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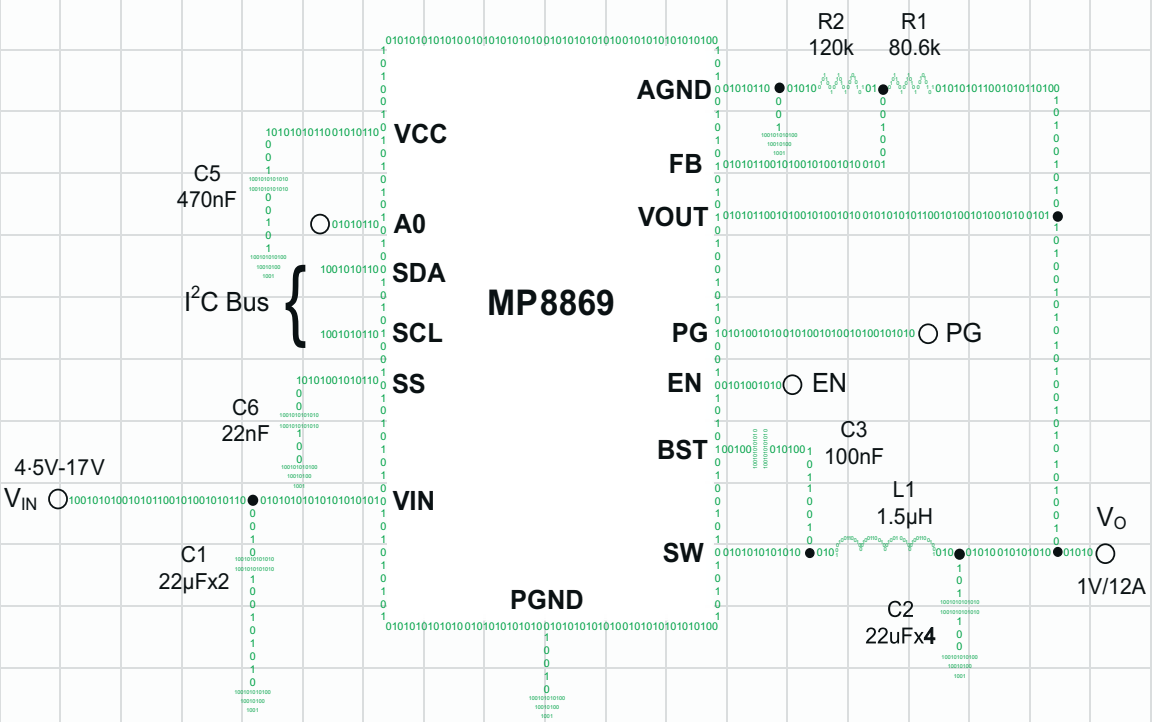

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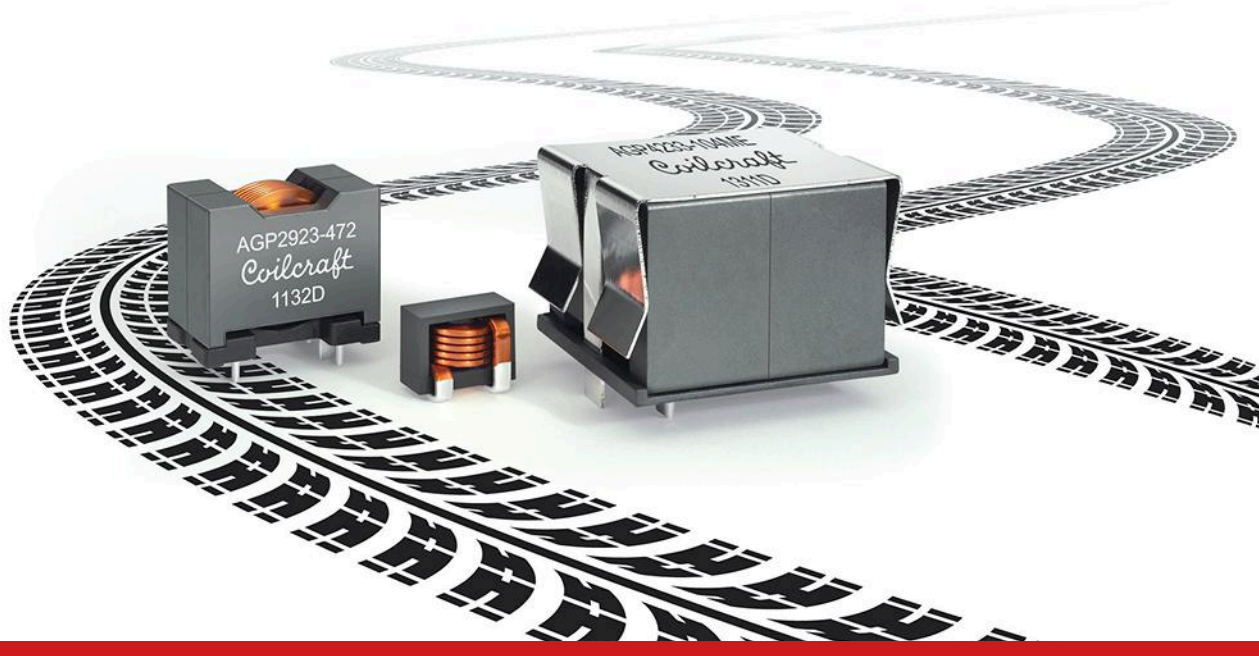

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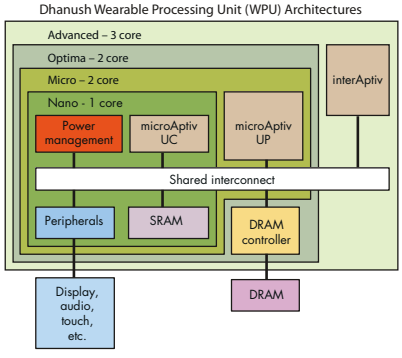

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10 REASONS TO LEASE, NOT BUY, TESTING EQUIPMENT

http://electronicdesign.com/blog/10-reasons-lease-versus-buying-test-equipment

With design cycles being cut in half and designs requiring faster test equipment with higher operating frequencies and greater bandwidths, savvy designers and engineering managers should be giving leasing (versus buying) a second look, for many reasons, but we narrowed them down to 10.

CELEBRATING BOB PEASE

It's hard to believe it has been five years since the analog industry lost one of its most highly respected gurus, Bob Pease. To celebrate Bob's memory, *Electronic Design* is releasing two eBooks in 2016 featuring a collection of reader favorites. These articles are timeless and showcase why Bob Pease will always hold a revered place in the analog industry. Visit www.electronicdesign.com to download Volume 1 of "Bob Pease on Analog."

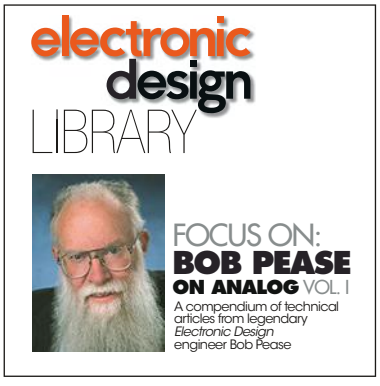

IMAGE GALLERY: HOVERBOARDS CONTINUE TO FLY

http://electronicdesign.com/embedded/hovering-over-ces-2016

Despite concerns over instances of exploding hoverboards (*see page 9 of this issue*), it's the demand for them that's really exploding. Take a look at Tech Editor Bill Wong's gallery of hoverboard images from this year's CES to see the latest looks and innovations in this booming market.

Q&A WITH TEKTRONIX CEO PAT BYRNE

http://electronicdesign.com/blog/qa-tektronix-ceo-pat-byrne-new-application-focus

As Tektronix undergoes a bit of rebranding, we talked with CEO Pat Byrne, who reiterated his company's commitment to "the kind of precision and accuracy that makes test and measurement the foundation for high-quality system design." For more highlights and an audio file of the entire interview, see Patrick Mannion's online exclusive.

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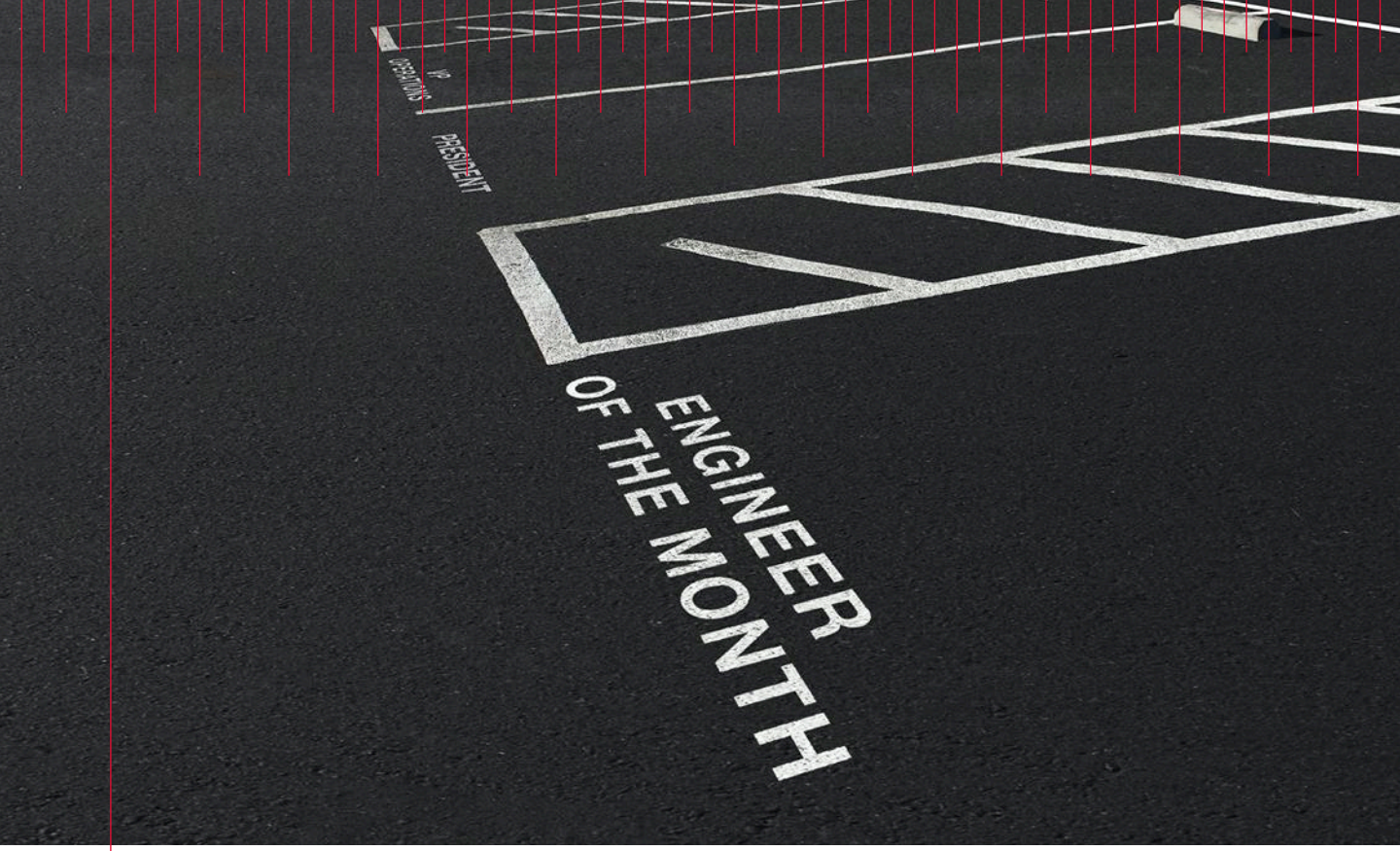

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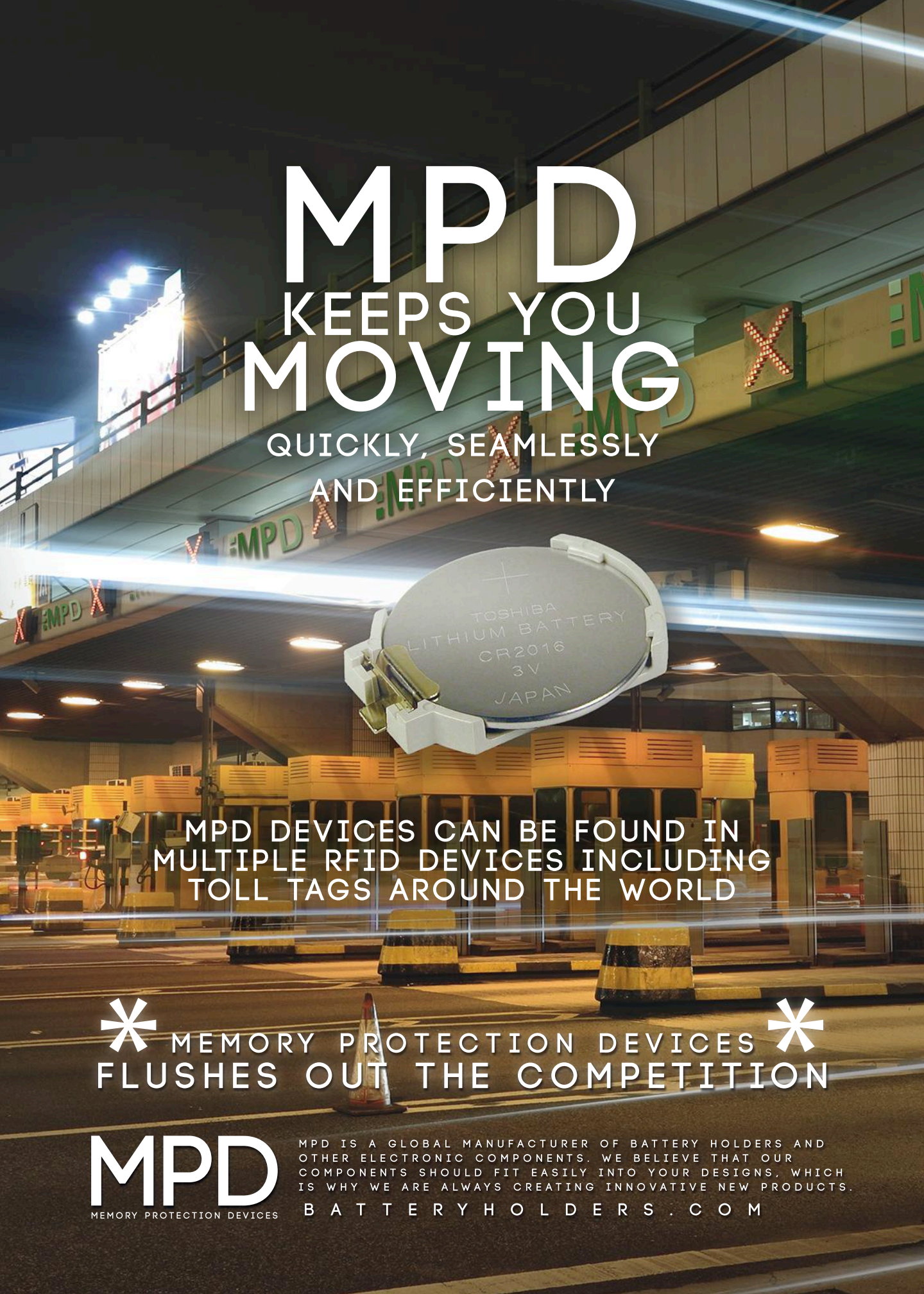
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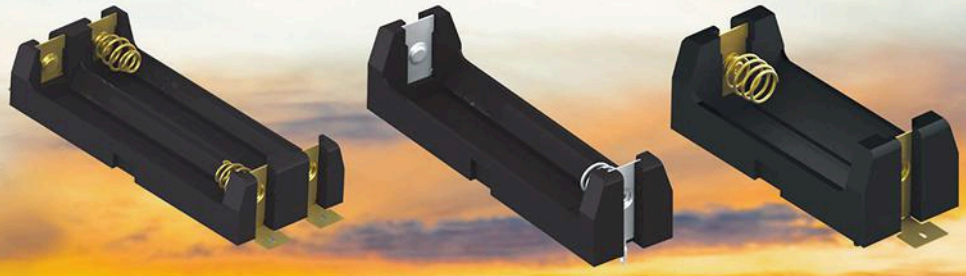

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What's Making Hoverboards Catch Fire?

