they are wrestling with 100- and 400-gigabit-per-second Ethernet (GbE) data transfers and related power integrity, channel characterization, and signaling issues.

Another interesting dynamic from the vendors' perspective is the consolidation of the semiconductor market, which narrows their potential customer base, and is pushing an emphasis on excelling in manufacturing and production test. All told, the changes and pressures hint at a reshuffling of leaders, with a more flexible approach to test clearly coming to the fore.

According to a report by Frost & Sullivan, the top five participants in the RF test and measurement market are Keysight Technologies, followed closely by Rohde & Schwarz. Next come Anritsu and Teradyne, followed by National Instruments in fifth place. The requirements of the market in the next few years may see a reshuffle, depending on how the respective companies solve for user requirements.

1. Tektronix's 5 Series MSO addresses the cost and ease of use part of the company's Shift Left strategy toward a more holistic approach to test that pushes more to the front of the development chain. *(Courtesy of Tektronix)*

STRATEGY 1: RIGOROUS TESTING

To help understand the decisions being made by test equipment providers, it's useful to take a quick look at some of the pressures designers and test engineers users are dealing with. In the case of the IoT, for example, time-to-market demands are putting designers new to wireless connectivity and security under pressure to learn quickly the nuances of wireless and RF design and implement appropriate security measures and then learn how to test them appropriately, with a scant budget.

With over-the-air firmware updates now possible through connected devices, it's tempting to perform baseline functional and compliance testing, and ship product as soon as

possible—and then, fix any issues that pop up through regular updates. This assumes the user will allow or enable the updates, or that the IoT device developer has the means to do it independent of the user.

Ak Emarievbe, founder of Belvor Technical Resources, a firm that specializes in providing turn-key solutions and consultancy services for wireless device and mobile network testing, has seen this happen, but advises strongly against it. By doing so, "You aren't taking into consideration the business impact: your brand is at stake," he says. "And then there are safety and indemnification risks, so I'm a firm believer in rigorous test."

Along with brand destruction, not performing rigorous electromagnetic compliance (EMC) tests for RF and emissions opens the door to FCC scrutiny. Just last November the agency slapped an as-yet unnamed company with a $90,000 fine and an obligation to send periodic reports to show it is in line with a strict compliance plan. The company's equipment fell out of compliance with rules governing devices operating in the Unlicensed National Information Infrastructure (U-NII) bands. The Commission's action was a clear and deliberate warning to device and equipment manufacturers that regulatory non-compliance will not be tolerated: they could have their authorization to market their products in the U.S. rescinded.

However, mistakes happen and features still need to be enhanced or enabled, so OTA firmware and software updates still have a role to play.

STRATEGY 2: LOW COST, EASE OF USE

It's clear that bare-bones testing isn't an option for serious product developers, so vendors are responding in various ways to help lower cost and make test easier. "The tools have to be user friendly and turn-key," says Emarievbe. "Many companies doing IoT don't have the resources of an Apple or a Qualcomm." Jessy Cavazos, industry director for test & measurement at Frost & Sullivan, pointed to the influx of newer engineers "that are raised on major consumer devices like the iPhone and tablet." A complete redesign from the ground up is required, says Emarievbe.

As part of its "Shift Left" strategy, which takes a holistic view of the full prototype, design, and manufacturing test chain, Tektronix undertook a redesign that addresses the cost, and ease of use, and time-to-market issues. This included a complete redesign of the user interface. "Our new 5 Series MSO *(Fig. 1)* has a faster and more intuitive touch interface," says Pat Byrne, president of Tektronix. It also has a stacked display mode and its FlexChannels provide 4, 6, or 8 digital channels and up to 64 digital channels, "along with the ability to switch between analog and digital on any given port without missing a beat," says Byrne.

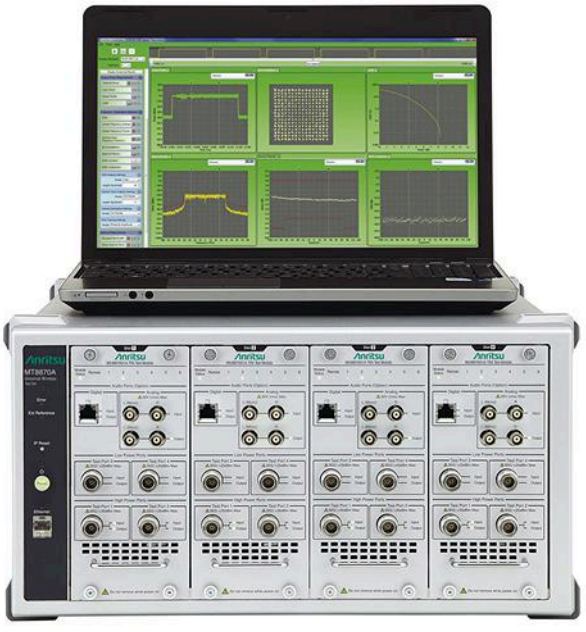
Tektronix's over-arching Shift Left strategy comes about as recognition that the role of test in design verification and simulation needs to be spread more evenly from the end of the development process to earlier phases in the development cycle. "A big part of this Shift Left work is to work toward a model where testing, simulation, compliance, and validation tools work together and yield similar results," says Byrne.

Another dynamic at play that is putting further downward pressure on cost is the disposable nature of the wireless devices being developed, said Adnan Khan, senior business development manager at Anritsu Company. As IoT technology evolves, chips, modules, and sensors are falling in cost. "Subsequently the cost of testing needs to be reduced to match the high-volume but low-cost market," says Khan. "There needs to be different testing at the chipset level, module level, and end host device level."

Given the low cost imperative, "the entire ecosystem, including the T&M market, has become creative in cost and time-to-market (TTM) dimension in the IoT space." One clear path to reducing test cost, says Khan, "is to have reuse of tests across the different hardware and only test the delta on what's needed."

STRATEGY 3: FLEXIBILITY

Given the nature of the two technologies, it seems counterintuitive that they would have similar requirements, but 5G and IoT both need flexible test solutions. From the IoT perspective, Anritsu's Khan pointed to the need to address both short- and long-range technologies. These include



2. Anritsu's MT8870A Universal Wireless Test Set takes a modular approach to support multiple wireless interfaces for high-volume manufacturing test. *(Courtesy of Anritsu)*

(Continued on page L50)

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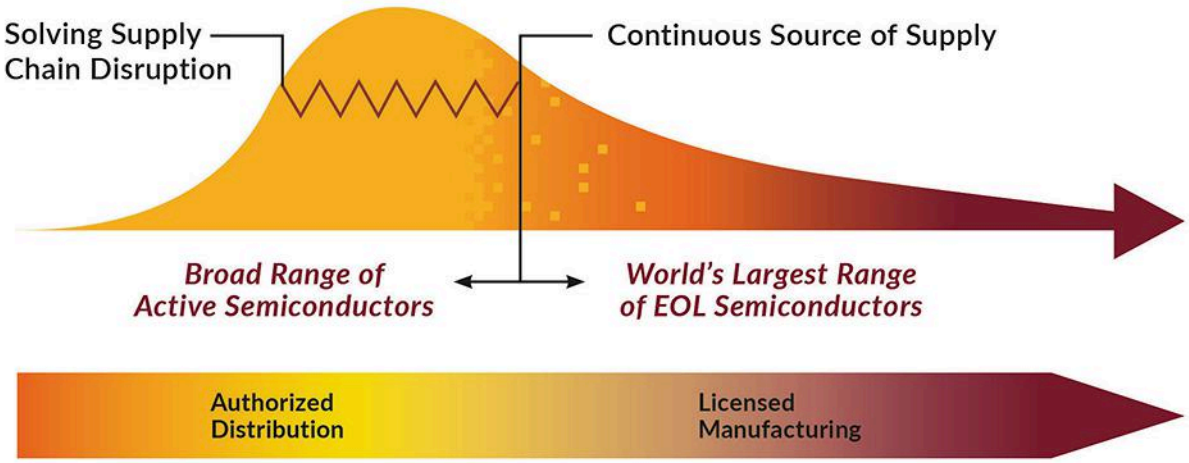

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(Continued from page L47)

Bluetooth and Wi-Fi for short range in the unlicensed bands, and longer-range LTE, NB-IoT, and LTE Cat M1 and M0 in the licensed bands.