Serious issues surround the countless videos of hoverboard fires posted on social media and shown on the news. Delving into the technical side of this fire-hazard situation, I found out the following:

The Consumer Product Safety Commission (CPSC) recently released a statement saying that it is working non-stop to find the root cause of hoverboards becoming a fire hazard. In the meantime, Northbrook, Ill.-based Underwriters Laboratories (UL) announced that currently there is no UL certification for hoverboards themselves.

It is very likely that the cause of fire is related to the battery packs inside the hoverboards—even though the fires have started in all sorts of different circumstances (e.g., during charging or while riding). Hoverboards use lithium-ion battery packs; there are usually around 20 rechargeable cells per pack. An individual cell looks very similar to an AA nickel-metal hydride (Ni-MH) battery.

Fires caused by lithium-ion batteries in laptops, phones, and even airplanes have occurred in the past. Now, such incidents have put hoverboards under the public microscope. Recently, some U.S. airlines banned hoverboards on passenger flights.

Inside a lithium-ion battery, there is a thin sheet of micro-perforated plastic (a separator) that keeps the anode and cathode apart while allowing lithium ions to pass through. The battery is charged by sending ions from the cathode to the anode. The battery is discharged when ions are transferred back from the anode to the cathode.

Until recently, the use of lithium-ion batteries had become more popular among small power tools or IT devices, such as laptops, cordless drills, electric screwdrivers, and e-bikes. Although lithium-ion batteries have great advantages, lithium does heat up and expand during charging. This causes leaked lithium ions to build up on a battery's surface, which might originate short-circuits and decrease overall battery life. Also, when a lithium-ion battery is overheated or damaged, it can burst into flames or even explode.

Researchers are trying to find the solutions to lithium's disadvantages. For example, a team of researchers at Stanford University just developed a lithium-ion battery that does not overheat through the use of nanotechnology.

Because the single most expensive component in a hoverboard is the lithium-ion battery pack, some hoverboard manufacturers are unfortunately using non-brand batteries to minimize costs. Many of these batteries clearly do not provide the same high quality and safety standard as, for example, those manufactured by Samsung SDI Co. Ltd. (one of the largest providers of lithium-ion batteries).

It is suspected that most of the hoverboards produced in China might not use original Samsung or LG batteries, with non-brand or counterfeit Samsung trademark batteries being used in their place. Plenty of those batteries are finding their way into the country inside hoverboards. Obviously, not all of the off-brand batteries are catching fire, with thousands of batteries produced per year. But the problem has become widespread enough to where the CPCS has sufficient cause to pursue an investigation. This effort could even lead to a battery or hoverboard recall.

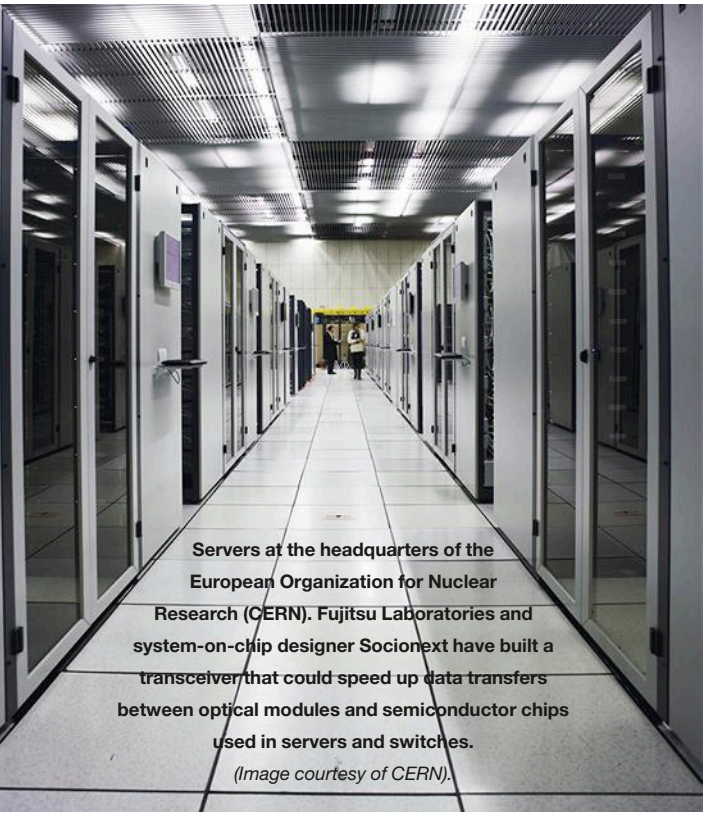
Unfortunately, to date there is no specific resource online where consumers can check the safety of their hoverboards. Meanwhile, the popularity of hoverboards continues to grow (*see "Hovering Over CES 2016" at electronicdesign.com*). If you are planning to purchase one and/or keep one at home, do yourself a favor: Keep a fire extinguisher nearby, and never charge it while unattended. ed

News

NEW TRANSCEIVER
Speeds Data Transfers for the Cloud

Over the last year, computer companies have been diving deeper into cloud computing, with Hewlett Packard making the controversial decision to spin out its information technology business, and Dell buying data storage company EMC last year. The widespread use of cloud computing is not only making for more competition, but also leading to new advances in servers that process data from the cloud.

Now, researchers have built a transceiver that could speed up data transfers between optical modules and semiconductor chips used in servers and switches. Built by Fujitsu Laboratories and system-on-chip designer Socionext, the transceiver can transmit data at 56 Gbits/s per channel—twice the speed of current transceiver standards.



Servers at the headquarters of the European Organization for Nuclear Research (CERN). Fujitsu Laboratories and system-on-chip designer Socionext have built a transceiver that could speed up data transfers between optical modules and semiconductor chips used in servers and switches.
(Image courtesy of CERN).

At the same time, the researchers were able to make the transceiver faster without adding powerful new circuits. They instead combined several existing circuits in order to reduce the total power the transceiver uses. The new design only requires eight circuits, as opposed to the 16 used by current transceivers (which transfer data at 28 Gbits/s). According to the researchers, this means the new transceiver can transmit data twice as fast without consuming any additional power.

The research could represent a major step toward reducing the amount of electricity used in data centers, which are notorious for swallowing huge amounts of power. There are limits to the amount of electricity that can be supplied to these data centers, owing to the cost of supplying power to the servers and the significant amount of heat radiating from them.

The researchers eliminated half the circuits using a new method for detecting time errors between circuits. The research team found that they could remove parts of the clock and data recovery (CDR) circuit, which reads electrical signals and adjusts the timing of other circuits to ensure that they can read incoming data accurately.

The CDR is normally paired with a so-called decision feedback equalizer (DFE), a circuit designed to boost weakened signals to ensure that they can be reliably transmitted between servers. The signals going in and out of the transceiver are more subject to degradation as communications speeds increase. The research focused on the CDR and DFE because they consume about two-thirds of the transceiver's total power.

In conventional transceivers, the DFE boosts the weakened signal depending on whether other circuits have determined that the signal represents 1 or 0. Because they operate on different clocks, the CDR will adjust the DFE's timing to ensure it captures the signal's waveform at the greatest amplitude, or when it's clearest.

The breakthrough came when the research team found that they could determine whether the DFE's timing was early or late without using the CDR. The researchers developed a new timing detection method that only detects the timing when three consecutive bits of the incoming signal are 100 or 011. With this new approach, the team could remove the CDR and other cir-

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cuits, such as the internal clock, combining them with the DFE.

The researchers said that the new technology is compatible with an upcoming 56 Gbits/s standard from the Optical Internetworking Forum, an organization that promotes computer networking technologies. Fujitsu Laboratories and Socionext plan to use the technology in components linking optical modules and chips. New products using the technology are expected in 2018. ■

CUSTOM SENSORS FUSE
Wearables with the Human Body

FROM THE TANGLED remains of Google Glass, to the smart watches developed by Apple and Samsung, and the portable health trackers built by Fitbit and Nike—most wearable devices have been designed as miniature versions of existing technology. But the next generation of wearables is expected to include sensors and other components that are uniquely designed to be woven into clothing, pasted onto the skin like a temporary tattoo, or wrapped around body parts like a bandage.

New research from IDTechEx, a technology research firm, predicts that the number of sensors custom-made for wearables will increase sharply over the next decade. In 2026, these parts will represent about 42% of all sensors used in wearable devices, up from 7% in 2015. According to the firm's previous research, manufacturers are expected to buy over 3 billion sensors during the next 10 years. But nearly a third of these sensors have not been developed yet.

The changing nature of wearable devices is most evident in healthcare, where advanced sensors are giving rise to new forms of medical treatment and health monitoring. At the end of last month, for instance, engineers from the University of California, Berkeley reported a new kind of wearable sensor that can measure sodium, potassium, glucose, and lactate levels in a person's sweat. The new sensor could help people monitor medical conditions or alert them when they are dehydrated.

Other companies are working toward sensors that are so thin and pliable that they behave almost like a second skin. Last month, the wearable technology company MC10 released a skin patch developed with L'Oreal to indicate how badly skin is being damaged by sunlight. It contains dyes that change color when exposed to ultraviolent light.

Around the same time, MC10 revealed another skin patch that contains a gyroscope, inertial sensors, and flexible integrated circuits that track the electrical activity of a person's muscles and heart. The patch measures only a tenth of

(Image courtesy of Sungsil Hwang, Flickr)

electroactive polymers, textile electrodes, washable inks, and printed piezoelectric sensors can be paired with circuit boards, batteries, and memory chips to create entire systems within clothing.

In the United States, the Flexible Hybrid Electronics Manufacturing Innovation Institute (FHEMII) is focused on reducing the time it will take for printed and flexible sensors to be used in military, industrial, and consumer devices. Toward the end of August 2015, the Department of Defense and several private companies invested about $171 million in the institute. ■

an inch thick and weighs around 0.2 ounces. The company expects it to be confined to medical research.

John Rogers, a material scientist based out the University of Illinois at Urbana-Champaign, founded MC10 several years ago as a commercial outlet for his research into flexible electronics. Instead of using uncommon materials like graphene, he builds sensors out of extremely thin sheets of pliable silicon. Among his research prototypes are sensors that can be wrapped around the human heart, medical sensors that can stretch and contract like human skin, and a dissolvable pressure sensor that can be implanted in the skull to measure brain trauma.

"The goal is really to blur the distinction between man-made electronic systems and biology," Rogers said in a lecture in 2013. He said that his goal was to design electronics that have the same properties as human skin, making it so that they appear to "melt" into our bodies.

But the healthcare industry is still grappling with regulatory and liability concerns that have prevented these sensors from being used in medical treatments. James Heyward, a technology analyst with IDTechEx, says that manufacturers, doctors, insurance companies, and patients have not yet agreed upon a clear system of liability for wearable sensor data. Heyward says that until then, this would remain a "significant barrier" to widespread use of new medical sensors.

According to Heyward, flexible sensors have the potential not only to add new capabilities to existing devices, but also create entirely new markets. The textile and electronics markets, for instance, have already begun to merge around electronic fabrics, or e-textiles. Heyward says that

Technology Report

WILLIAM WONG | Technical Editor

Reduce MCU Power in IoT Apps with These Techniques

Designers can choose from a number of options when trying to meet the Internet of Things' low-power demands for wireless mobile devices.

Microcontrollers are the bedrock of the Internet of Things (IoT) movement. They interface with the plethora of sensors that provide information to the cloud and other IoT devices via wired and wireless links. Though they may be small and use little power, a significant amount of power is consumed when taken collectively. They're often battery-powered or even scrounge power from other sources, such as solar power. Thus, it becomes paramount to minimize power utilization in order to reduce the overall load and increase operational time for battery-operated IoT devices.

There are a variety of ways to reduce power requirements for IoT devices, from architectural solutions to system transistor design to software methodologies. All can play a part, although determining the proper combination for a particular application can be a daunting task for a developer, especially when cost, functionality, security, and other factors come into play.

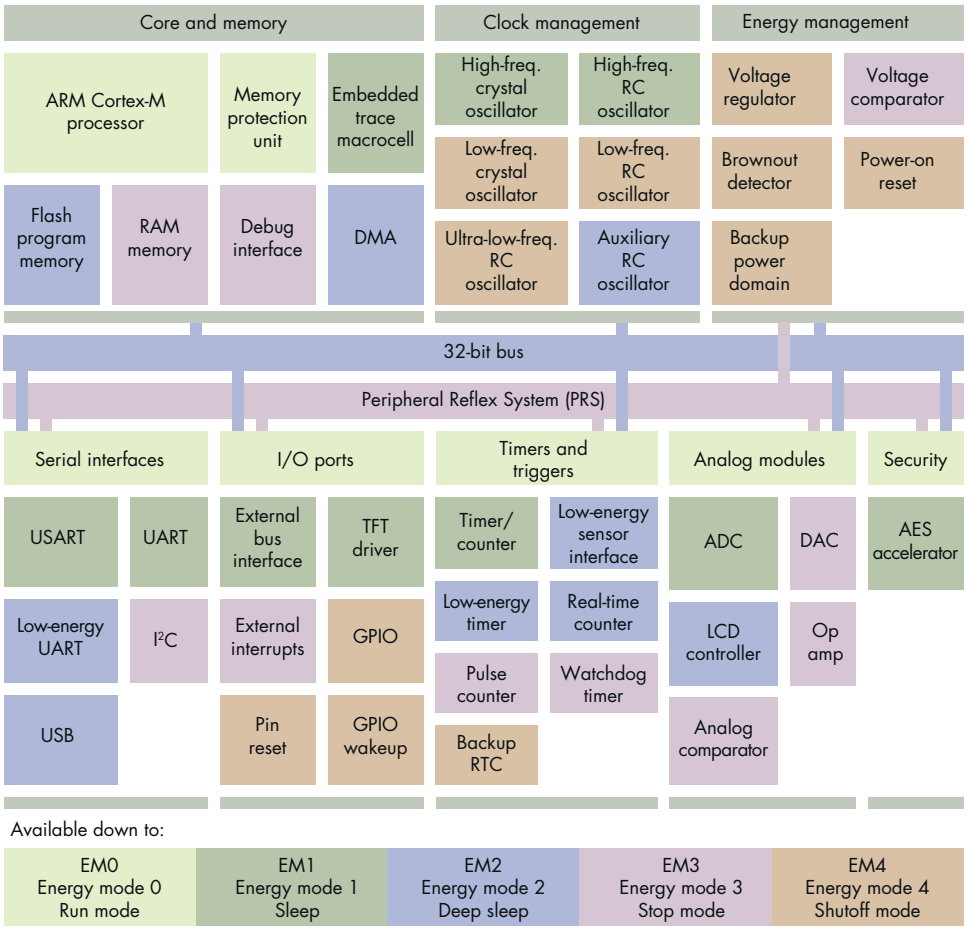
LOW POWER BY PARTITIONING

One way to conserve power is to minimize the power required to run peripherals. A number of vendors provide low-power peripherals that usually have more limited performance or functionality, but are sufficient for a wide range of applications Silicon Labs takes that approach *(Fig. 1)*—its low-energy peripherals can also run when the system is in deep-sleep (EM2) mode with the CPU core off. The typical peripherals will operate in the higher-performance sleep (EM1) mode, though this uses more power.

The challenge for developers is to determine if transitions between modes can occur fast enough to handle associated events. By having active peripherals, information is able to be collected and possibly analyzed to determine if a transition needs to occur. This transition typically wakes up the processor to programmatically handle the event.

Silicon Labs' Peripheral Reflex provides an intermediate functionality to link peripheral events so that an event from one peripheral can trigger another peripheral. For example, an analog-comparator transition would cause an analog-to-digital converter (ADC) to capture some information, and it might induce a counter to increment all without waking up the processor.

Most microcontroller vendors have a form of the Peripheral Reflex system implemented on certain products. Cypress Semiconductor's PSoC *(see "Smart Peripherals Make Low-Power IoT Possible" on electronicdesign.com)* takes this to the extreme with almost FPGA-like configurability. PSoC chips have a set of analog and digital building blocks with a programmable connection matrix. Peripherals like UARTs and



1. Silicon Labs implements peripherals with different performance and power requirements to help optimize power utilization.

timers can be customized and linked for autonomous operation, offloading the processor.

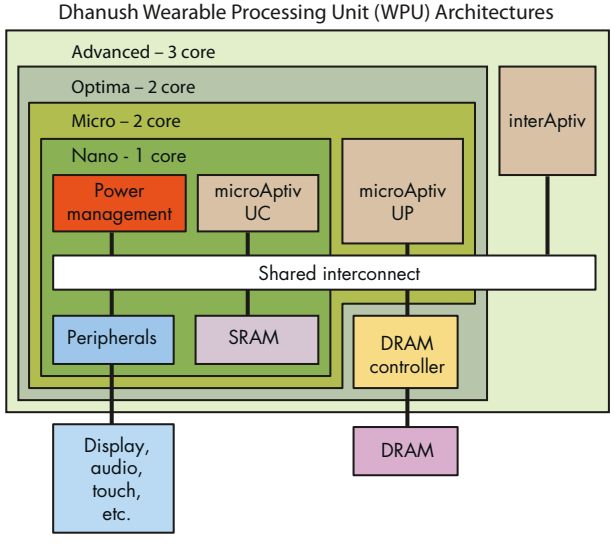
Sometimes a processor is needed to handle a job, but a high-performance core may be overkill for particular functions. Ineda Systems takes a hierarchical approach to the problem with two or more cores *(Fig. 2)*. It allows a higher-performance core to handle jobs that aren't possible with the lower-performance core, while allowing the latter to handle jobs such as peripheral management *(see "Hierarchical Processors Target Wearable Tech" on electronicdesign.com)*.

Asymmetric core designs are much more common, even at the low end of the spectrum. NXP's LPC4300 includes ARM Cortex-M4 and Cortex-M0 cores *(see "Dual-Core Cortex-M4 And M0 MCU Redefines Digital Signal Control" on electronicdesign.com)*. The lower-end processor is often the manager that handles watchdog chores in addition to low-speed, low-power peripherals.

LOW-POWER TRANSISTOR DESIGN

Another way to conserve power is to implement a low-power transistor design. Shrinking the system can help, but often this approach is more about improving performance. Of course, getting the job done faster and then sleeping can result in a low-power solution as well.

Ambiq's sub-threshhold Apollo Cortex-M4 design optimizes transistor design to reduce overall power requirements *(see "Subthreshold Cortex-M4F Design Sips Less Power Than Cortex-M3" on electronicdesign.com)*. The resulting system draws less power, making it possible to use high-performance features like floating point. The chip consumes only 30 µA/MHz executing from flash, and a



2. Ineda Systems' architecture employs multiple MIPS cores with differing performance and power characteristics.

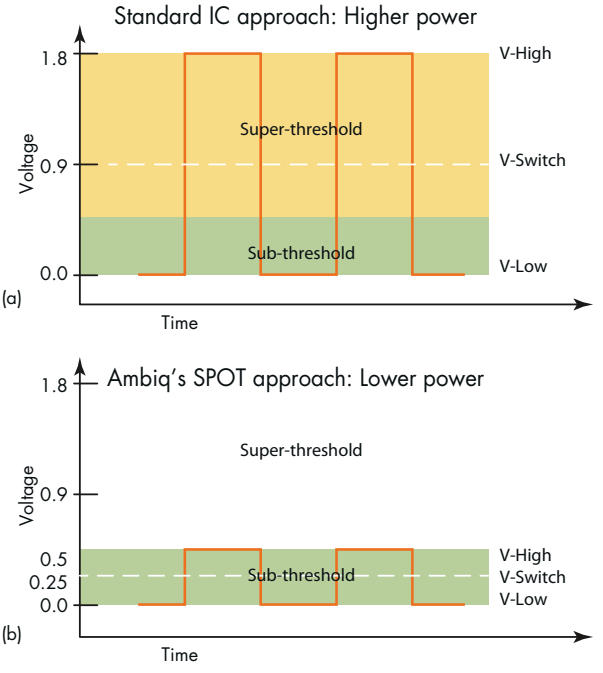
mere 100 nA in ultra-low-power sleep mode with the real-time clock (RTC) running.

The power savings reaped from Ambiq's approach are due to the difference between conventional super-threshold and sub-threshold designs *(Fig. 3)*. Keith Odland, Senior Director of Marketing at Ambiq Micro, explains the differences between sub- and super-threshold:

"At the very elemental level, sub-threshold and super-threshold really refer to the 'state' of a field effect transistor (FET) as it 'turns-on.' In other words, when a transistor is completely on (large gate to source voltage; V_{GS}), it conducts much more current than when the transistor is 'kind-of-on' or 'just starting to turn on' where it conducts much less current. This difference can be several orders of magnitude (i.e., 1000s of times different)."

The problem is quite difficult, and Ambiq's part actually operates many of the digital circuits in a "near-threshold" region. Still, the resulting system delivers an EEMBC ULP-Bench *(see "Interview: Markus Levy Discusses The EEMBC Ultra Low Power Benchmark" on electronicdesign.com)* benchmark result of 377. The previous watermark was 185.

Sometimes memory can make a difference in a low-power design. Texas Instruments' FRAM-based MSP430 addresses applications where non-volatile storage allows fast start up and shut down while allowing complete RAM retention *(see "Microcontroller Utilizes FRAM For Code And Data" on electronicdesign.com)*. Flash-based solutions cannot retain RAM when the system is completely shut down, and moving data between flash and RAM is slow and uses more power.



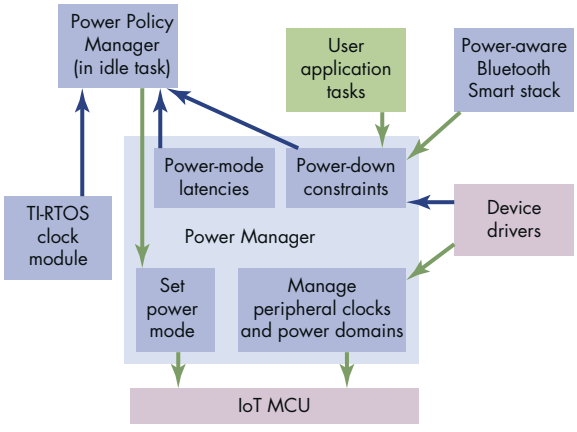
3. Conventional super-threshhold designs maintain a wide voltage swing (a), while Ambiq's sub-threshhold design (b) significantly shrinks the voltage range for a comparable reduction in overall power requirements.

LOW-POWER SOFTWARE DESIGN

Embedded developers usually take advantage of low-power modes to minimize power requirements. This was once a simple chore due to the limited number of power modes. Typically, lower-power modes limited system functionality in a simple fashion, such as reducing the clock rate or limiting the number of active peripherals.

These days, more power-mode options are available, with many more complex variations. The added lower-power peripherals discussed earlier often operate differently for each power mode. Managing power modes in a multitasking system becomes even more difficult as devices and applications have different requirements at different times.

Texas Instruments' TI-RTOS addresses this challenge *(see "RTOS Employs Profile-Based Power Management" on electronicdesign.com)*. The TI-RTOS power-management system *(Fig. 4)* utilizes constraint and status information from applications and device drivers to determine when a state transition should occur, as well as the proper state for the device. This allows a Bluetooth Smart stack to indicate the need to be periodically enabled, in order to exchange information with wireless peers. The stack doesn't specify if there's an occurrence of a transition, but will inform the RTOS when such events take place (e.g., completion of an operation). The TI-RTOS is available in ROM for many of the company's microcontrollers, such as the CC2640 SimpleLink Bluetooth chip.



4. The TI-RTOS power-management system takes constraint and status information from all enabled applications and device drivers to optimize power utilization.

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Automotive Power
HONG LEI CHEN | Product Manager
Avago Technologies

OPTOCOUPLERS
Improve EV Charging Stations

The need for fast charging systems for electric vehicles poses several challenges that can be addressed by using optocouplers.

The full version of this article, with additional illustrations and complete reference notes, appears on our website at http://electronicdesign.com/power/optocouplers-help-promote-safe-efficient-ev-charging-stations. Here is a condensed version of the article for print:

1. Here's a typical scene of an electric vehicle being charged at a charging station.

The worldwide electrification of transportation has grown rapidly through recent years. The global electric-vehicle (EV) stock was about 180,000 by the end of 2012. This number grew by 3.7 times, reaching more than 665,000 through the end of 2014 per IEA (International Energy Agency) Global EV Outlook reports. The report forecasts that by 2020, approximately 20 million EVs will be on the road.

Rapid growth of the EV fleet is driving strong demand for a charging infrastructure to extend the vehicles' travel range. An EV charging station, also called Electric Vehicle Supply Equipment (EVSE), supplies electric energy to the EVs (including electric cars, trucks, buses, etc.) while providing a network connection. *Figure 1* shows an EV at a charging station.

IHS Automotive forecasts the installation base for global EV charging stations to skyrocket from 1 million units in 2014 to 13.6 million by 2020. The market-research firm estimates that there will be 4.3 million units installed in the Americas; 4.1 million units in Europe, the Middle East, and Africa (EMEA); and 5.3 million in Asia (including Japan).

Governments such as those in Germany, China, and the United States are steadily making more funds available to develop charging infrastructure. China, for example, plans to deploy 4.5 million EV charging stations by 2020. This effort will support the plan of cumulative production and sales of 5 million units of BEVs and PHEs by 2020, reports *www.gov.cn*, a website run by the central Chinese government. Compared to 31,000 charging stations built through the end of 2014, the target of 4.5 million units implies a whopping compound annual growth rate (CAGR) of 129%.

STATION TOPOLOGY AND SAFETY ISOLATION

The need for safety isolation is present in all functions of an EV's on-board electronic systems as well as in EV charging stations. On-board systems include the high-voltage battery-management system, dc-dc converter, electric motor drive inverter, and on-board charger. For on-board systems, optocouplers must provide reinforced reliability and safety insulation capability, which suits applications such as gate driving, current/voltage sensing, and digital communication. This article focuses on the isolation solution for off-board charger designs, which often find industrial-grade devices to be sufficient.

An EV charging station typically includes functional blocks, such as the ac-dc rectifier, power-factor-correction (PFC) stage, and dc-dc conversion to regulate the voltage to a level that's suitable for charging the vehicle battery. *Figure 2* shows a simplified block diagram of a dc-charging-station design. In high-frequency isolation topology, galvanic isolation is provided in the dc-dc converter stage by a high-frequency transformer. In addition, multiple isolation devices provide various signal isolation functions while maintaining a safety isolation barrier between the high-voltage power section and low-voltage controller section. Within all of these stages, power devices like MOSFETs and IGBTs are used to perform the switching functions.

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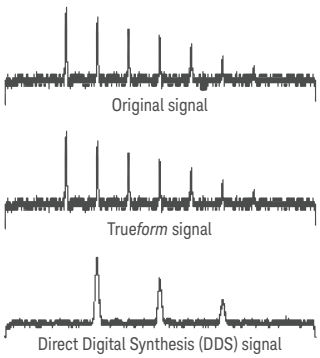

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Located in the center of the system is the microcontroller unit (MCU), which controls the PFC and dc-dc converter with pulse-width-modulation (PWM) signals. The charging control is based on voltage, current information, and other data, such as temperature, user inputs, and so on, to carry out calculations and control instructions in order to fulfill the designed function.

Digital communication ports are employed to communicate between EVSE and the EV for charging control, and between EVSE and the charging-station control center, and thereafter to the cloud, for charging data reporting, remote monitoring, and diagnostics.

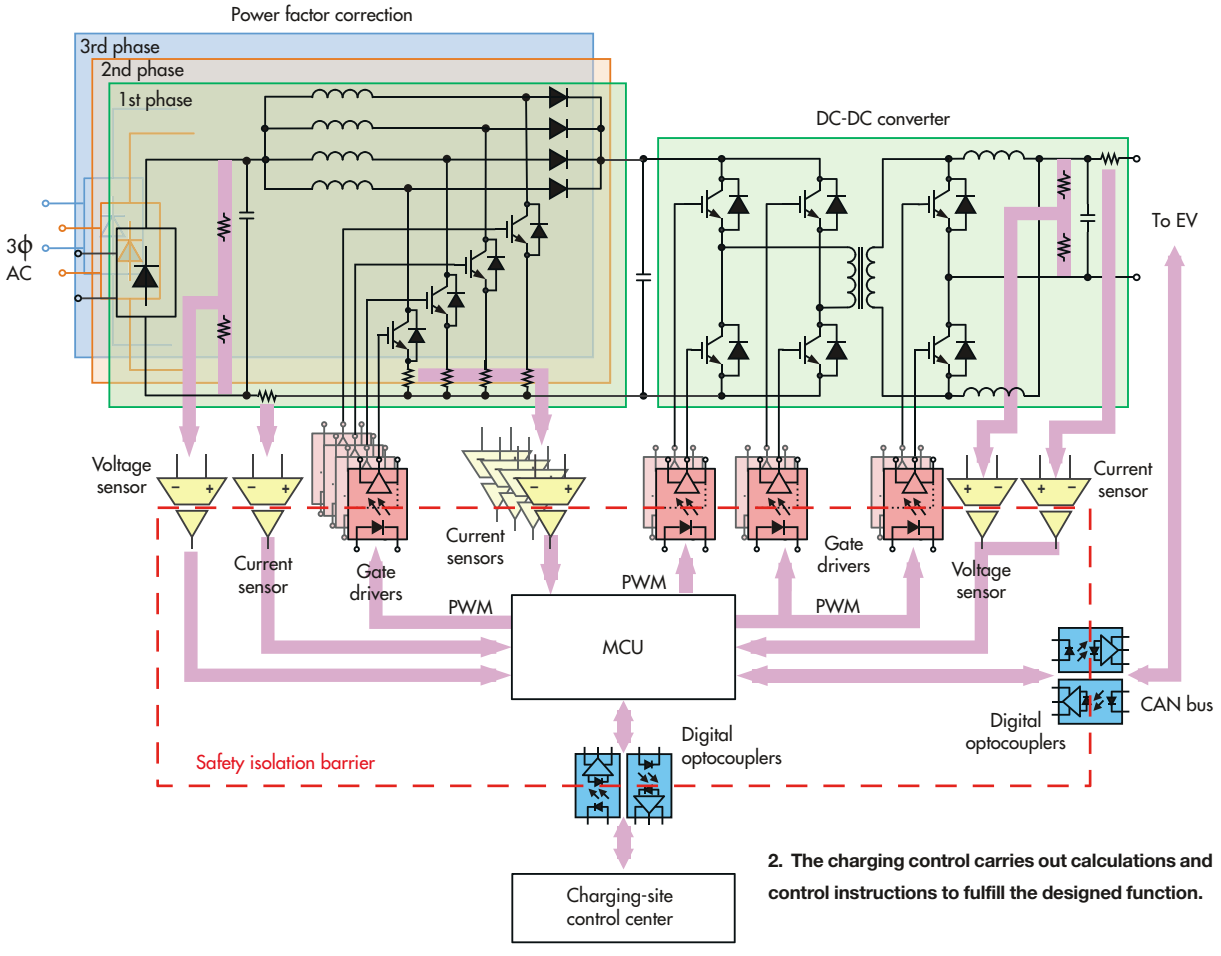
As seen in *Fig. 2*, a safety isolation barrier is built up along the line formed by optical coupling points of the various optocouplers. This is important to ensure that the design safety aspects comply with regulatory standards.

Besides galvanic isolation, the other key factor that often requires close attention in power converters, including the one in the EV charging station, is power-conversion efficiency. This article introduces how to use several optocouplers from the catalog to implement efficient charging-station designs for safety isolation.

GATE DRIVERS

In an EV charger, the MCU alters the PWM signals to switch the power MOSFETs or IGBTs on and off and adjust the duration of each status to regulate output voltage/current according to battery-charging mode. A PWM signal from the MCU normally needs amplification to increase output current in order to switch the power device at the desired frequency. It does so by driving the gate of a MOSFET or IGBT with a device simply called the gate driver.