"Given the variety of technologies that need to be verified, we need to develop flexible and efficient test solutions that reduce the cost-of-test," he says. Anritsu's solution to this problem is the MT8870A Universal Wireless Test Set, specifically designed for high-volume manufacturing test *(Fig. 2)*.

It has a mainframe form factor with modules that support the major protocols, including LTE Cat M1, LTE, NB-IoT, V2X, and Zigbee/Z-Wave, as well as the latest Wi-Fi and Bluetooth standards.

The modular approach provides the flexibility to add more as designs evolve, making it a good end-of-line test instrument.

To test access-points (APs) and stations (STAs), Anritsu also has the Wireless Connectivity Test Set, the MT8862A. This evaluates the Wi-Fi protocol and measures the Tx/Rx characteristics of WLAN devices (IEEE 802.11 a/b/g/n/ac).

As useful as the MT8862A may be, the rise of MIMO in Wi-Fi and now massive MIMO technologies in 5G, combined with the move to millimeter wave (mmWave) bands at 28 GHz, 39 GHz, and higher, makes coupling over cabling unrealistic. Instead, over-the-air (OTA) testing is required, which in turn requires the use of large, expensive, fully shielded walk-in anechoic chambers to perform controlled tests.

Few companies can afford these, so it often requires that devices under test (DUTs) be physically brought or sent to a lab for a fully battery of tests. However, octoScope has developed another option: the octoBox personal wireless testbed *(Fig. 3)*.

"With the octoBox personal wireless test bed, engineers can run an automated battery of common tests and shorten a typical QA cycle from weeks to days," says Leith Chinitz, octoScope's CTO. The tests include throughput, roaming, association capacity, and adaptation to impairments such as interference, path loss, multipath, and motion. As it's possible for each engineer to have a completely isolated personal testbed at their desk, "different tests can be performed in parallel by multiple engineers and results saved in a common database," says Leigh. The DUT inside the octoBox rotates on a platform to simulate movement and ensure tests and done from every possible angle.

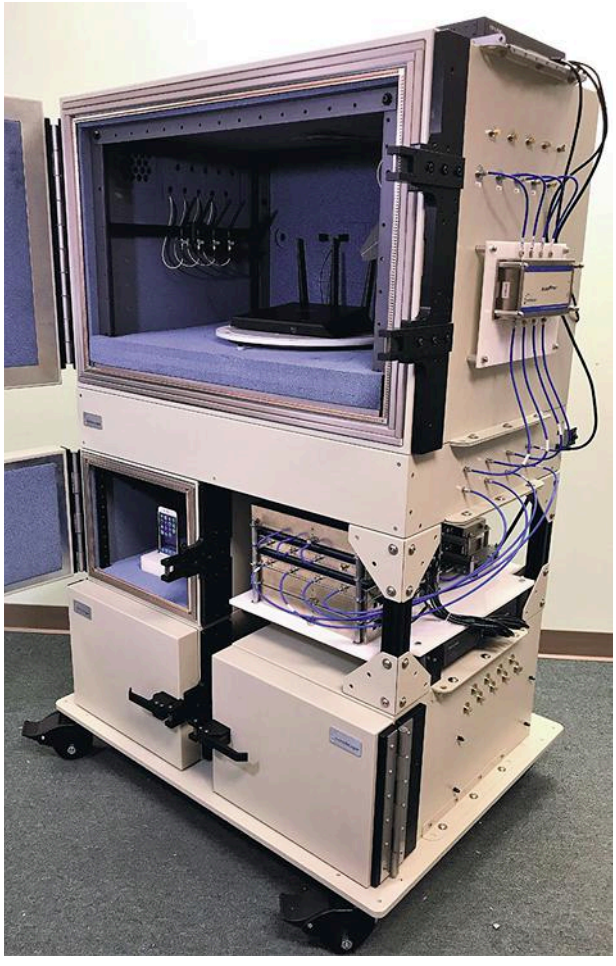
5G FAVORS MODULAR VS. BIG BOX

At the time of this writing, the first of the 5G NR standards are about to be finalized by the 3GPP at a meeting in Lisbon. While it seems to be coming fast, National Instruments has been preparing for longer than anyone, says James Kimery, the company's director of marketing and RF communications, explicitly claiming the title of leader in 5G test.

It's generally accepted that the nascent stage of the standards begs a highly flexible, modular, software-based approach to avoid having to constantly redevelop hardware. However, the devil is in the details. Keysight and NI have taken the open-standard PXI module approach. "While others such as Anritsu and Rohde and Schwarz also have strong credentials, their modular approach is 'proprietary modular,'" says Cavazos. "Keysight has been able to put solutions together very quickly for customers using PXI."

The use of a software-based approach, while useful, can lead to incompatibilities, says David Hall, senior group manager of test systems at NI. "The net result over time," he says, "has been a vast set of disparate software tools that do not interoperate throughout the software workflow of building, deploying, and maintaining a test system." NI has addressed this with its LabVIEW NXG and SystemLink, "which independently tackle engineering challenges from different parts of the engineer's workflow," says Hall.

While the high-frequency and wide-bandwidth testing



3. The octoBox personal wireless testbed allows fully OTA testing and coupling between AP and STA, at any location. *(Courtesy of octoScope)*

required for 5G is not new to test-equipment vendors that have been catering to military and aerospace customers, the low-cost requirements and the rate of change of the standards and the number of frequency bands will continue to keep them under pressure to step up.

DATA CENTER CHALLENGES INCREASING

With data rates now reaching to 400 GbE with PAM 4 signals, and soon PAM 8, Cavazos sees both as a great challenge for test-equipment vendors supplying bit-error-rate testers (BERTs). However, she also sees a great opportunity for designers to increase throughput without increasing band bandwidth. This assumes they can offset channel losses, minimize signal distortion, and keep a high signal-to-noise ratio (SNR).

To help them make accurate measurements under these conditions, Tektronix claims that its DPO700000SX 70-GHz real-time oscilloscope has the lowest noise in the industry. It emulates clock recovery, receiver equalization, and filtering required for an electrical reference receiver and signal analyzer.

Keysight and Anritsu are also in the BERT space and with PAM 8 on the horizon, all will be eager to keep and expand their market position.

HALLMARKS OF A LEADER

For designers on the front lines, there are solutions from startups that can reduce a $200,000 test system down to something that meets their specific requirements for $10. However, as many of those we spoke to are quick to point out, it's important to think it through. Large companies such as NI, Keysight, Anritsu, and Tektronix spend a lot of time in industry standards meetings and know what's coming and are already preparing for it.

Yes, says Emarievbe, look for turnkey solutions. "But do your research to make sure you aren't debugging their [test vendor's] equipment in *your* lab," he adds. Sometimes lower cost brings unwelcome surprises. If the costs prove too much for the task at hand, consider renting or leasing from companies such as Continental Research.

Also, factor in that both good vendors and rental companies have support teams that can help and advise on an appropriate test strategy, and the equipment necessary to get it implemented.

Finally, the upshot of the IoT is that a good test vendor will be incorporating data-gathering and analysis techniques to help accelerate "time to insight." If they aren't doing so, ask when they plan to start. ed