In EV charging-station designs, choosing advanced power devices and appropriate gate drivers can also help achieve efficiency goals. Silicon-carbide (SiC) MOSFETs are rapidly emerging in the power-device market, delivering several benefits over conventional silicon-based power MOSFETs and IGBTs. One benefit is that it reduces switching losses because a high-voltage SiC MOSFET doesn't have the tail current losses found with IGBTs. In addition, the SiC MOSFET's high current density and small die size results in lower capacitance compared to silicon MOSFETs. Hence, higher switching-frequency operation is possible, which improves system efficiency. At a 600-V blocking voltage level, the SiC MOSFET-based system achieves 4% better efficiency than the conventional IGBT-based design (*Fig. 3*).



2. The charging control carries out calculations and control instructions to fulfill the designed function.

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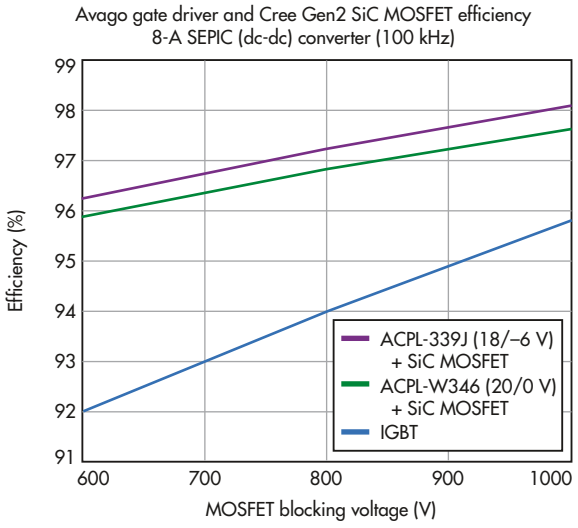
VOLTAGE AND CURRENT SENSING

EV batteries employ three primary charging methods: constant voltage, constant current, and a combination of the two. Most EV charging systems use a constant voltage for the initial portion of the charging process, followed by a constant current for the final portion. To effectively implement these charging methods, voltage at various nodes and current through several branches need to be measured and fed back to the MCU for calculation, which will adjust PWM signals accordingly. For example, in *Fig. 2*, voltages at the dc link and the charger output require continuous monitoring and accurate readings. Besides voltage information, currents in the PFC stage—through the input and output rails—are required to be measured.



3. High efficiency can be achieved with Avago gate drives and Cree SiC MOSFETs.

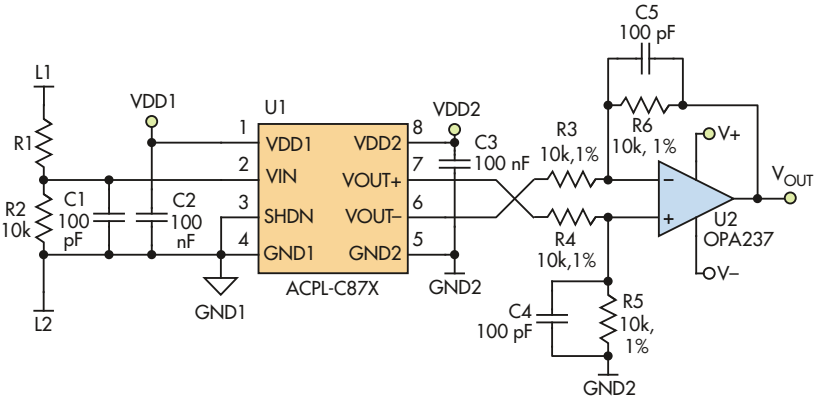
One common method of measuring higher voltages uses a resistive potential divider to step down the voltage to a suitable level. A linear sensing chip then measures the voltage and sends it to the MCU. A current-sensing circuit often employs a precision shunt resistor to convert the current to a small voltage, which is sent to the MCU via some signal-conditioning devices.

However, it's always a challenge when transmitting the signals accurately from high-voltage areas, such as the PFC and dc-dc converter stages, to the low-voltage controller side. This is due to high switching noise and ground loop noise across these two areas. These common circuit problems can ruin data accuracy, damage the MCU, and threaten user safety. In these situations, isolation amplifiers like the ACPL-C87X and ACPL-C79X series are handy to carry out voltage- and current-sensing functions.

Using the ACPL-C87X isolated voltage sensor is straightforward. A detailed dc-voltage-sensing circuit with the ACPL-

C87X is shown in *Fig. 4*. Given that the ACPL-C87X's nominal input voltage for V_{IN} is 2 V, a user needs to choose resistor R1 according to $R1 = (V_{L1}-V_{IN})/V_{IN} \times R2$. For example, if V_{L1} is 600 V and R2 is 10 kΩ, then the value of R1 is 2990 kΩ.

Several resistors can be combined to match the target value. For instance, 2-MΩ, 430-kΩ, and 560-kΩ resistors in series equal exactly 2990 kΩ. The downscaled input voltage is filtered by the anti-aliasing filter formed by R2 and C1 and then sensed by the ACPL-C87X. The isolated differential output voltage ($V_{OUT+} - V_{OUT-}$) is converted to a single-ended signal (V_{OUT}) via a post amplifier (U2). V_{OUT} is linearly proportional to the line voltage on the high voltage side and can be safely connected to the system microcontroller. With the ACPL-C87X typical gain of 1, the overall transfer function is simply $V_{OUT} = V_{L1}/(R1/R2+1)$.



4. This circuit offers high-voltage measurement with conversion to an isolated ground referenced output.

Utilizing an isolation amplifier to sense current can be as simple as connecting a shunt resistor to the input and subsequently getting the differential output across the isolation barrier (*Fig. 5*). By choosing an appropriate shunt resistor, a wide range of current—from less than 1 A to more than 100 A—is able to be measured.

In operation, currents flow through the shunt resistor, and the resulting analog voltage drop is sensed by the ACPL-C79X. A differential output voltage is created on the other side of the optical isolation barrier. This differential output voltage is proportional to current amplitude and can be converted to a single-ended signal using an operational amplifier, such as

the post amplifier shown in *Fig. 4*, or sent to the controller's analog-to-digital converter (ADC) directly.

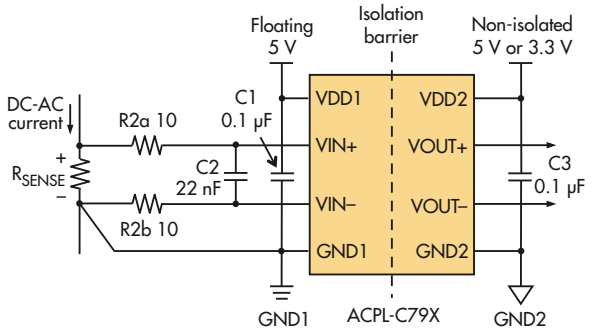
DIGITAL COMMUNICATION

An advanced control scheme is necessary to implement a charging control protocol between the charging station and the EV. This is another area prone to divergent standards. For example, the SAE J1772 specifies the Control Pilot signal communication method using duty-cycle modulation for AC Level 1 and 2. For the digital communication required in dc charging, the SAE committee is working on updating the J2931, which proposes power-line-communication (PLC) schemes on the Control Pilot signal or mains. Tesla apparently participated in the SAE committee process and made the decision to use the same control signaling scheme as the SAE J1772.

The most popular plug standard, CHAdeMO (based on EV sales with fast-charging type), chooses a controller area network (CAN) for fast charging. High communication reliability is required because the 500-V/100-A output of the dc fast charger could lead to a fatal accident if one error occurs, according to the Japanese association's website. That association considers CAN to have a highly reliable record as a standard communication method for automotive electronic control systems. Its higher noise tolerance reportedly surpasses PLC as a communication method for an electronic control unit (ECU) to control the charging process.

The CHAdeMO standard provides a pair of CAN bus lines to connect the charger side and vehicle side at the coupler interface. Coupler pins 8 and 9 are assigned as CAN-H and CAN-L, respectively, to which a CAN transceiver can be connected.

Adding optical isolation between the CAN transceiver and CAN controller significantly improves system safety, as optocouplers provide a safety barrier that prevents any damage from cascading to the system MCU. This arrangement also enables more reliable data communication in extremely noisy environments, such as high-voltage battery-charging systems. *Fig. 6* shows how to use optocouplers to implement isolated CAN bus digital communication for fast-charging-station designs. A similar circuit is applicable for the vehicle side, which requires automotive-grade parts.



5. By choosing an appropriate shunt resistor, a wide range of current—from less than 1 A to more than 100 A—can be measured.

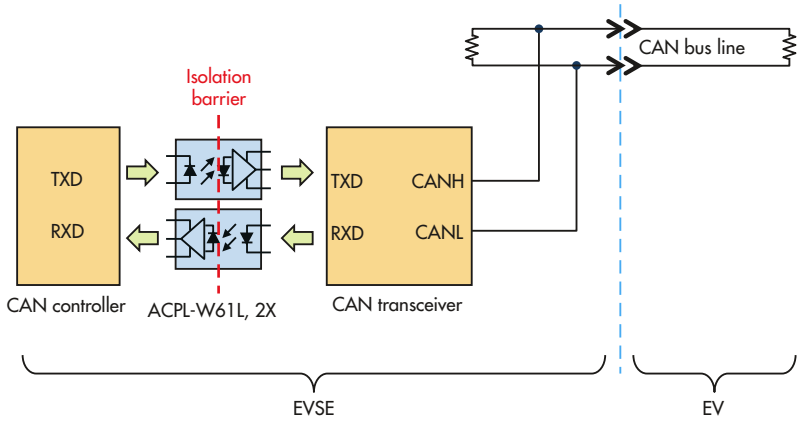
In *Fig. 6*, a pair of 10-MBd fast optocouplers (part ACPL-W61L) is used to transmit and receive data. The product, which requires just 1.6 mA of LED current, comes in an SSO-6 package less than half of the size of a traditional DIP-8 package. Per the UL1577 rating, the ACPL-W61L withstands high voltage of 5000 VRMS for one minute. Designed to transmit signals in the presence of strong transient noises, this part promises common-mode transient immunity of 35 kV/µs. In designs with different data speeds, other optocouplers can be used in place of the ACPL-W61L. These include the 5-MBd-rated ACPL-W21L, and the 25-MBb dual-channel bidirectional ACSL-7210.

CONCLUSION

Ultimately, EVs help reduce dependence on petroleum while tapping into the relatively inexpensive source of electricity. They also help reduce the emissions of greenhouse gases and other pollutants, which can be further improved as electricity generation portfolios add more renewable sources.

The EV charging infrastructure is a key factor in widespread EV adoption. In an EV charging station, complex power-supply systems are employed to deliver huge amounts of energy to the battery in the vehicle within a short period of time. Safety isolation is imperative, since the low-voltage control system, high-voltage power system, and user-accessible interface coexist in a single charging station.

Efficiency in energy conversion is another critical design consideration in EV chargers. Optocouplers, such as the gate drivers, voltage sensors, current sensors and digital communication optocouplers, deliver both safety isolation and respective electrical function in a single package, helping lead the way toward highly efficient systems.



6. This setup delivers isolated CAN bus digital communication for a fast-charging-station design.

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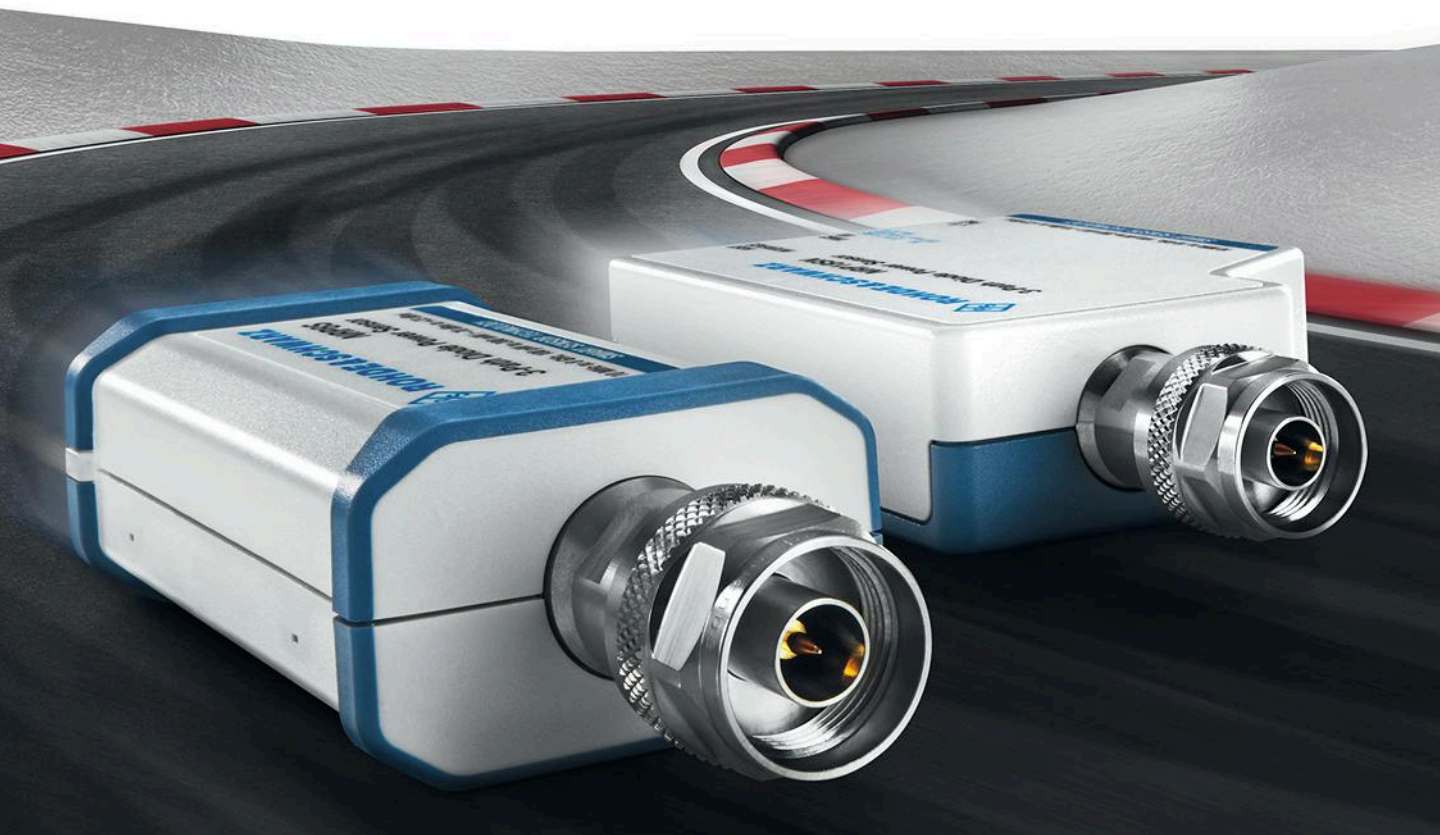


ROHDE&SCHWARZ

MARIA GUERRA | Technical Editor

Taking an In-Depth Look At MicroTCA Power Modules

The development of new architectural specifications for information and communication technology equipment brings new power-module design challenges.

Power modules are very significant components for a MicroTCA system. They distribute the power and provide an interface to the MicroTCA Carrier Hub (MCH) for power management. Design specifications for power modules provide flexibility to power system designers that could impact the cost, performance, and reliability of a MicroTCA system.

MicroTCA belongs to the nine families of PCI Industrial Computers Manufacturers Group (PICMG) standards. MicroTCA was designed for building smaller systems than AdvancedTCA while retaining the high availability architecture of the latter. Let's describe briefly the MicrotTCA standard and its background before taking a closer look of MicroTCA power modules.

MicroTCA

The Advanced Telecommunications Computing Architecture (ATCA, or AdvancedTCA) is a series of open-standard specifications developed by the PICMG in 2002. AdvancedTCA was designed to provide an open, multi-vendor architecture that would satisfy the requirements of the next generation of carrier-grade communications equipment.

The specifications provide enough information to allow board, backplane, and chassis vendors to independently develop products that will be interoperable when combined together. Details include board dimensions, equipment practice, connectors, power distribution, and robust system management architecture.