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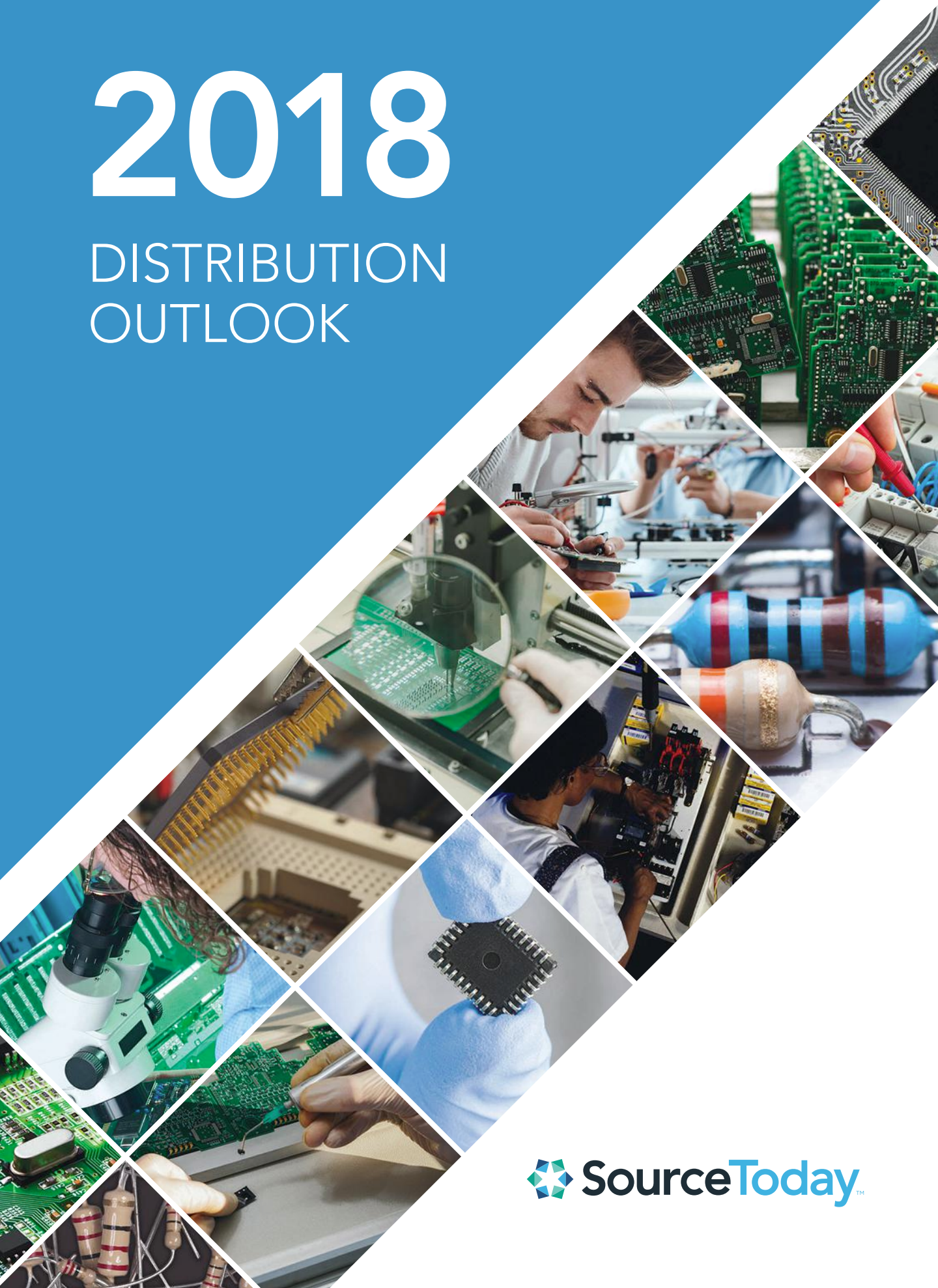

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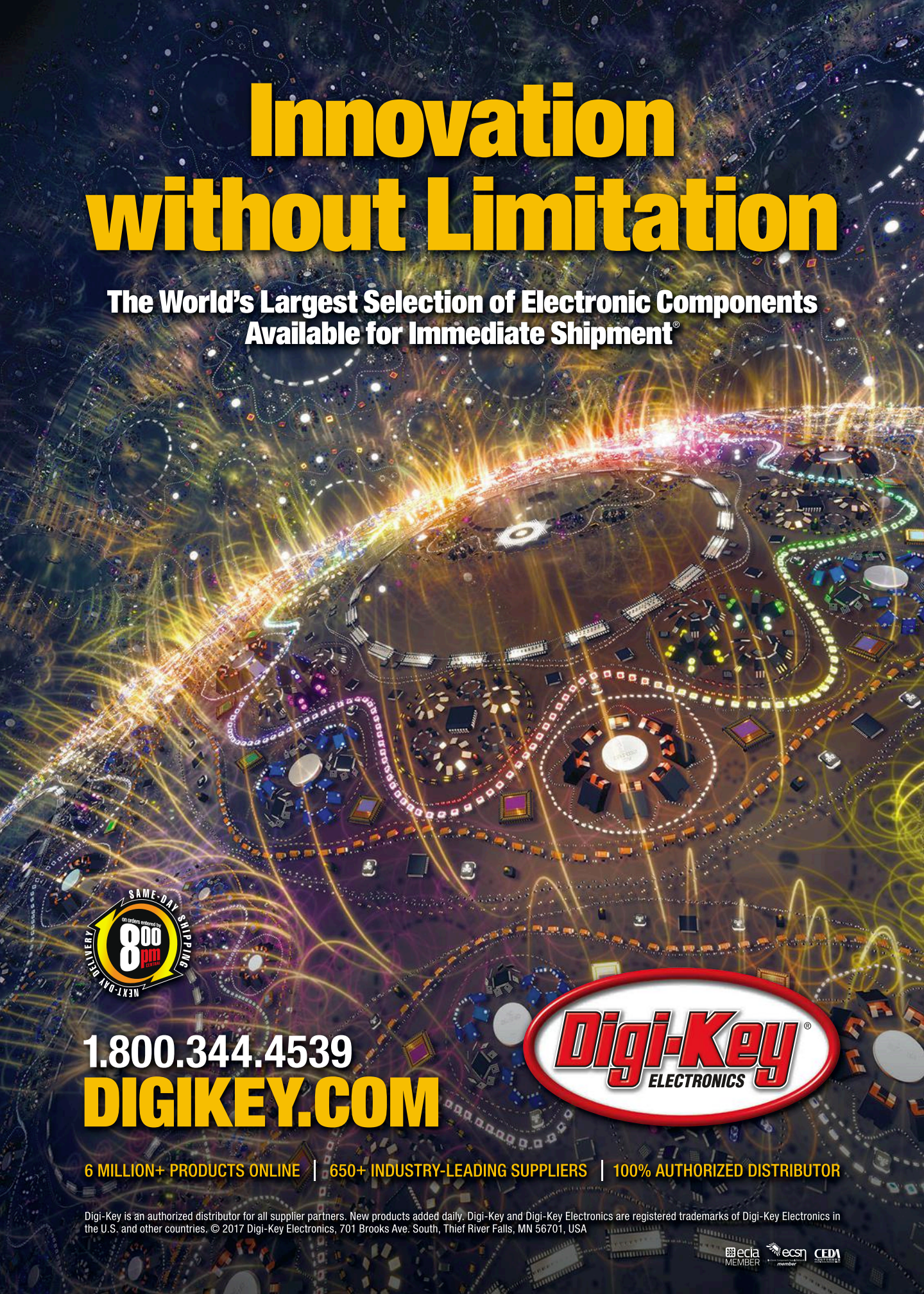
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Leading the Way to a Bright Future

In our annual Leaders coverage, we select key industries and applications and share what companies at the forefront are doing and what that means to the market overall.

We live in a time when technology is changing, improving, and revolutionizing the way we live and work every day. From how our vehicles operate to how we communicate and order parts, the world is quickly advancing. Tasks are becoming automated and intelligent with enhanced security. In our special Leaders issues, we spotlight key strategies, applications, and technologies across four of our core brands and look at the current landscape. We also pinpoint which companies are leading the charge into the future.

In *Electronic Design*, for example, we examine leading applications and technology solutions for wide-bandgap power—specifically, gallium nitride and silicon carbide. We also delve into the security issues around embedded devices, an issue that is becoming more critical as more devices and systems connect to the cloud.

When it comes to manufacturing and automation, the Industrial Internet of Things (IIoT)/Industry 4.0 is increasingly taking hold. As machine learning and artificial intelligence are increasingly leveraged, these networks will be self-learning and eventually largely self-managing. IoT also is discussed in our test and measurement article together with 5G, as we look at how those technologies are changing the test landscape. Similarly, an article on automotive electronics examines which automakers are furthest along on the road to the driverless vehicle and what technologies and developments are fueling their success.

Speaking of the electronics market, our *SourceToday Distribution Outlook* offers insight into why distributors are bullish about next year's outlook. This positive attitude is quite new, as electronics distributors have largely struggled amid generally soft market demand since the recession in 2008-09. Yet they're foreseeing brisk business across most markets, which hopefully will put an end to the slump. *SourceToday Distribution Outlook* also covers trends and features highlights of key interviews regarding expectations for electronics distribution in 2018.

Our *Machine Design* brand also focuses on key applications and technologies that are impacting the design universe now and going forward. A feature on 3D printing, for example, looks at how leaders in this area are looking to boost manufacturing speed. Industrial automation is, of course, a major focus here as well, with data and analytics being used to inform processes and other improvements. Also featured are "smart" motion systems and adhesive improvements, which are benefiting manufacturing. Even the seemingly simple fastener is discussed, as companies profiled have simplified installation using automated/robotic approaches, working with single-piece fasteners, or exploring various materials.