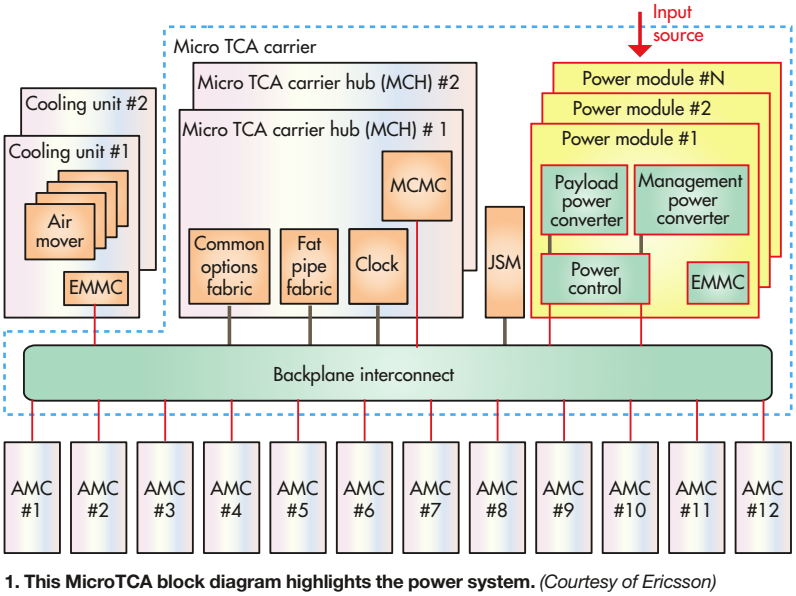
In 2005, the PICMG developed the Advanced Mezzanine Card (AMC) standard that defines the requirements for add-on modules to expand the functionality of an AdvancedTCA carrier board. These modules are also suitable for MicroTCA applications.

This standard, which provides a scaled version of AdvancedTCA for small-scale applications, was ratified by the PICMG in July 2006. Its focus is the latest generation of open-architecture platforms for information and communication technology (ICT) equipment. MicroTCA builds upon the heritage of previous architectures and technologies, specifically AdvancedTCA and AdvancedMC.

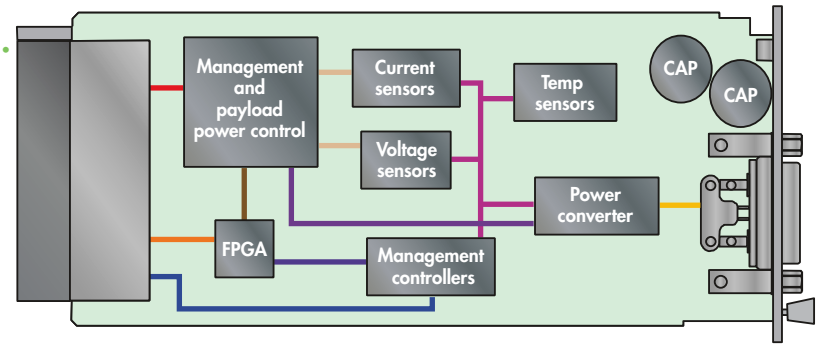
MicroTCA is suitable for applications that require lower power levels within an enclosure—customer-premises equipment (CPE), for example. Its main characteristics are modularity and scalability.

The system provides a mechanical and electrical platform for telecommunications and enterprise computer network equipment. As shown in *Fig. 1*, the principal components are:

- Between one and four power modules (PMs)
- Between one and two MicroTCA Carrier Hub (MCH) cards
- Between one and 12 Advanced Mezzanine Cards (AMCs)
- Between one and two cooling units (CUs)
- Mechanical resources needed to support all above elements



1. This MicroTCA block diagram highlights the power system. *(Courtesy of Ericsson)*



2. In this UTC011 functional block diagram, multiple temperature sensors on-board monitor for over-temp conditions within the module. *(Courtesy of VadaTech)*

MicroTCA POWER MODULES

The power module contains the majority of the power-conversion and control circuitry. It also eliminates the need for the large planar carrier board of the AdvancedTCA systems.

Power modules are responsible for monitoring and protecting a MicroTCA system from power variations. A typical MicroTCA system supports one of the following power sources: –48 V dc, –60 V dc, +24 V dc, and universal ac in the range of 100 to 240 V ac.

Conversion of the power-input source to 12 and 3.3 V is done to provide payload power to each AMC and management power, respectively. Centralized MicroTCA power modules deliver higher power conversion density where some power modules can deliver up to 600 W.

Any given power module can be either primary or redundant; it cannot simultaneously serve both roles. One power module may deliver current to any load channel at any given time with the objective of limiting the maximum overcurrent possible for any channel. In the event of failure in any output channel of a primary power module, the redundant power module will take over responsibility for all of that primary power module's output channels.

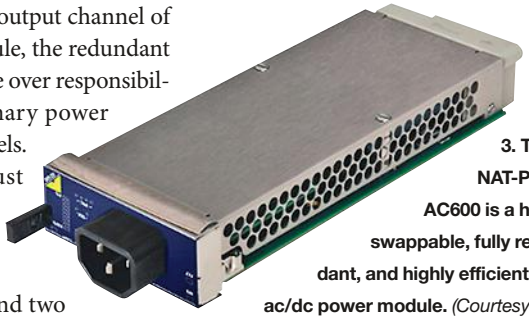
Power modules must be capable of supply payload and management power to up to two cooling units and two MicroTCA carrier hubs (MCHs). Therefore, power modules are designed to provide a total of 16 output power channels, or 32 channels if payload and management power are considered separately.

Power modules also provide an interface to the MCH for power management. They can detect a new AMC and enable hot-swap support without affecting the rest of the system. Power management of the MicroTCA carrier has two distinct stages:

- The early power stage starts from the moment a source of energy is made available to the PM and ends when the carrier manager assumes control of power-management tasks.
- The normal power stage begins once a carrier manager is elected by one or more powered and initialized MCHs.

Autonomous mode may also be used during system maintenance—for example, when all MCHs are removed from a system but the remaining load modules must continue to operate undisturbed.

(continued on p. 31)



3. The NAT-PM-AC600 is a hot-swappable, fully redundant, and highly efficient ac/dc power module. *(Courtesy of Networking, Automation, and Technology)*

MARIA GUERRA | Technical Editor

Maximizing Automotive Battery Power

Battery technologies are steadily improving, while automotive battery management systems are optimizing the run time and lifetime of batteries.

Rechargeable batteries have a great impact on the performance of electric vehicles because they eventually determine their driving range. To maximize cell life in a battery pack, it is important to understand the behavior of Li-ion batteries and the alternatives available for battery-management systems.

Rechargeable lithium-ion batteries, for example, are frequently used in electric vehicles. Compared to other batteries, lithium-ion batteries have higher energy density, higher cell voltage, and low self-discharge. The following factors each impact the performance of Li-Ion rechargeable batteries.

CELL PERFORMANCE

Charging a battery to a 100% state of charge or discharging it to 0% state of charge degrades the life of a battery. The capacity of a battery cannot be considered the only characteristic that will maximize the battery's performance. Aspects like longer battery life and the number of charge cycles, for example, need to be considered when designing high-performance rechargeable batteries.

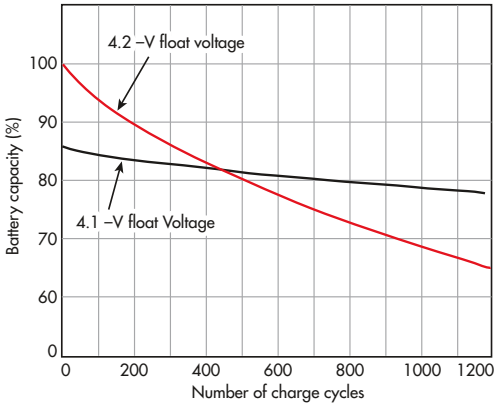
POWER LOSS

During the lifetime of a lithium-ion battery, there will be inevitable power losses. Some of the factors are:

Self-discharge: After a full charge, a lithium-ion battery's inherent self-discharge is about 5% of its capacity in the first 24 hours. At higher temperatures (more than 20°C), self-discharge losses increase. The self-discharge of a battery increases with temperature, age, and usage.

Internal resistance: Charge-discharge cycles eventually reduce the battery's active material and cause other chemistry changes, resulting in increased internal resistance and permanent capacity loss. Cell aging results in an increase of the internal impedance of the cell, thereby affecting its ability to perform because of poor conductivity.

Voltage: Most lithium-ion cell packs have a float voltage of 4.2 V as the best balance between capacity and cycle life (*Fig. 1*). In contrast, a single battery has a voltage of 3.6 V (average voltage at discharging state). When the battery is maintained for long periods of time at 4.2 V or very close to 100% state of charge, however, capacity loss will occur and the lifetime of the battery will shorten.



A battery can deliver approximately 500 charge/discharge cycles before the battery capacity drops to 80%. *(Courtesy of Linear Technology)*

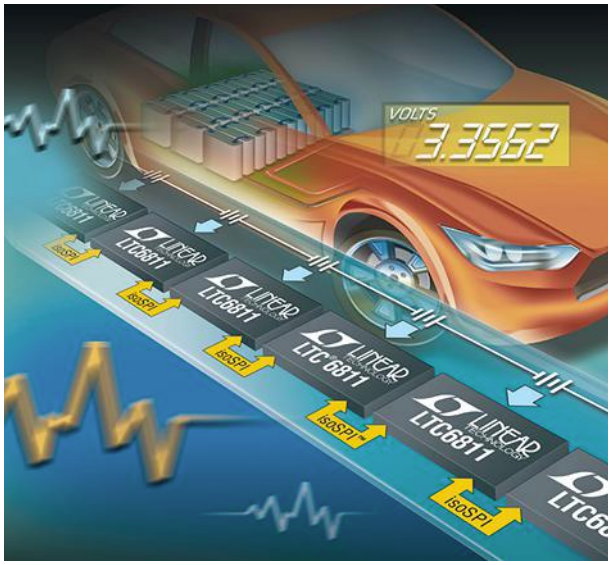
BATTERY BALANCING TECHNIQUES

There are no two exactly equal lithium-Ion cells. Thus, the weakest cell in a battery pack limits the performance of the overall pack. Once the weakest cell reaches state-of-charge limits, the whole battery pack stops charging.

To maximize cell life and avoid battery stack failure, the state of charge of each cell must be constrained by accurately measuring the voltage of each cell with the assistance of a battery management system. This might include balancing to maximize the life of a battery pack by preventing the weakest cell from being overcharged or over-discharged. Engineers use different techniques to keep a balanced battery pack using passive balancing and active balancing.

Passive balancing: Energy is removed from the most charged cell and is wasted as heat, usually through resistors.

Active balancing: Energy is transferred between cells, usually through dc-dc converters.



The LTC6811 contains an ultrastable voltage reference, high voltage multiplexers, 16-bit delta-sigma ADCs, and 1Mbps isolated serial interface. *(Courtesy of Linear Technology)*

AUTOMOTIVE BATTERY MANAGEMENT SYSTEMS

An electric-vehicle battery pack contains dozens of battery cells configured in series that handle high power and high energy capacity within a limited space. Among other factors, automotive battery management systems need to handle electrical noise systems and the wide operating temperatures generated by electric vehicles.

Battery management systems are designed using a wide range of functional blocks, different architectures, and ICs that can be created to optimize battery performance. Some common functional blocks are field-effect transistor (FET) drivers, fuel gauge monitoring, cell voltage monitoring, and temperature monitoring.

Some solutions require microcontrollers and some others run independently. Let's look at these two products as examples of battery management systems: a high-voltage battery stack monitor by Linear Technology and a 16-cell battery monitor with passive cell balancing by Texas Instruments.

Linear Technology's latest high-voltage battery stack monitor is the LTC2811 (*Fig. 2*). The LTC2811 enables high reliability, high stability, and high measurement accuracy systems through the inclusion of internal diagnostic capability to verify proper operation such as open wire detection between battery and monitor, auxiliary voltage reference to confirm primary reference accuracy to within +-5mV, and dual-channel measurements to confirm multiplexer and ADC accuracy to within 0.01%.

LTC6811 also supports ISO 26262, a standard that defines automotive functional safety. ISO 26262 provides a framework for developing and validating automotive products that are safe from electronic and electrical system malfunctions, including automotive BMS malfunctions.

The LTC6811 can measure up to 12 series-connected battery cells at voltages with better than 0.04% accuracy (*Fig. 3*). Integrated into the LTC6811 is a 2-wire isoSPI for high RF noise immunity to 1 Mbps and up to 10 meters of cable. The LTC6811 offers both active balancing and passive balancing. It includes internal passive balancing field-effect transistors (FETs) that can discharge individual cells or directly control larger high-power external FETs. The LTC6811 can be configured to discharge cells while in a low-power state, such as when the battery pack is at rest.

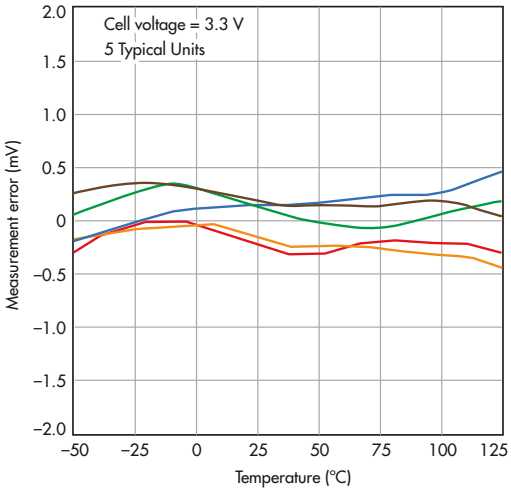
"Accuracy is the most important aspect of a battery management system because the state-of-charge needs to be constrained. It is necessary to have a flat voltage charge/discharge curve in the usable discharge range," says Linear Technology's senior product marketing engineer, Gregg Zimmer, who also highlighted the presence of a sub-surface Zener reference in the LTC6811to provide stability and accuracy by constantly measuring each cell's voltage within less than 1.2 mV of error.

Texas Instruments offers the bq76PL536A-Q1 designed for high-reliability automotive applications (Fig. 4) for protection against over-temperature, over-voltage, and under-voltage. The bq76PL536A-Q1 is an integrated 16-cell monitor that provides pins for direct drive of external N-FETs for passive cell balancing with power resistors.

It is intended to be used with a host controller to maximize the functionality of the battery management system. The bq76PL536A-Q1 offers high accuracy analog-to-digital (ADC) with 14-bit resolution with internal reference and it is able to communicate with a host microcontroller via a high-speed universal asynchronous receiver/transmitter (UART) interface.

The device contains user selectable self-test features to diagnose functional blocks within the device, such as automatic shutdown in the event of over temperature, calibration integrity, and so forth. The bq76PL536A-Q1was not developed in a manner to meet all ISO26262 specifications but it can still help customers meet functional safety standard requirements through built-in self-tests to validate defined internal functions.

As we can see from these products, each of them has different protection features. There are products for every costumer need and after all it is up to the costumer to decide which battery management system works best for them.



The LTC6811 measures every battery cell within less than 1.2mV of error. *(Courtesy of Linear Technology)*

4. The bq76PL455A-Q1 enables accurate computation of a battery pack's state of charge and state of health by precisely measuring cell voltage and also provides passive and active cell-balancing support to extract the maximum amount of energy from the battery. *(Courtesy of Texas Instruments)*

ENVISIONING THE FUTURE

"The constant advances in power electronics and the tremendous interest of several vehicle manufacturers in electric vehicle, together with the constant development of battery chemistries and battery management systems, will certainly improve the efficiency of batteries and help the rise of the electric vehicle market," says Zimmer.

Battery performance is a fundamental ingredient in the success of electric vehicles. Researchers keep looking for better battery chemistries that could help improve battery life and the number of charge cycles to design high-performance rechargeable batteries. Power electronics will keep advancing while battery management systems will benefit from the latter. Automotive battery management systems will continue to work on maximizing driving distances and life time for battery packs. ed

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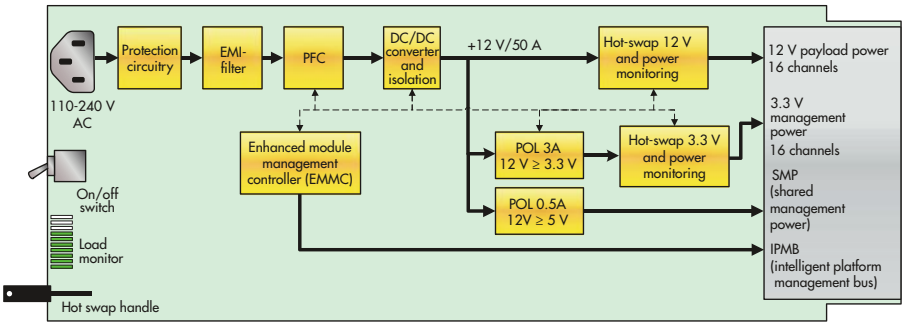
Michael Kultgen and Jon Munson, "Battery stack monitor extends life of Li-Ion batteries in hybrid electric vehicles."
Battery University website.



4. The NAT-PM-AC600 includes a robust Enhanced Module Management Controller that interfaces the power-control functionality via the Intelligent Platform Management Bus to the MicroTCA Carrier Hub. *(Courtesy of Networking, Automation, and Technology)*

APPLICATIONS

MicroTCA was originally intended for smaller telecom systems at the edge of the network. But it has moved into many non-telecom applications. Standardized, ruggedized versions are becoming popular in mobile, military, telemetry, data-acquisition, and avionics applications because MicroTCA offers an open-bladed architecture that reduces size, weight, power, and cost.

POWER MODULE: UTC011

For example, VadaTech is a manufacturer of embedded boards, enabling software, and application-ready platforms that offers solutions for a range of markets, including the military and aerospace markets. One of its products is a single-module power module, the UTC011 *(Fig. 2)*. The VadaTech UTC011 is a 241/460W power module for use in a MicroTCA air transport rack chassis.

The power module runs at 84% efficiency when running at maximum load, resulting in 200/400 W (available to the system). It is fully compliant with the MicroTCA.0 revision 1.0 specification, including dual-redundant I2C buses (IPMB-0).

POWER MODULE:NAT-PM-AC600

Networking, Automatization, and Technology (NAT) is a supplier for board- and system-level products based on AMC and MicroTCA. It offers the NAT-PM-AC600 power module, which is an example of a high-density and high-efficiency power module that could easily be used in applications such as medical, security, and industrial machine control *(Fig. 3)*.

Supplying 600 W, it provides electrical support for the expected workload of 12 AMCs, two cooling units, and two MicroTCA carrier hubs. It supports redundancy as well as load-sharing modes in accordance with the Micro TCA specifications. In case of an input power-supply failure, the power for the onboard EMMC can be provided by SMP power from other power module. As a result, the MCH is able to analyze root-cause failure *(Fig. 4)*.

CONCLUSION

Power modules are critical to the success and reliability of a MicroTCA system, due to the amount of power functions that are centralized on them. There are many power modules in the market that comply with the MicroTCA family of specifications (MicroTCA.1, Micro TCA.2, MicroTCA.3, and MicroTCA.4). Depending on the applications, designers are able to apply the specifications and produce equipment with high efficiency, reasonable size, and modularity. ed

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PICMG Open Modular Computing Standards.

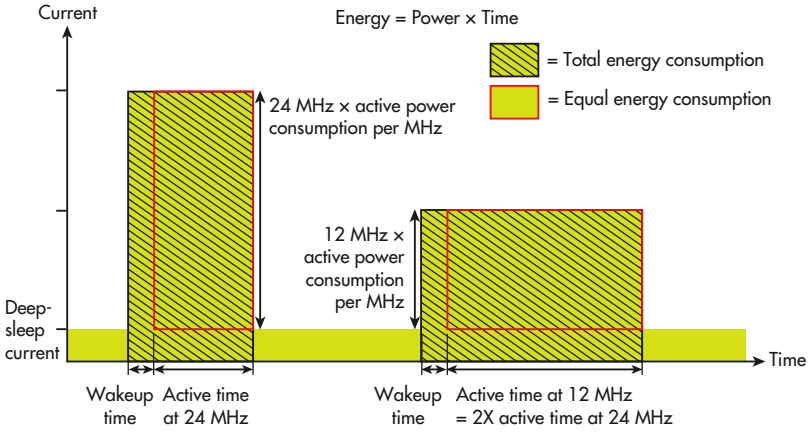
Engineering Essentials

STEVEN COOREMAN | Software Engineering Manager
IoT MCU & Wireless, Silicon Labs

Power-Saving Tips When Rapid Prototyping ARM Cortex-M MCUs

Combining the flexibility of a rapid-prototyping framework with the best practices in low-power programming shouldn't be a big mystery.

More and more, we're seeing novel ideas, products, and applications arise from enthusiast developer communities rather than big corporations. Think of all the recent technology products from crowdfunding sites like Kickstarter, Indiegogo, and Tindie. With billions of devices projected to make up the Internet of Things (IoT), a wealth of opportunities awaits entrepreneurial developers. But before reaping the potential rewards, there are challenges to overcome.



1. Lower clock speeds don't necessarily mean lower total power consumption.

Getting to market faster than the competition is imperative in today's IoT era. The concept of being first to market with a viable product is widely accepted in the industry. To succeed with fast time to market, you need to shorten the development time. In the software/firmware engineering world, multiple rapid-prototyping frameworks have sprung up to accelerate this effort with various degrees of success. Most are not very effective in minimizing power consumption, though. And with increased focus on battery life for IoT devices, this becomes a major design challenge.

WHERE DOES MY ENERGY GO?

First, let's take a step back and consider the relationship between power and energy consumption in semiconductors. Since microcontrollers (MCUs) basically comprise massive amounts of transistors set up as switches, the most important factor in the total power consumption is the active (or switching) power. Every

```
void sleep(void) {
        PRIMASK = 1;
        if (lowest_possible_core_mode == sleep) SLEEPDEEP = 0;
        else if (lowest_possible_core_mode == deepsleep) SLEEPDEEP = 1;

        do_housekeeping_sleep(lowest_possible_vendor_mode);
        WFI();
        do_housekeeping_wakeup();
        PRIMASK = 0; // Callbacks will execute here!

        return; // Return control to the user
```

Pseudocode for sleeping without race conditions on Cortex-M.

LINEAR TECHNOLOGY

DESIGN NOTES

60V Buck-Boost LED Driver with Up to 98% Efficiency Has Internal PWM Dimming and Spread Spectrum – Design Note 548

Keith Szolusha

Synchronous buck-boost converters with four power switches can deliver very high efficiency while providing both step-up and step-down DC/DC conversion. Combining the capabilities of two separate converters (buck and boost) has the advantage of reduced solution size and cost. Four-switch converters should be able to operate with just two switches for highest efficiency when only step-up or step-down conversion is needed. However, they must also be able to utilize four-switch operation as V_{IN} and V_{OUT} approach each other, and to transition gracefully between these regions of operation. Combining control loops for two-switch boost, two-switch buck, and four-switch operation, and designing nearly flawlessly transitions between these regions of operation has its challenges. However, the next generation of buck-boost converters masters these challenges and more.

The LT®8391 60V four-switch buck-boost LED driver is designed to drive high power LEDs up to 250W and to flawlessly transition between two-switch boost, four-switch buck-boost, and two-switch buck regions of operation. A patent pending four-switch buck-boost current-sense resistor control scheme provides a simple, yet masterful method for the IC to run in peak current mode control in all regions of operation with a single sense resistor. This new generation buck-boost LED driver features spread spectrum frequency modulation and internally generated PWM dimming, which work together. The LT8391 has flicker-free PWM dimming with both internal and external PWM dimming, even when spread spectrum is turned on (another patent pending technique).

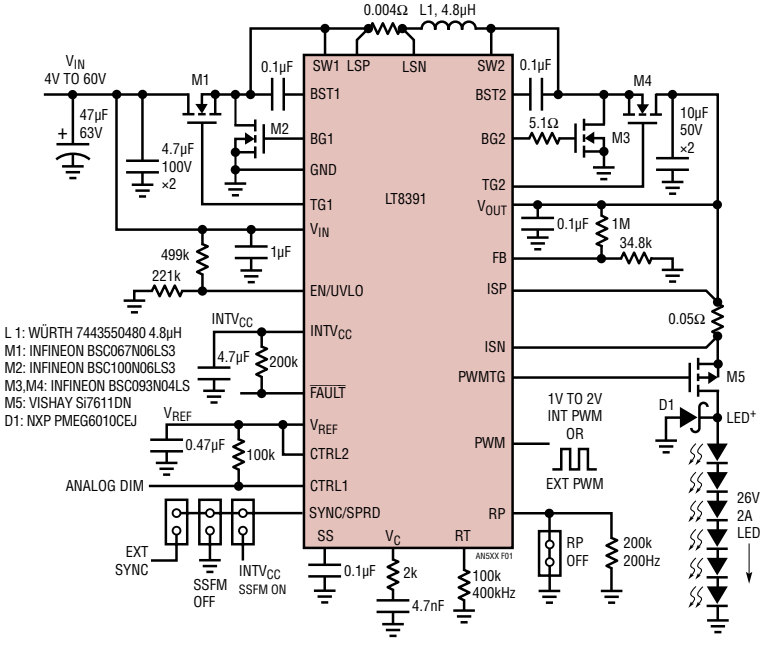


Figure 1. LT8391 4V to 60V Four-Switch Synchronous Buck-Boost LED Driver Powers a 25V 2A (50W) String of LEDs at Up to 98% Efficiency.

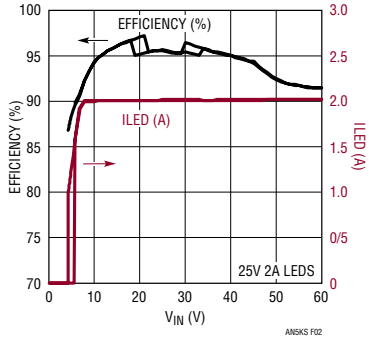


Figure 2. (a)The Efficiency of Figure 1 50W LED Driver Has a Peak of 98% and Ranges from 95% to 97% Throughout the Typical 9V to 16V Automotive Input Range. (b) The LT8391 Peak Inductor Current Limit Can Maintain Stability with Reduced Output Power at Low V_{IN}.

98% Efficient Buck-Boost LED Driver

The LT8391 high power buck-boost LED driver in Figure 1 drives 25V of LEDs at 2A from a wide input voltage range. Efficiency can reach 98% at its highest point. Over the typical automotive battery range of 9V to 16V, the converter operates between 95% and 97% efficiency. With a single high power inductor, the temperature rise is low, even at 50W. At $12V_{IN}$, no component rises more than 25°C. At $6V_{IN}$, the hottest component rises less than 50°C with a standard 4-layer PCB and no heat sink or air flow. This leaves room to increase the power output of the converter, making hundreds of watts possible.

The LT8391 operates down to $4V_{IN}$, where I_{IN} can get very high. The LT8391 is designed to either handle very high input currents or use its peak switch current limit to operate with stability at low V_{IN} while reducing output power. This allows the converter to run through automotive cold-crank voltages or other drops in V_{IN} without an increase in power component size or cost.

The LT8391 can achieve 1000:1 PWM dimming with no flicker. The high side PWM (TG) MOSFET PWM dims a grounded LED string. It also acts as an overcurrent disconnect during short-circuits.

Internally Generated PWM Dimming

The LT8391 has both standard external PWM dimming and internally generated PWM dimming. LT8391's unique internal PWM dimming eliminates the need for components such as clocking devices and microcontrollers to generate accurate PWM brightness control at ratios as high as 128:1. The IC's internally generated PWM frequency, such as 200Hz, is set by a simple resistor on the RP pin. A voltage between 1V and 2V on the PWM pin determines the PWM duty cycle. The duty cycle of the internal dimming is chosen as one of 128 steps and internal hysteresis prevents duty cycle chatter. The <±1% accuracy of internally generated PWM dimming is the same for all regions of operation.

Spread Spectrum Frequency Modulation (SSFM) Reduces EMI

SSFM reduces EMI in switching regulators. Although the switching frequency is most often chosen to be outside the AM band (530kHz to 1.8MHz), unmitigated switching harmonics can still violate stringent automotive EMI requirements within the AM band. Adding SSFM significantly reduces EMI both within the AM band as well as other regions.

When activated, SSFM drops the LT8391's 50W LED driver EMI below both the peak and average EMI requirements of CISPR25 (Class 5) in the AM band. CISPR25 average EMI limits are 20dBµV lower in some places than peak limits, and harder to pass for switchers. For this reason, LT8391's novel SSFM reduces average EMI more than its peak. There is 18dBµV or more reduction of average EMI and about 5dBµV of peak EMI reduction.

In some LED converters, SSFM and PWM dimming do not work together without causing flicker. SSFM, a source of changing switching frequency, may appear as noise to the outside world in order to spread EMI lower than its non-spread peak values, but it can work with PWM dimming for flicker-free operation. Linear's patent pending PWM dimming and SSFM operation runs both functions simultaneously with flicker-free operation, even at high dimming ratios. At 1000:1 PWM dimming with external PWM and at 128:1 internally generated PWM, SSFM operates with flicker-free LED current.

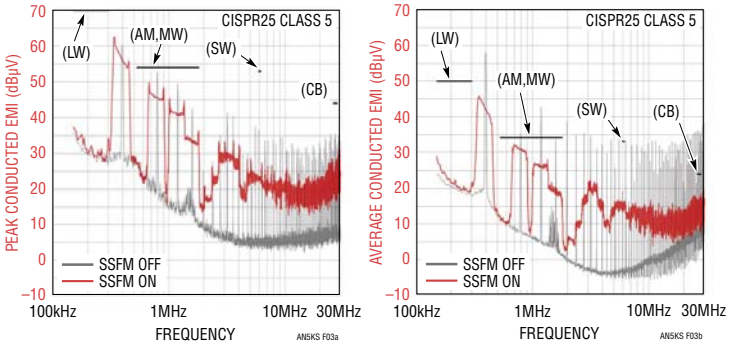


Figure 3. SSFM Reduces LT8391 Peak and Average EMI Below CISPR25 Class 5 Limits. Average EMI Has Even Greater Reduction Than Peak EMI.

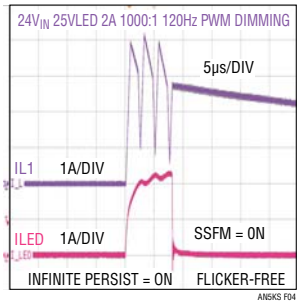


Figure 4. Infinite-Persist Scope Capture Shows Flicker-Free Dimming with PWM and SSFM Working Together.

Data Sheet Download

www.linear.com/LT8391

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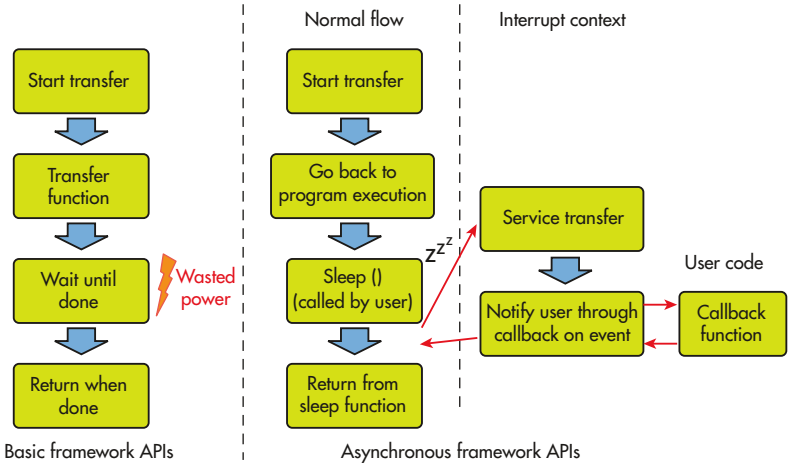


2. An asynchronous programming model is more complex, but allows you to reap the benefits of autonomous operation possibilities of the MCU.

switching transistor dissipates an amount of energy on each transition equal to the load capacitance times supply voltage squared. More transitions per second (aka a higher core frequency) will thus lead to higher active power consumption, but also shorter execution time, as shown by the red areas in *Fig. 1*.

The total active energy consumed equals the instantaneous active power consumption multiplied by the time during which the circuit was consuming said power, so you will end up with the exact same active energy expended as performing the same operation at a higher frequency. Taking into account other factors that are at play, it's generally better to execute your program as quickly as possible to get rid of the extraneous power consumption of inactive parts of the circuit.