In *Microwaves & RF*, we cover a topic that connects with all of our readership in both their personal and work lives: 5G communications. These much-heralded, next-generation networks still may take different approaches, leaving millimeter wave's role still somewhat to be determined, as just one example. We look at the companies on the forefront of these network rollouts and those that must support them to track their moves and predict who will shape the 5G landscape. The Leaders section also takes a fun turn by exploring solid-state cooking to see who the players are and what its real near-term potential may be.

Stay tuned for more of this type of coverage going forward, as we strive to keep you informed of who is leading the charge of using new technology and solutions and how they are doing it. Happy reading!

JOHN SIMPSON | Contributing Editor

Electronics Distributors Bullish on Outlook for 2018

For the first time in years, electronics distributors are confidently predicting robust sales for the 12 months ahead. Credit brisk business across most market segments in the first three quarters of 2017 for their upbeat outlook.

North American distributor sales figures published in November by the Electronic Components Industry Association (ECIA) document solid growth for the third quarter of calendar year 2017, reaching their highest dollar value since the association began collecting the data in Q1 2015. Sales increased 2% quarter on quarter and 12% compared to a year ago (Fig. 1). Book-to-bill was a strong 1.29, making for four positive book-to-bill quarters out of the last five. Through the first three quarters of 2017, distributor sales are up 9% compared to year-earlier totals.

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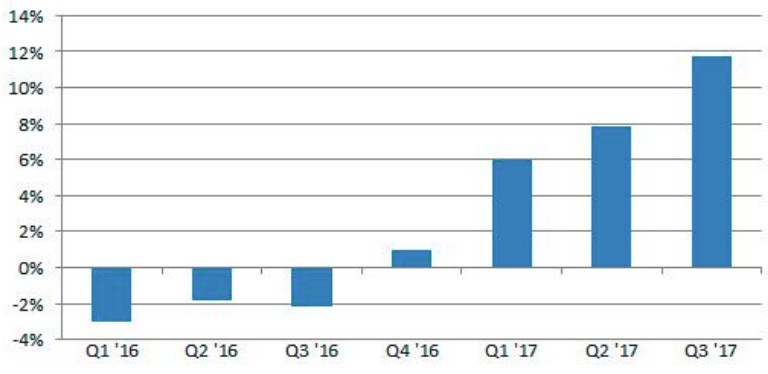
Figure 1. Distributor Sales % Change to Previous Year



Courtesy of ECIA

According to ECIA, sales increased 2% quarter on quarter and 12% compared to a year ago.

NON-TRADITIONAL COMPANIES VIE FOR A PIECE OF THE CATALOG BUSINESS

—A Question for Chris Beeson, Executive Vice President, Sales and Supplier Management, Digi-Key Corporation

What challenges do you see for your company on the horizon?

"I think the ecosystem is getting more demanding. There are a lot of creative people out there, and the barrier to entry to get into this business is so much less than what it used to be. You wake up every day and you have to be curious about, what should my model look like tomorrow? Is my content enough? How do I fit into the ecosystem?

"We have some very good competitors—and there are some non-traditional companies that are now trying to enter into a space that has [traditionally been occupied by] Digi-Key. We hope that's done in a means that is healthy and productive at the customer level. We're now seeing a lot more 'spend $200, get 50-dollar coupons; free shipping.' Many companies are coming in and they think it's best-price-wins. And it's really greater than that.

"For a lot of people who want to enter the space—with a web and digital orientation—it may look relatively easy from the outside. But when you get into it, you see the magnitude of details involved. We jokingly call it a thousand little things done right every day—a thousand is a big number—and it's *not* quite that easy. It's a different business model, a different P&L orientation than what a lot of traditional distributors have. And so that's really a change for them to try to enter the space."

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(Continued from page ST 4)

"The difference this year is that strength has continued all throughout the year," says Faris Aruri, vice president of supplier marketing at Sager Electronics. "The last three or four years, by this time, we were giving up a lot of the gains that we got earlier in the year. Just based on this momentum that we have in September and October, we're going to put up a similar or even higher number for 2018."

It wasn't always this way. Electronics distributors have struggled amid generally soft market demand for much of the period since the 2008-09 recession. Component manufacturers have responded to the conditions with consolidation and capacity cuts to help calibrate supply with demand. Still, in the relatively flat market of the past five years, customers have had the negotiating leverage afforded by relatively abundant component availability and short lead times.

"It's been a buyer's market for so long," says Michael Knight, executive vice president at TTI Inc. "It's a hard mindset to get out of—that parts are plentiful and I'm always going to be able to get a better price."

That situation began to turn around in earnest in the second half of 2016. Surging demand in a number of sectors, including automotive, industrial, and consumer electronics, has since stretched lead times and boosted prices of a number of components, including discrete semiconductors, resistors, and memory chips. ECIA data shows that, by the third week of September, passives and semiconductors both had average lead times of over 11 weeks. Discrete semiconductors and resistors carried lead times of over 16 weeks.

According to Tobey Gonnerman, executive vice president at Fusion Worldwide, in June and July 2017 his firm experienced a 20-fold increase in the number of resistor requests compared to those received over similar periods during the previous year. "This is noteworthy in that there are many players in the resistor space, plenty of manufacturers to regularly manage the risk," he wrote in a blog post. "When manufacturers start calling independent distributors like Fusion for such a readily available commodity, that means there is exceptional—and perhaps unprecedented—demand."

Growing demand, low inventories, long lead times, and higher component prices give hope for distributors that better margins are on the horizon. With shrinking part supplies, and reports of double-ordering, customers now increasingly face the prospect of purchasing certain components on an allocation-only basis. What a difference a year makes.

HIGH DEMAND IN 2018 FORECAST ACROSS MAJOR END MARKETS

Analysts predict continuing strong demand in 2018 in most growth markets for electronic components, including automotive, the Internet of Things (IoT), and consumer electronics. According to market research company IC Insights, demand is rising for electronic systems in new cars, particularly for autonomous vehicles, vehicle-to-vehicle and vehicle-to-infrastructure communications, on-board safety, convenience, and environmental features. IC Insights forecasts that the automotive segment will be the fastest-growing electronic system market through 2021 (Fig. 2), with automotive integrated circuit (IC) sales growing 22% in 2017 and 16% in 2018.

Market intelligence company TrendForce, meanwhile, has reported that in 2018 major automotive chip suppliers will begin shipping solutions that allow vehicles to achieve Level 4 "High Automation" technologies as defined by SAE International. Key applications that automakers will incorporate these components into include radar modules, image sensors,

(Continued on page ST 8)

AUTOMOTIVE, AFTERMARKET ELECTRONICS AMONG THE GROWTH DRIVERS FOR 2018

—A Question for Kevin Hess,
Vice President of Marketing, Mouser Electronics

What is the current outlook for Mouser and what do you see as the biggest growth drivers in 2018?

"Our forecast for 2017 a year ago was to grow, we were thinking, 10%. In fact, we're probably going to grow 21-24% this year. So things are going well. Europe and Asia are still outpacing the Americas; we're growing over 30% in both regions and 14% in the Americas, which is our biggest piece of the pie. Going into 2018, you're hearing a lot of people saying Q1 and Q2 should be strong and then we'll start seeing a flattening out. So what we're anticipating is probably a good first half of the year.

"What will to continue to drive growth, I think, are the automotive industry—all of the electronics that are now going into cars and into aftermarket products through automotive—as well as IoT, connected devices, wearables, etc. And it's not large-production-type stuff; it's smaller—thousands of pieces instead of millions of pieces.

"For Mouser, what's going to drive our business are new products. Just to give an idea: this year, 28% of our sales will be from components we introduced in the last four years. We need to keep adding those new products so that, three to four years down the road, they comprise 30% of our sales. If we stop bringing them out, that's going to negatively affect our future business."

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(Continued from page ST 6)

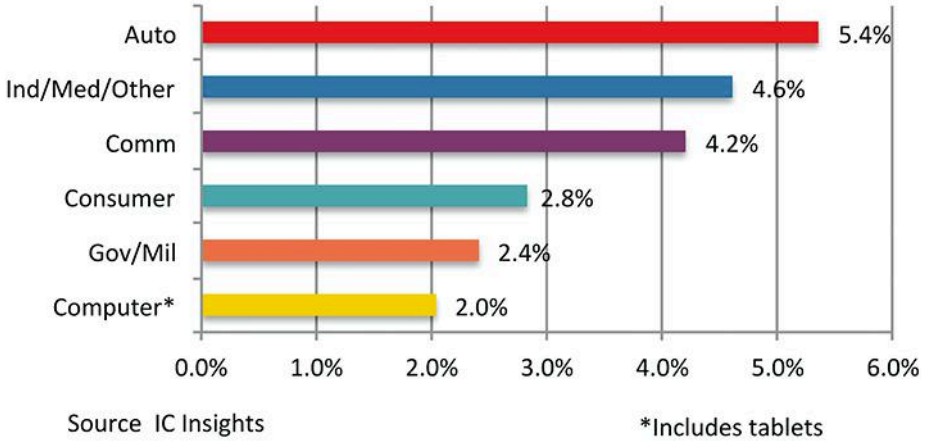
automotive processors, displays, advanced driver assistance systems, and connected-vehicle platforms.

"I think transportation remains a great growth opportunity for our industry," says Karim Yasmine, vice president of sales and marketing for Future Electronics. "It is a business that has been traditionally known as direct-oriented, but they're much more open now. Those tier 2 and tier 3 transportation and automotive companies are all interfacing with distribution looking for design support."

IoT will also get a boost in 2018, TrendForce says, with the commercialization of 5G in the new year in the U.S., China, Japan, and South Korea—as well as the emergence of the next-generation WiFi standard, 802, which will help with the bandwidth burden that more connected devices will bring. TrendForce predicts the global population of 5G subscribers will approach 500 million by the end of 2022; IHS Markit forecasts that the number of connected IoT devices worldwide will grow at a compound annual growth rate of 12%, from 27 billion in 2017 to 125 billion in 2030.

"It seems that at least in 2017 the dynamics of growth across the board are unbroken," says Georg Steinberger, chairman of the European Semiconductor Distribution Market, which like the U.S. Semiconductor Industry Association reported record quarterly sales during the year. "Newer designs in fields like IoT or e-mobility will see higher components content, so the future looks rather positive from a sales and volume perspective." *(Continued on page ST 10)*

Figure 2. Worldwide Electronic System CAGRs ($, 2016-2021F)



IC Insights forecasts that the automotive segment will be the fastest-growing electronic system market through 2021.

THE CHANGING SKILLS REQUIRED OF DISTRIBUTION PROFESSIONALS

—A Question for Karim Yasmine, Vice President, Sales & Marketing, Future Electronics

What kinds of knowledge, skills, and abilities are you looking for in new hires?

"In terms of skill sets, I think you need to aim for a balance. There is no doubt that you want to hire the millennial counterpart to the customer. So that means hiring young, dynamic, hungry people from outside the business who don't have all these ideas of what *can't* work in our industry. But at the same time, we continue to look for seasoned professionals who understand how things work—they're the best people to train these new people.

"So we're not in this 'uni-model' of scouting for only younger people who are going to be the answer to the changes in the industry. Because the reality is that there are still very strong purchasing and engineering communities that are looking for seasoned veterans who have seen many cycles and many situations—and there's good value in those people as well.

"Increasingly, though, I think the desired profile involves someone who is hungry and also has technical knowledge. I think in the past our industry didn't emphasize the technical side as much when it came to sales. Certainly FAEs had to have that [technical aptitude]. Now, what I think we're interested in on the sales side are people who are passionate about technology and are savvy enough to be able to introduce new products and solutions to our customers."

It All Started in 1887 as a Small Boston Storefront Selling Speaking Tubes.

130 years later, Sager Electronics has grown into a leading North American distributor of interconnect, power and electromechanical electronic components. Acquired 5 years ago by TTI, Inc., a Berkshire Hathaway, Inc. company, Sager continues to operate with the same dedication to its core values – integrity, service and adaptability.

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(Continued from page ST 8)

Mobile phone sales, meanwhile, are expected to return to year-over-year growth in 2018, with Gartner Inc. forecasting shipments totaling 1.9 billion units. Smartphones will represent 86% of total mobile phone shipments in 2018, up 6% from 2017, and Gartner expects Apple's iPhone X to be the sales driver in North America, China, and Western Europe despite its high price.

"Given the late November availability of the iPhone X, we expect the iPhone's replacement cycle to flow more strongly into 2018," says Roberta Cozza, research director at Gartner.

GLOBAL RISK INDEXES EASING

"It's interesting to see the diversity of industries that are doing well. We're encouraged from that perspective, and there's no indication that that's slowing down," notes Chris Beeson, executive vice president, supplier management and supply chain at Digi-Key. "A lot of us, going into the year, weren't anticipating this robust of a year," he adds.

Indeed, past performance is not necessarily the best predictor of the future, and a number of unknowns lurk in the political and economic arenas. In the short term, U.S. policymakers will grapple with tax reform, (likely) infrastructure legislation, and the confirmation of a new Federal Reserve chairman, Jerome Powell. Over the longer term, negotiations over NAFTA and Brexit loom as additional factors that could impact electronics component markets.

Assessing the effect of the current political and economic environment on global supply chains, Dun & Bradstreet (D&B) in mid-November reported that its Chartered Institute of Procurement and Supply (CIPS) Risk Index fell (i.e., improved) for the third consecutive quarter. However, the firm notes that despite recent improvement in the risk environment, the Q3 score is only slightly below the index's all-time high, recorded in Q4 2016 (see country-risk heatmap in Fig. 3).

The largest drop in risk was in Western and Central Europe, where a series of stabilizing political outcomes helped to reduce the region's contribution to global risk in Q3, according to D&B. The formation of a government in Macedonia following months of political deadlock and the abandonment of street protests by the opposition Democratic Party in Albania helped to stabilize the region and reduce risk.

In addition, the European Union's free trade agreement (FTA) with Canada came into force in September, eliminating many taxes and duties on goods traded between the EU and Canada. The EU also appeared to make progress in talks with Japan and Indonesia about FTAs in the future, D&B said.

However, political risk around the world could spill over into the economy and impact supply chains, D&B cautioned. This risk stems particularly from the U.S., where the lack of clarity from the Trump administration around trade—and threats to pull out of a major trade deal with South Korea—could impact Asia. Similarly, the renegotiation of the NAFTA trade agreement among the U.S., Mexico, and Canada could affect the stability of the North American region in the coming months, the business credit-reporting firm said.

"The outcomes of various ongoing negotiations, such as Brexit and NAFTA, could change the face of global trade and cause significant disruption to supply chains in the future," notes CIPS Economist John Glen. "This could cause delays, increase costs, or reduce the quality of supplies businesses have access to, so it is now more important than ever for businesses to have robust contingency plans in place."

(Continued on page ST 12)

HOW TECHNOLOGY IS TRANSFORMING THE DISTRIBUTION INDUSTRY

—A Question for Michael Knight, Executive Vice President, TTI Inc.

How is technology impacting electronics distributors—and is there a seismic shift under way?

"It's not a cataclysmic change—it's a gradual change and I don't think it's unique to our industry. Technology is changing the way we all interact in business—and actually making it less personal. That's been an ongoing trend that's been developing for a long time.

"At some point in the not-too-distant future, you're going to see a lot more computers buying from computers. You already have artificial intelligence out there today that can teach itself to play Go—which is infinitely more complicated than chess—and defeat a [human] grandmaster. So a computer buying from another computer seems ridiculously simple in context. And I think there's much more of a business case to spend money developing that than spending it to develop something that wins at Go.

"The primary purpose of the supply chain is to make sure your line doesn't go down—in the face of uncertain demand from your end customer, uncertain supply from component manufacturers, etc. So you want to make sure you have continuity of supply so you can build on time and ship on time. Today there are a lot of people involved in that. People are expense—and there is an ongoing push to take cost out. I think you're going to see more people being taken out of the equation—sales people, planning people, purchasing people."