Your MCU's datasheet therefore mentions specs for maximum clock frequency, as well as a current consumption figure in the unit of current per megahertz. Peripherals often will have additional constraints on the clock frequency due to the transistors again: The smaller the transistor, the smaller its capacitance, and the less energy it will consume by switching. Its transition time will grow longer though, leading to lower achievable speeds.

As a result, MCU vendors reduce power consumption by making design decisions on each part of the IC to find the most efficient mix of smaller, slower, but more energy-friendly transistors, versus bigger, faster and higher-power transistors. So if your application only needs a 1-MHz communications bus, it's better to select an MCU with a maximum of 10 MHz versus one that scales to 100 MHz.

SLEEPING—THE MOST COMMON WAY TO CUT CONSUMPTION

Since you can't do anything about how the vendor sized the transistors or designed and laid out the circuit, we'll move on to software techniques. For the purpose of this article, let's select a generic MCU based on a Cortex-M0+ core, which in turn is based on the ARMv6-M microarchitecture.

By using this core, we already get some provisions to reduce power. From the *Cortex-M User Guide* (Chapter 2.5, Power Management), we see that two specific instructions are implemented: wait-for-event (WFE) and wait-for-interrupt (WFI). These instructions will halt the core execution until the occurrence of either an event or interrupt. To correlate this action with our power theory, it will switch off the clock to the processor core, meaning that all of those transistors will stop switching, significantly reducing power consumption when you don't need the core.

In addition, there's a SLEEPDEEP bit in the core registers. According to the *Cortex-M0+ User Guide*, "regular" sleep mode stops the processor clock, while deep-sleep mode (when SLEEPDEEP is set) will stop the system clock, switch off the phase-locked loop (PLL), and switch off the flash memory.

Deep sleep can have additional properties depending on the MCU vendor, since it's defined by ARM as being partly implementation-specific, although vendors generally don't diverge too much. They can and do, however, implement even more power states, which you can use to your advantage. Read your MCU's reference manual to find out.

SLEEPING IS A TOOL, NOT A GOAL

You may think, "Okay, let's get our program to go to sleep as quickly, as fast asleep, and as often as possible." While you would be correct for the most part, another tradeoff also should be considered.

Waking up from a sleep mode requires time and energy, and these two variables change with how deep the MCU sleeps, as shown in the table. While switching between run mode and the first sleep mode might be quick and painless, switching in and out of deep sleep is definitely not due to the need to restart clocks and re-initialize peripherals.

For this reason, you should perform measurements on different versions of your code to determine if it's more appropriate to use a higher-power sleep mode. The other alternative is to not go to sleep at all, and subsequently reduce the clock frequency appropriately.

EFM32 HAPPY GECKO WAKEUP TIMES

From/to	EM0 (run mode)	EM1 (sleep mode)	EM2 (deep-sleep mode)	EM3 (stop mode)	EM4 (shutoff mode)
Wakeup time to EM0	—	Few cycles	2 µs	2 µs	160 µs

MAXIMIZING SLEEP TIME

Sleep mode is entered by calling WFE or WFI, and execution will resume when there's an event or (enabled) interrupt pending, respectively. Thus, if you want to successfully implement a sleeping, power-efficient application, interrupts are needed to signal the core when to wake up to do processing. They're especially useful for long-running operations or external events, such as button presses, data transfers, ADC conversions, and waiting for a timer or RTC to expire.

Since the processing core is the most power-hungry part of an MCU, doing as much as possible without its active involvement is the biggest impact you can have on reducing the MCU's energy consumption.

To that end, the vast majority, if not all, of Cortex-M-based MCUs also implement direct memory access (DMA). Using DMA, you can move data between peripherals and RAM while the core is sleeping, resulting in longer sleeping times and reduced energy consumption.

Some MCU vendors take this technique of reducing processing core involvement even further. They allow you to implement custom logic (such as Cypress' PSoC family) or have specific on-chip constructs (such as the Peripheral Reflex System of EFM32 MCUs) that enable peripherals to work together without waking up the core.

CHANGE THE PROGRAMMING MODEL

But how do you take advantage of all of these goodies in a rapid-prototyping context? Consider for a moment the basic APIs of an MCU's rapid-prototyping framework (not an RTOS). Odds are that the interface works something like the left side of *Fig. 2*. When you want your system to do something, you call a function to do it, and that function returns when the action is complete. The framework is set up in this manner because the programming flow is simple and linear.

However, this approach comes with a major downside. Your program is stuck doing one task, so you can't easily perform another task at the same time. The implementation could enable the function to go to sleep during the transfer, but then you run into other questions, such as, "How deep do you sleep?"

To save power, we must therefore make changes in the way the underlying system works, and how the user interfaces with it. To that end, one can implement an "asynchronous programming model," as illustrated on the right side of *Fig. 2*.

This means you call a function to start a long-running action, and that function immediately returns after setting up the system for the requested action. The action will then be executed in the background with the help of interrupts and possibly DMA transfers until completion, all of which is transparent to the user.

But what if the user wants to know that the transfer actually finished? In this case, the asynchronous model supports so-called callback functions. These functions can be written by the user and passed as an argument when calling the "start action" function. The callback function then gets called when the action is complete, or when something else happened to cause the action to be aborted, leveraging the power (savings) of autonomous operation.

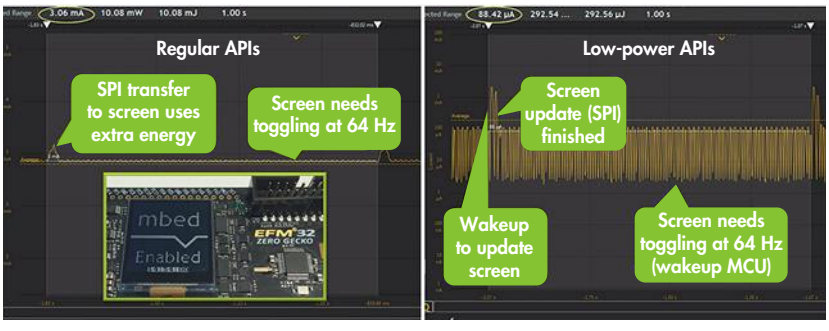
SLEEPING REVISITED

Since all of this happens independently of the main program, the user can now be given the option of sleeping. By letting the user choose, we actually enable better ways to optimize power. The programmer knows the expected behavior of the application, so he/she can make a decision to sleep or not to sleep.

For the system to know how deep to sleep in such a case, it also must keep track of the peripherals in use and their power-mode constraints (e.g., through reference counting). Then, when the user calls sleep, you check those counters and go to the lowest possible sleep mode, turning off every idle clock to stop as many transistors as possible from switching.

AVOIDING RACE CONDITIONS

Seasoned programmers will notice a problem here. Because the system is doing housekeeping between deciding which sleep mode to enter and executing the actual WFI instruction, it's possible that the action we were waiting for has already completed, and the callback function executed at that time. This is very inconvenient, since the decision on the sleep mode has already been made, but the conditions for that decision may have changed through the callback.



3. Replacing a synchronous programming model with an asynchronous version shows a 35X improvement in energy consumption.

For example, if the callback was from a timer, but that callback started a serial transfer, it's possible that the system will now continue entering a lower sleep mode than the serial transfer supports. This messes up the whole program behavior in the process—and possibly sleeping permanently.

To prevent our MCU from turning into Sleeping Beauty, we need a prince

to come and save us. It turns out that prince comes in the form of a bit in the Cortex-M core. That bit, called PRIMASK, disables all interrupts (except for the non-maskable ones, such as HardFault) from executing. However, doesn't that shut down our wakeup source?

When you examine the definition of the WFI instruction, you will see that it not only wakes up to service an interrupt, but also when an interrupt becomes pending that would have happened if PRIMASK wasn't set. This means that if an interrupt occurred between making the decision and calling WFI, WFI will not put the core to sleep but rather return immediately. Also, turning off PRIMASK will result in the interrupt getting serviced, as indicated in the code listing *(p. 32)*.

REAL-WORLD EXAMPLE

To show what kind of impact this has on a real-world rapid-prototyping environment, we implemented these techniques inside of the ARM mbed framework. It provides an API that's completely hardware-independent from a user's perspective. The same application code can run on any Cortex-M MCU, regardless of the vendor, as long as the vendor implemented the mbed HAL for its MCU.

To demonstrate the effect of these changes, we measured the power consumption of an application built with mbed *(see https://developer.mbed.org/teams/SiliconLabs/code/memLCD-Demo/)* driving a graphical LCD while keeping track of time.

Considering that the power profile shown in *Fig. 2* includes the LCD's power consumption, the results are impressive. *Figure 3* shows the impact of different program functions on the application's energy profile. Using the regular mbed APIs, the average current over one iteration is 3.06 mA. When we implement the same demo using the asynchronous programming model and sleep in between, we can reduce current consumption to a low 88 µA, leading to a factor 35 improvement in battery life.

CONCLUSION

While this article only scratches the surface regarding power-saving techniques, it's clear that using a rapid development framework like ARM mbed OS should not be a battery-life killer. Using common, vendor-independent techniques can greatly reduce your application's energy consumption, and that's a great starting point for energy optimization. ed

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ideas for design

Computer Sound Card Provides Simple Internet-Based Appliance Remote Control

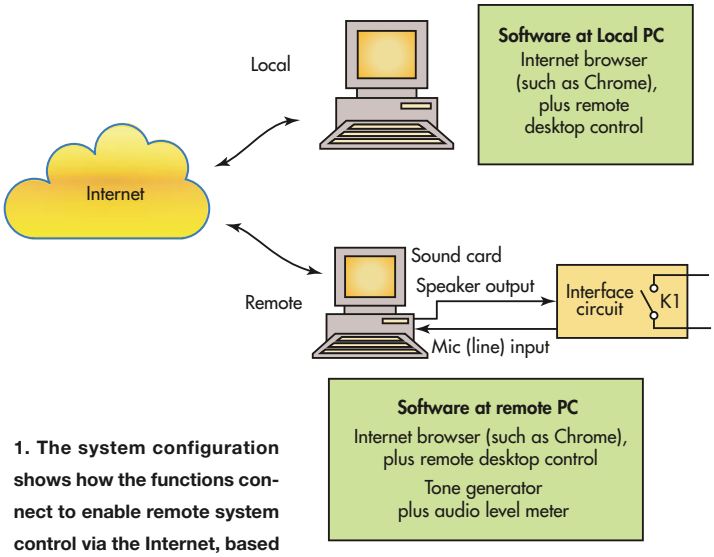
JOSÉ M. MIGUEL | RF-LAB, UNIVERSITAT POLITÉCNICA DE CATALUNYA (UPC), BARCELONA, SPAIN jmiguel@tsc.upc.edu.

USING A STANDARD PC SOUND card and straightforward circuit, you can implement low-cost on/off control of home appliances via the Internet. The system consists of a local computer (located where you are) and a remote computer connected to a simple and inexpensive interface circuit with relay output (*Fig. 1*).

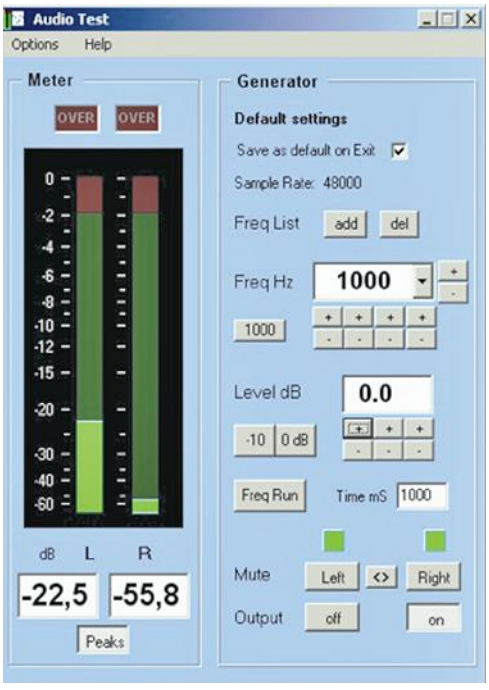
The local computer needs a browser and an application that offers access to the remote computer over the Web, as if you were sitting right in front of it. If you have installed Chrome as your browser, you can add Chrome Remote Desktop. If you use another browser, TeamViewer offers free remote access. This circuit also allows you to check from the local computer if the command is actually being executed.

In addition to the browser and remote-desktop access, an application to generate an audio tone through the sound card is needed at the remote computer. Dozens of these sinewave generators are available. One good choice is Audio Testset from Darkwood Designs. This free software also incorporates a level meter that measures the input-voltage level applied to the mic/line input of the computer's sound card (*Fig. 2*).

When you access to the desktop of the remote computer and operate the tone generator, a 1000-Hz, 2-V sinusoidal voltage

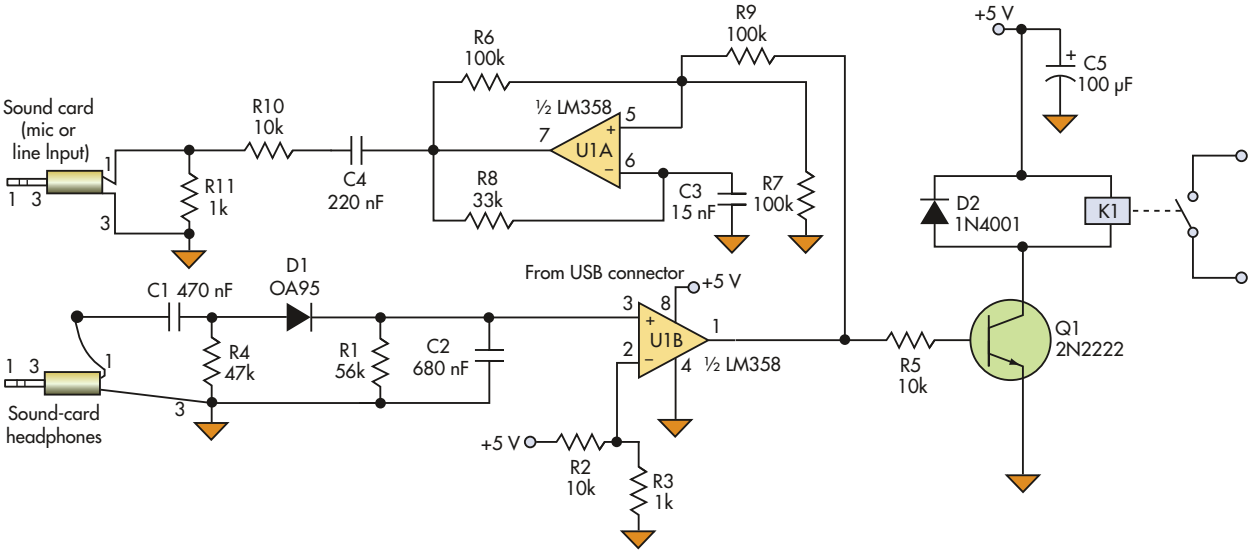


1. The system configuration shows how the functions connect to enable remote system control via the Internet, based on the use of a standard computer sound card.



2. A level meter with digital readout and combined with a sinewave test generator, such as this one from Darkwood Designs, is critical to the operational setup.

is available at the speaker output of the computer sound card. (Adjust the reproduction audio volume to the highest value.) This signal is connected to the input of the interface circuit, then rectified via germanium diode D1 and filtered by R1/C2 into a dc voltage that feeds the non-inverting input of a comparator built around one-half of op-amp U1 (*Fig. 3*).



3. The interface circuit uses common, standard components, with the filtered sound-card output driving a 2N2222 transistor that, in turn, controls the ac-line relay.

A 0.5-V signal is developed via the divider formed by R2 and R3 at its inverting input. In this way, when the tone generator is remotely activated, the comparator's output goes high and activates the relay K1 via transistor Q1. The relay switches the appliance load on and off, so be sure the relay contacts have sufficient peak and RMS voltage and current ratings. (Note that Q1, a 2N2222, can switch up to 800 mA, so select a relay with appropriate coil-current specifications.) Diode D2 clamps the inductive kick of the relay coil when it is de-energized.