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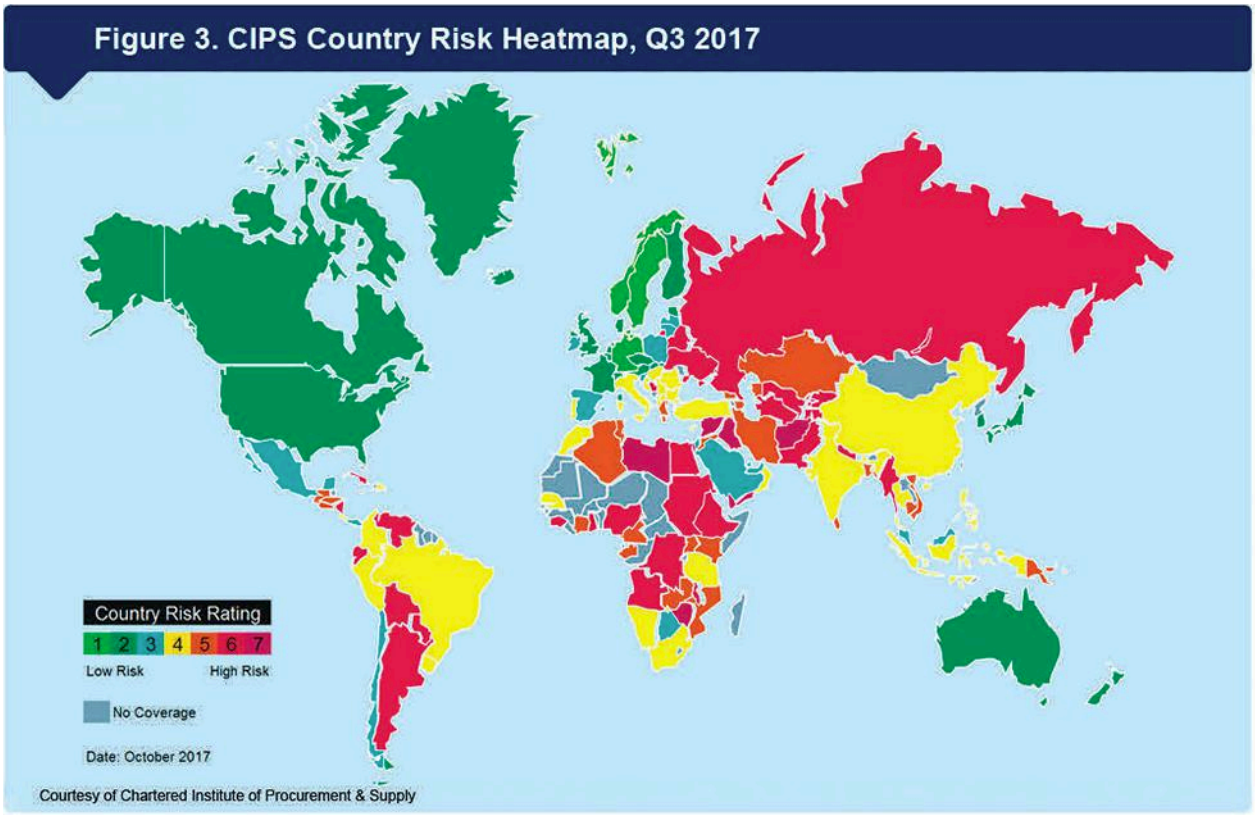

As the map above illustrates, the Q3 score is only slightly below the CIPS Risk Index's all-time high, recorded in Q4 2016.

ECONOMIC FORECASTS, LEADING INDICATORS PREDICT STRENGTH

In its October World Economic Outlook, the International Monetary Fund (IMF) reported that the worldwide upswing in economic activity is strengthening, projecting global growth to rise to 3.6% in 2017 and 3.7% in 2018. "Broad-based upward revisions in the euro area, Japan, emerging Asia, emerging Europe, and Russia more than offset downward revisions for the United States and the United Kingdom," the IMF says. But the recovery is not complete, IMF adds, noting that while the baseline outlook is strengthening, growth remains weak in many countries and inflation is below target levels in most advanced economies.

The Conference Board—which counts among its membership approximately 1,200 public and private corporations and other organizations across 60 countries—largely agreed with IMF in its mid-November outlook. The organization said that global GDP growth, which it predicted would grow at 2.8% a year ago, is likely to reach 3% for 2017 and carry on at that rate through 2018.

"Global growth has finally left the starting gate since the global economic and financial crisis," says Chief Economist Bart van Ark.

The Conference Board said 2017's growth uptick reflects a combination of "unique" events, including the stabilization of energy and commodities prices, improved business confidence based on hopes for fiscal stimulus and tax reforms by the U.S. administration, a cyclical recovery in Europe, and China's policy-driven growth stimulus. "These events are unlikely to provide sustained growth going forward," the Conference Board adds, however.

In the manufacturing sphere, purchasing managers index (PMI) data for October show that companies are operating amid the best global business conditions in six-and-a-half years, says Chris Williamson, chief business economist at IHS Markit. The JPMorgan Manufacturing PMI edged up to 53.5 in October, its highest level since April 2011 (Fig. 4).

While the current upturn remains weaker than the expansion of 2009-11, the broad-based nature of the expansion is "encouraging" in terms of its sustainability, Williamson said. Only three of the 29 countries covered by IHS Markit's manufacturing PMI surveys reported deteriorating business conditions.

(Continued on page ST 14)

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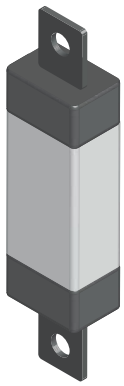

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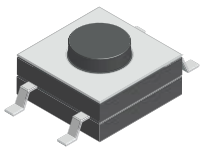

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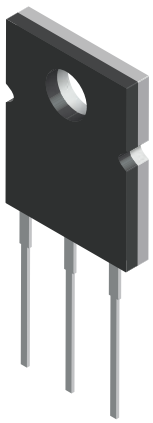

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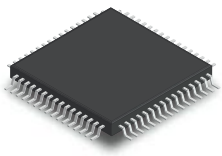

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(Continued from page ST 12)

Figure 4. PMI Is at its Highest Level in Over Six Years

Courtesy of IHS Markit

Purchasing managers index (PMI) data for October shows that companies are operating amid the best global business conditions in six-and-a-half years.

As for U.S. industrial production, the Institute for Supply Management's (ISM's) Production Index registered 61% in October which, although a decrease of 1.2 percentage points from September, nonetheless indicates the 14th consecutive month of growth. "Production expansion continues at a strong pace in spite of supply chain difficulties, including the reduction of inventory levels seen during the period," Timothy Fiore, chair of ISM's Manufacturing Business Survey Committee, says, alluding to Hurricanes Harvey and Irma.

"We're in what I think of as a period of sustainable growth," adds Dan Stewart, vice president of marketing at Allied Electronics. "Industrial production (IP) has been ticking along at 2-3-4% growth—that's a pretty sustainable rate. If IP were at 5-6-7%, that's not sustainable."

CONNECTED DEVICES, CORD-CUTTING COULD DRIVE FUTURE GROWTH

TTI's Michael Knight said that the emergence of new connected products that are now under development could help distributors power through a mild recession if one were to occur at some point beyond 2018.

"Everybody who makes anything electronic is trying to figure out how to connect to the cloud, how to collect data off it, and how to use the data," Knight says. "All that connected stuff is going to replace all of the currently unconnected stuff."

Moreover, new battery technology will allow customers to "cut the cord," creating incentive for them to replace corded products with cordless versions, he adds.

"They're going to be faster, smarter, smaller, and more energy efficient," Knight says. "It's going to take a long time to flush all the old things out and replace them with new ones—but it's going to happen." ■

MEETING CUSTOMERS' NEED FOR A SEAMLESS DIGITAL EXPERIENCE

—A Question for Dan Stewart,
Vice President of Marketing, Allied Electronics

How are customers' interactions with distributors changing with respect to how they research part availability, prices, etc.?

"If you talk to the engineer—regardless of whether they are board level, automation control, etc.—what he or she wants is access to good information, the ability to find parts easily, and a seamless experience with the distributors that they work with. And really what that boils down to is their digital experience.

"It's gone from the perspective of having a salesperson who can help you out with whatever you need to 'I want to be able to do things for myself.' So what we've got to figure out is how to create a simple but effective online experience, particularly for our engineers. That sounds relatively easy. But when you put it into practice and look at things like being able to receive back-order information from our suppliers all the way through to us and to our customers, it's a really demanding thing to achieve.

"So we've invested quite a lot into our search capabilities to allow us to use algorithms to much better connect our engineers with the parts that they're looking for based on that computer-generated intelligence. It's really about how we seamlessly communicate with our customers in a very integral fashion, which I think is just as big of a challenge for us as it is for everyone else."

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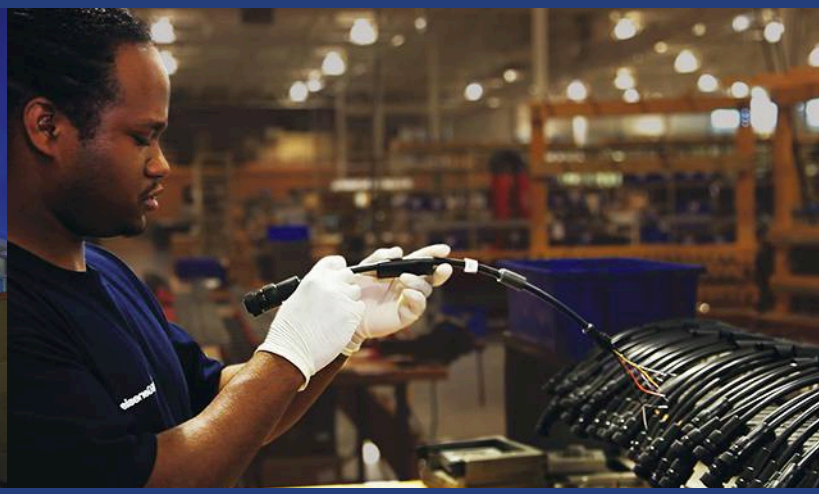

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NANCY FRIEDRICH | Director of Editorial Content

Behind the Scenes: Electronic Distributors

Through a survey of our audience, we learned what they are buying, what concerns them most about their business or the world at large, and what their current goals are.

It's no secret that electronics distributors have been suffering more downs or flat periods than ups for roughly the past decade. While the electronics distribution market looks like it will be stabilizing and even more profitable in the near future, the rapid pace of technology changes and the global economy are certainly going to impact the business. To gauge how our electronics-distribution audience feels and thinks about various points, we did a survey earlier this year covering a number of topics. There were almost 900 respondents, the bulk of whom identified themselves as working in engineering while about a sixth labeled themselves as procurement professionals. Roughly 100 executive managers weighed in with their opinions as well. They answered questions covering everything from cost concerns to regulations, compliance, and worrying trends to plans for technology investment.

To provide some background about who those respondents are, we asked them to identify what they or their company buys through distribution. Allowing multiple categories to be chosen, we learned that the majority purchase semiconductors and connectors and interconnects, at 85% each, while 82% selected passive components. Electromechanical devices totaled 76% while development boards totaled 60%. So what did they tell us?

COST CONCERNS CONTINUE TO REIGN

Given the rise of automation via sensors, networking, and the resulting Internet of Things (IoT), many respondents noted that their customers are looking to integrate technology solutions. They also are exploring new supplier relationships with the goal of lowering cost. In fact, of a 100% mean total, 32% said that removing costs from the supply chain was their uppermost goal for 2017. That priority came in even above the integration of new technologies, which 21% said was most critical. Right below that, 20% chose "explore procurement relationships with new suppliers and distributors and/or 'maker' companies" as their top goal. The last priorities were "increase transparency and collaboration with supply-chain partners" (15%) and "expand into new geographies" (12%).

DIGITAL ROADMAP

Obviously, technology innovations have greatly impacted the distribution business in recent years. As a result, we wanted to ask our respondents to estimate the general level of digital maturity achieved by a number of specific nodes in the company's supply chain: distributors; component and equipment suppliers; their own company; OEMs in their industry; contract manufacturers/EMS providers; and logistics providers. We defined digital maturity as "the extent to which companies and organizations have successfully and seamlessly integrated the information flow across their supply-chain nodes via investments in digital technologies." The response choices were kept simple: just starting, on the path, or more mature. For each node, close to 50% were marked as "on the path."

Specifically, component and equipment suppliers came in at the top with 52% being labeled *(Continued on page ST 18)*

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(Continued from page ST 16)

as on the path and 24% each identified as "more mature" and "just starting." Distributors came next with 51% being labeled as on the path and 25% identified as more mature, leaving only 24% at "just starting." Interestingly, respondents saw their own companies as lagging behind progress, with 44% on the path and 34% just starting. The remaining three nodes—OEMs in their industry, contract manufacturers/EMS providers, and logistics providers—all were estimated to be 45% to 46% on the path. We next asked about the adoption of digital technology. When it came to the pervasive use of smarter analytics and technologies including cloud computing, artificial intelligence, and advanced data analytics, 11% confirmed adoption of at least some of those technologies. Adoption was being planned by 16% and considered by 32% of respondents. Surprisingly, 41% cited no plans to adopt.

We next asked about the ability to sense real-time demand at a granular product category level and ability to communicate changes electronically with both distributors and supply-chain partners. While 13% had already adopted this technology, another 16% were planning on doing so. Those considering adoption totaled 32% while quite a large number—39%—declared that they had no plans to adopt such technology.

Our final category in this section was agile, demand-driven supply chains that can quickly pivot to meet changing needs. Here, 17% had adopted solutions while 16% were planning to do so. Those considering adoption numbered 34%. An almost equal percentage—33%—had no plans to adopt. When we zeroed in on specific landscape-changing technologies like 3D printing and cloud implementations, however, we found quite a lot of interest in their adoption and implementation. To improve procurement and supply-chain operations and processes, the respondent's employers had already invested as follows: 30% in 3D printing, 25% in cloud-based services, 19% in both data analytics and IoT technologies, 12% in artificial intelligence/predictive analytics, and 4% in blockchain.

Overall, "plans to invest" revealed the following: 15% for 3D printing, 13% for cloud-based services and data analytics, 11% for IoT technologies, 13% for artificial intelligence/predictive analytics, and 6% for blockchain. We found that the executive-management respondents were more impressed with cloud and AI/predictive analytics and more apt to invest accordingly.

Although all of these areas are dynamic, we are quite interested in blockchain as a new form of currency and watching the role it will have in distribution and beyond. Possibly because it is still very new and many hadn't heard of it, however, it ranked lowest when we asked what impact it would have on business—a 41% total for responses of major and modest combined. 3D printing, in contrast, totaled 68% and cloud-based services got 67%, predicting their impact. IoT technologies was next at 61% citing major and moderate impact while data analytics (59%) and artificial intelligence/predictive analytics (57%) followed.

THE INTERNET OF THINGS

In the survey, we defined IoT as: interconnecting various sensors and computing devices embedded in consumer or industrial objects via the Internet, enabling them to send and receive data. The precise question we posed was: "Is your company developing any IoT applications, subsystems, or solutions?" While 43% of our total respondents answered "yes," 37% said "no" and 19% were unsure.