When the comparator's output goes high, an audio-relaxation oscillator built around the other half of U1 is also enabled. The frequency of this oscillator is adjusted by R8 and C3 to be in the audio range (1300 Hz for the values indicated). The generated square wave is attenuated by R10 and R11 and feeds the line/mic input of the sound card. The level meter of the Audio Testset software then will detect it, showing it as a long green bar seen in the figure.

The computer's USB connector can provide the 5-V supply voltage for the circuit. Note that the system used one of the two channels of the computer sound card. Therefore, you can duplicate the interface circuit and control another appliance.

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All models are Reach compliant, RoHS compliant, conflict-mineral free, and have been qualified per the CB scheme with safety approvals to UL/cUL/IEC/EN60950-1 standards suiting the converters for use in any application where space is critical. The ultra-compact DIP-8 packaged MFW02 and MFW03 models are in stock and available now with prices starting at $8.26 each/500 for the 2 W single output models.

MINMAX

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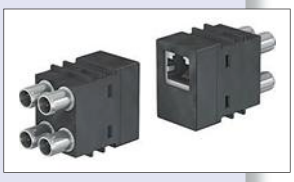
10 GbitE Modular Connector System Equipped for CAT6A



MULTI-CONTACT'S new CombiTac-10GBIT-RJ45 S combines power up to 300 A, signal, thermocouple, coaxial, fiber optic, pneumatic, and hydraulic connections in a single modular connector system. Built for applications requiring all-in-one space saving modular connectors that guarantee long life performance under the most demanding mechanical and environmental conditions, the 10 Gbit module meets high speed CAT6A Ethernet needs in industrial applications such as data communication from machines/equipment to manufacturing control networks, M2M and real time data sharing between facilities.

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STM32 MCU Embedded Development Offered for Linux Users

STMICROELECTRONICS is extending opportunities to design free of charge with its STM32 MCUs for Linux system users including professional engineers, academics, and hobbyists. While most development tools for embedded computing have been available only for Windows PCs, the STM32CubeMX configurator and initialization tool and the System Workbench for STM32 (SW4STM32), an IDE created by Ac6 Tools, supported by the openSTM32.org community, are now both available to run on Linux OS.

System Workbench for STM32 supports the ST-LINK/V2 debugging tool under Linux through an adapted version of the OpenOCD community project.

STMICROELECTRONICS

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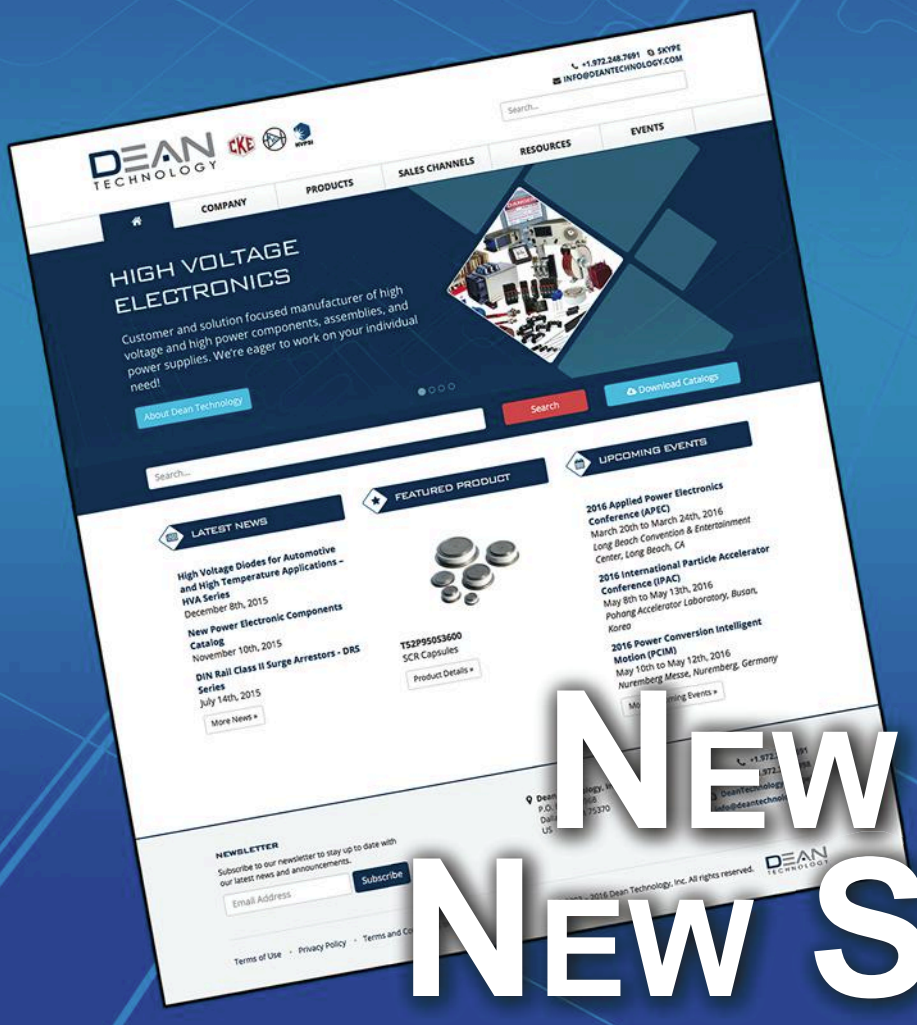

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FITARA-Compliant Network Emulator Supports High PPS Throughput

THE EDS-10/40G NETWORK emulator from East Coast Datacom supports copper or fiber Ethernet for 10/100/1000, 10 GbE, and 40 GbE WAN Emulation testing in one platform. The COTS hardware design supports high PPS throughput rates, and is fully FITARA hardware-compliant. FITARA compliance allows users to expand the capabilities of the system or replace system parts with Intel COTS hardware. The unit supports a host of user-defined options for network bandwidth, latency, jitter, packet loss, and other important network impairments. A pipelined software architecture exploits the power of Intel multicore XEON processors. Network I/O is sped up by new high-performance Intel network adapter cards, the Netmap software framework, and careful tuning of the Linux operating system

Stages of processing such as input, traffic selection, shaping and delay emulation, packet manipulations, and output are assigned to different cores, according to speed requirements and the complexity of the processing. This allows the emulator to scale performance as the number and speed of the LAN ports grow. Supplied in a 2U-high, rack-mount, or benchtop chassis, the EDS-10/40G network emulator has a list price of $16,995.

EAST COAST DATACOM
www.ecdata.com

MCUs with Integrated PLL Simplify EtherCAT Implementation

INFINEON TECHNOLOGIES seeks to reduce EtherCAT implementation complexity with its XMC4300 series of MCUs. Specifically developed for industrial applications that make high demands on design flexibility, connectivity, and real-time performance without compromise to EtherCAT communication features, the series targets applications comprising factory automation, industrial motor control, I/O modules, and robotics. The new series builds on the XMC4800 series, which places special emphasis on communication and actuators and sensors. Both series are integrated with EtherCAT node on an ARM Cortex-M processor with on-chip flash and analog/mixed signal capabilities.

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UPS Provides Cyber Security for Industrial Control System Backup

BEDROCK AUTOMATION'S cyber-secure UPS.500 standalone UPS for industrial-control system applications features onboard electronics that enhance the performance advantages of Li-Ion polymer battery technology, manage deep authentication cyber protection and enable secure Ethernet communications. The UPS provides 24 Vdc 12 Ah of power for any DCS, PLC, PAC, or SCADA RTU application. An onboard secure MCU controls the Li-Ion polymer battery cell-by-cell, augmenting its positive features. The onboard electronics enable the patented embedded deep trust ICS cyber security, which works transparently and instantly upon startup to manage the authentication process. And with the secure onboard MCU comes secure 10/100 Mbit Ethernet IPv4 and IPv6 communications

and support for SSL Embedded Web Server and embedded IEC 62541-OPC Unified ArchitectureServer. Bi-directional communications enable control, diagnostics and status reporting. More than 35 diagnostic variables can be monitored, trended, alarmed, and historicized via SCADA, enterprise, and cloud applications securely.

Encased in a sealed aluminum housing and compliant with IP67 and NEMA 4X standards, the UPS is rugged and shock- and vibration-proof for use in extreme environments. The Bedrock UPS.500 is due for delivery in June 2016 with a suggested price of $4,000.

BEDROCK AUTOMATION
www.bedrockautomation.com

Crimson-Enabled E3 I/O Platform Integrates Networking

A RUGGED E3 I/O MODULE platform from Red Lion Controls includes 17 high-density I/O modules with hardened metal enclosures and powerful communication options. Designed to withstand the critical demands of localized and distributed I/O applications, the Crimson 3.0 software-enabled I/O modules feature robust networking capabilities with redundant Ethernet ports and built-in serial communication. With one RS-485 terminal block and dual Ethernet ports that include user-selectable Ethernet modes for ring, pass through and two network, the E3 I/O modules can eliminate the need for additional switching devices. The modules also offer up to 34 mixed I/O points including input/output, analog/discrete and temperature I/O for complex industrial applications.

RED LION CONTROLS
www.redlion.net

Portable Power Source Offers 3 kV Medical-Grade Isolation

THE MD SERIES of rugged, portable medical-grade power sources from Triad Magnetics claim to safely and reliably isolate medical devices, diagnostic instruments, patient monitoring equipment, and electrical stimulus therapeutic equipment from the power line. The series is available with output voltage of 120 Vac in ratings from 250 VA to 2,400 VA, with two or four NEMA 5-15 receptacles. Units are available with 240 Vac or 120 Vac input and feature 3 kV galvanic isolation, 5% no-load to full-load regulation, and 92% typical efficiency at full load and less than 10 µA typical leakage.

The construction of the MD Series toroidal transformer minimizes leakage currents from the power line through to the patient and equipment. The series offers the capability of providing medical-grade power to several different instruments within the space of a patient's room. The MD Series of power sources are priced ranging from $136.87 each/10 for the 250 VA models to $457.69 each/10 for the 2,400 VA models.

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BILL WONG | Embedded/Systems/Software Editor
bill.wong@penton.com

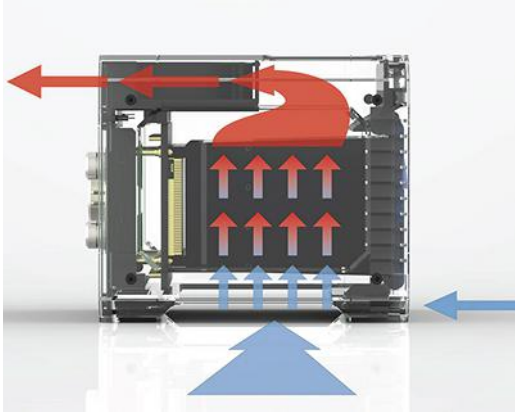
KISSing Costly Cooling Solutions Goodbye

The VITA 48.8 is following the KISS principal to provide low-cost air cooling to rugged VPX systems.

Cooling is always a challenge in rugged embedded applications, especially military applications. Air-cooled systems tend to be easier to work with, but often do not have the cooling capacity of conduction-cooled systems. It is also not a great idea to just blow air across components as in a conventional PC or laptop, given the rugged target environment.

The emerging VITA 48.8 Air Flow Through (AFT) standard aims to keep 3U and 6U VPX systems cooler with more efficient air cooling while still enclosing the boards. A typical system would have air flowing up between boards in the system (*Fig. 1*). The spacing is the key as the actual air flow is something that can be done on a per-system basis. More novel design flows can be critical to the success of rugged system designs that may be deployed in compact drones or other aircraft.

SWAP-C (size, weight, power and cost) is the watchword for rugged embedded systems and VITA 48.8 is designed to address the high power densities (as high as 200 W per square centimeter) that are being seen in the aerospace and defense industries. VITA 48.8 allows heatsinks to be attached directly to metal sidewalls on both sides of the board. The sidewalls are air cooled in addition to protecting the components on the interior. The approach also allows VITA 57 mezzanine cards to be incorporated into the cooling framework.



1. VITA 48.8 uses a combination of conduction and convection cooling. Heatsinks attach directly to sidewalls that are then air-cooled.

The module system follows the KISS principle by eliminating the use of wedgelocks and ejector/injector handles commonly found on rugged VPX systems. This reduces cost and weight in addition to simplifying the system design.

Curtiss-Wright Defense Solutions recently displayed a functional prototype implementation (*Fig. 2*) of VITA 48.8 at the 2016 Embedded Tech Trends conference. Ivan Straznicky, Curtiss-Wright Defense Solutions CTO & Technical Fellow, Chair of the VITA 48.8 working group, notes, "VITA 48.8 will cool high-power and high-power-density modules. For example, Curtiss-Wright has analyzed and designed AFT for 3U modules with high heat density processors and a total of 70W on a basecard, plus 25-30W on mezzanine cards, for a total of 95-100W."

2. Curtiss-Wright Defense Solutions was showing preliminary VITA 48.8 systems at the 2016 Embedded Tech Trends conference.

The standard does not use module-to-chassis conduction cooling. This allows the chassis to be made of different materials such as lightweight plastic or composite materials. The demonstration chassis was actually built using a 3D printer.

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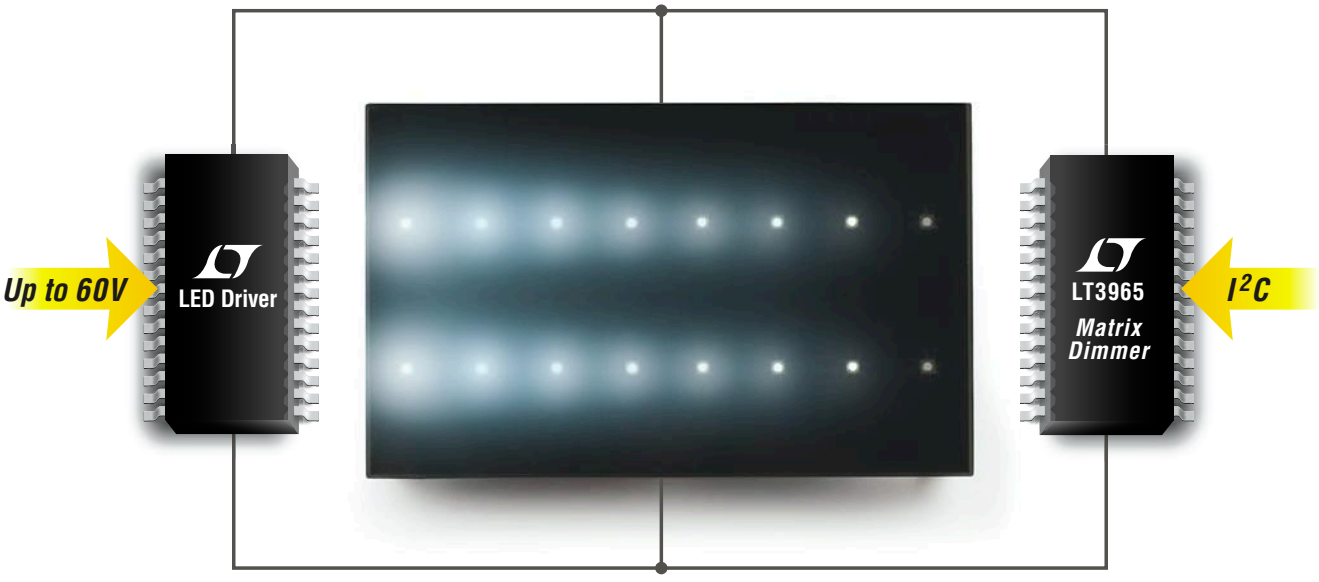
Matrix LED Dimmer



Any Brightness, Any Pattern with I²C Control

The LT®3965 is an eight channel LED bypass switching device with I²C serial interface, designed for dimming individual LEDs in a string using a common LED driver current source. Each of the eight channels can be independently programmed to bypass the LED string in constant on or off, or PWM dimming with or without fade transition. The LT3965 uses eight individually controlled floating source N-channel 17V/500mA MOSFET switches, enabling it to drive one to four LEDs per channel. Up to 16 LT3965s can be used on the same bus for larger LED arrays.

Features

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- Independent Brightness per Switch
- I²C Serial Communication
- 1-4 LEDs per Switch
- Synchronized Flicker-Free Dimming

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