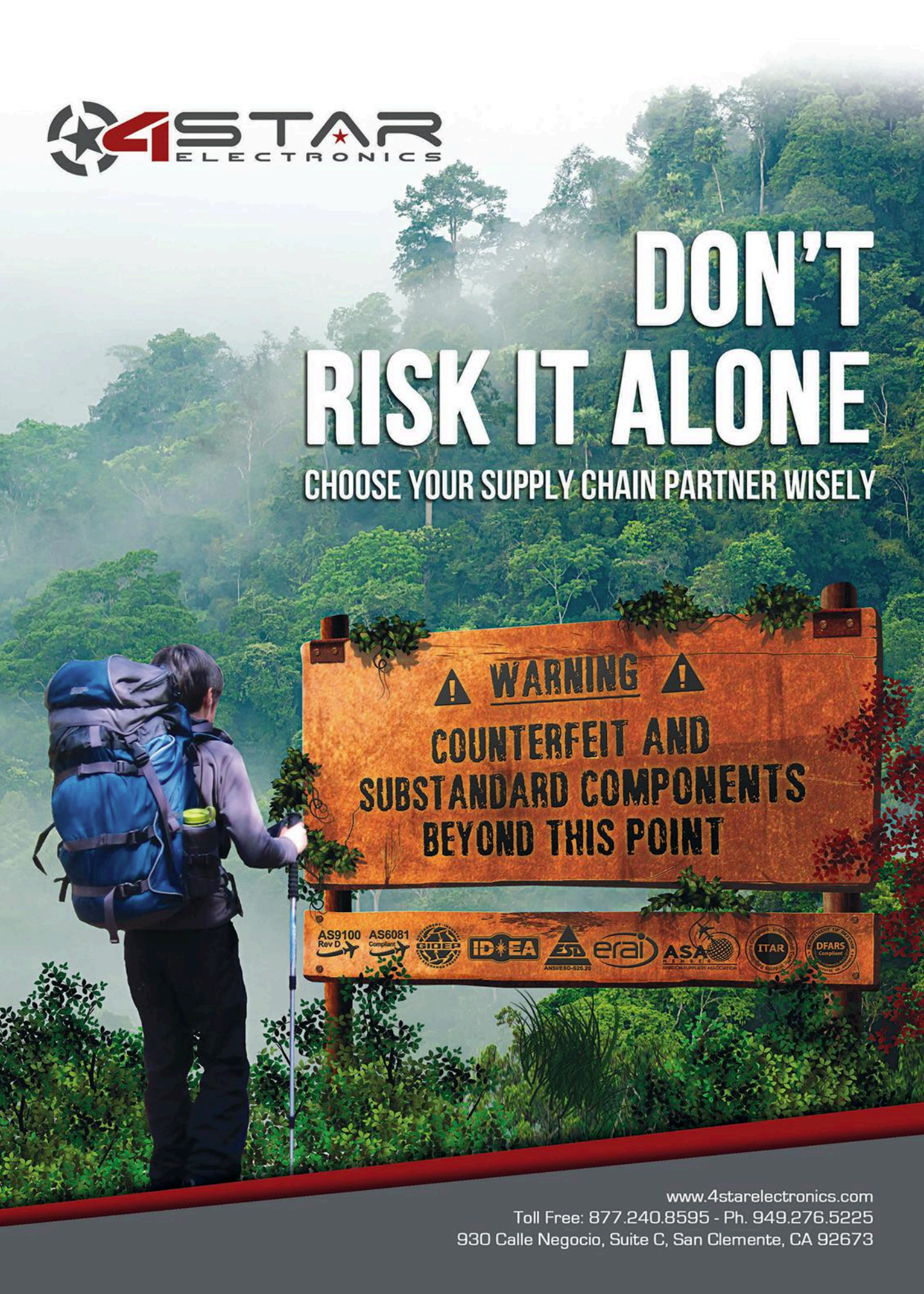
For those who answered "yes," we next asked which end-application markets their company targets for its IoT applications, subsystems, or solutions. They reported the following: 53% industrial, 33% infrastructure and smart buildings, 29% automobiles and transportation, 26% security, and 21% smart buildings. For those at companies developing IoT apps/solutions, we asked which components or enabling technologies they were interested in obtaining from their distributors. They responded that they were most interested in development boards (43%) followed by kitting (37%), custom reference designs (29%), and systems integration (28%).

KNOW THE RISKS

Finally, we asked our survey respondents to rank various issues in terms of their importance as risks for their supply-chain and procurement operations. Unsurprisingly, the three marked highest were component counterfeiting, regulatory compliance, and data security. At the top slot, 42% of respondents said they were very interested in issues surrounding counterfeit parts while 30% were somewhat interested. The audience marked high interest in both environmental (ROHS3, REACH, etc.) and import/export compliance by 30% and 29%, respectively. Those who are very interested in the issue of conflict minerals totaled 17% while 27% were somewhat interested.

For EOL/part-obsolescence management, 29% were very interested with 39% somewhat interested. The last two issues we asked about were "M&A activity threatening supply options and sourcing" and "China's investment in semiconductor design and production." Although those are very timely, "hot" issues, the survey respondents didn't seem to feel they were going to have a lot of impact on their companies day to day this year. Only 11% were very interested in either issue, with 31% or 32% being somewhat interested.

The survey shows that the electronics-distribution business continues to be increasingly dynamic. While business is growing stronger and projections are good, it's key that electronics distributors adopt the technology, automation, and intelligence that their customers will not just expect, but eventually require. Smart cloud-based systems and the IoT are quickly taking the place of old-fashioned customer service—a trend that shows no signs of slowing down.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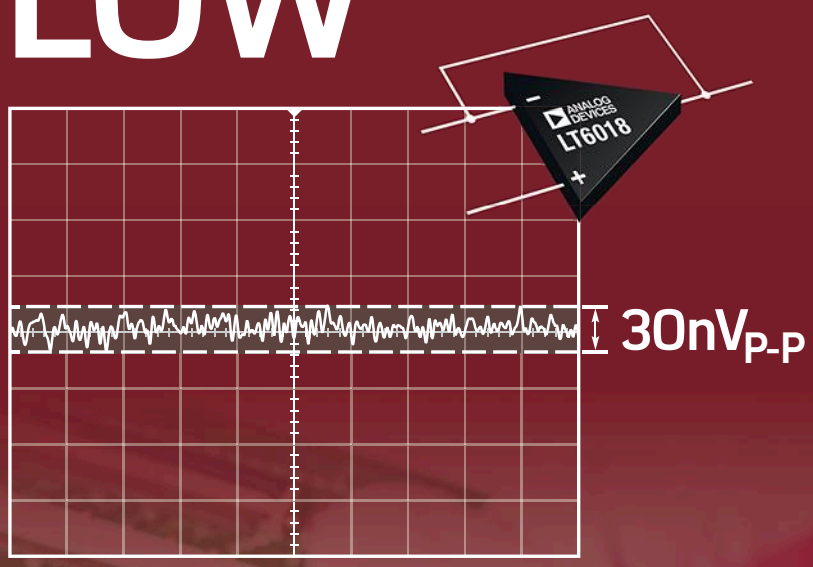

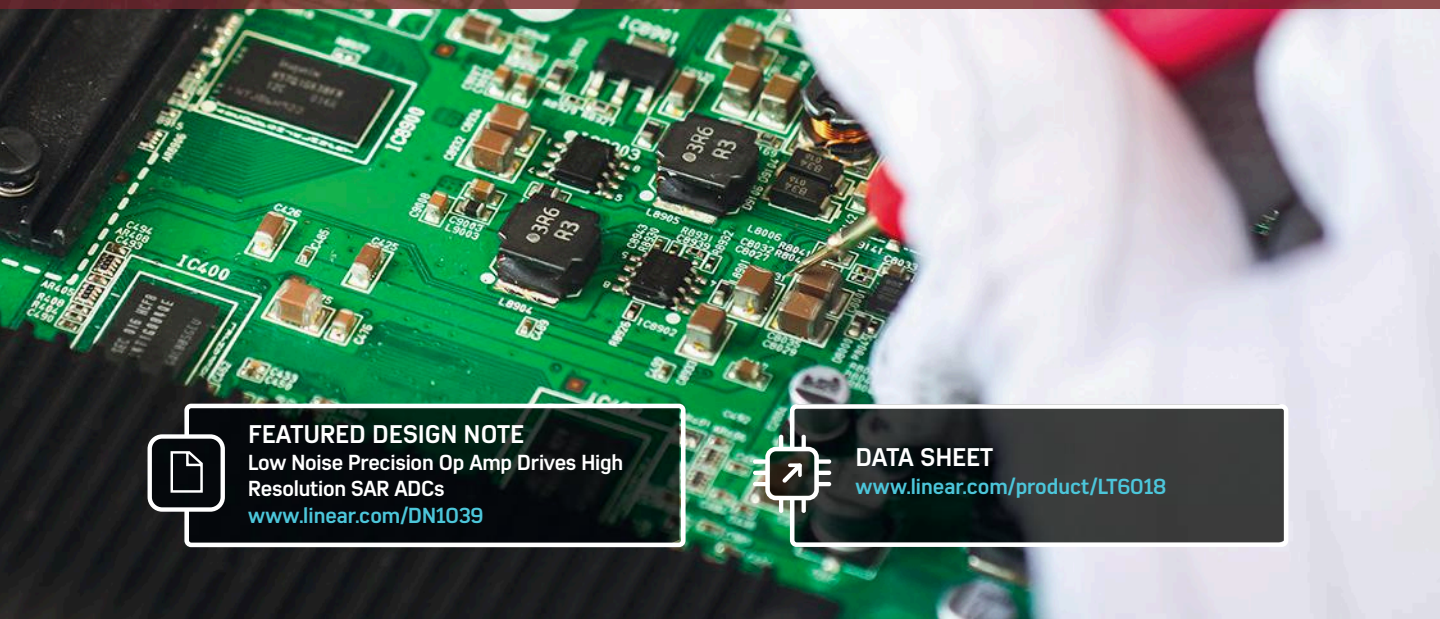

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