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Issue 23/2011
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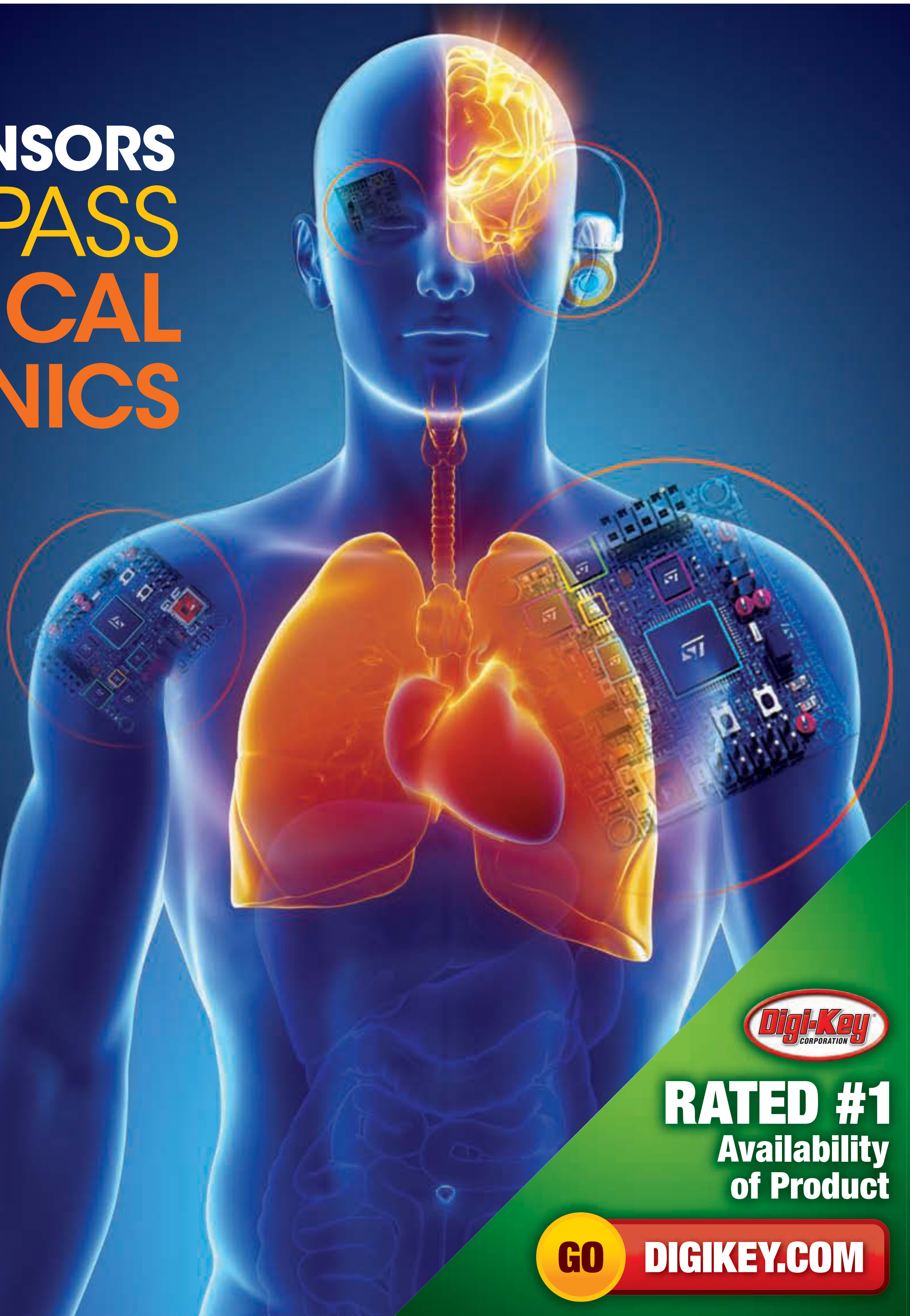

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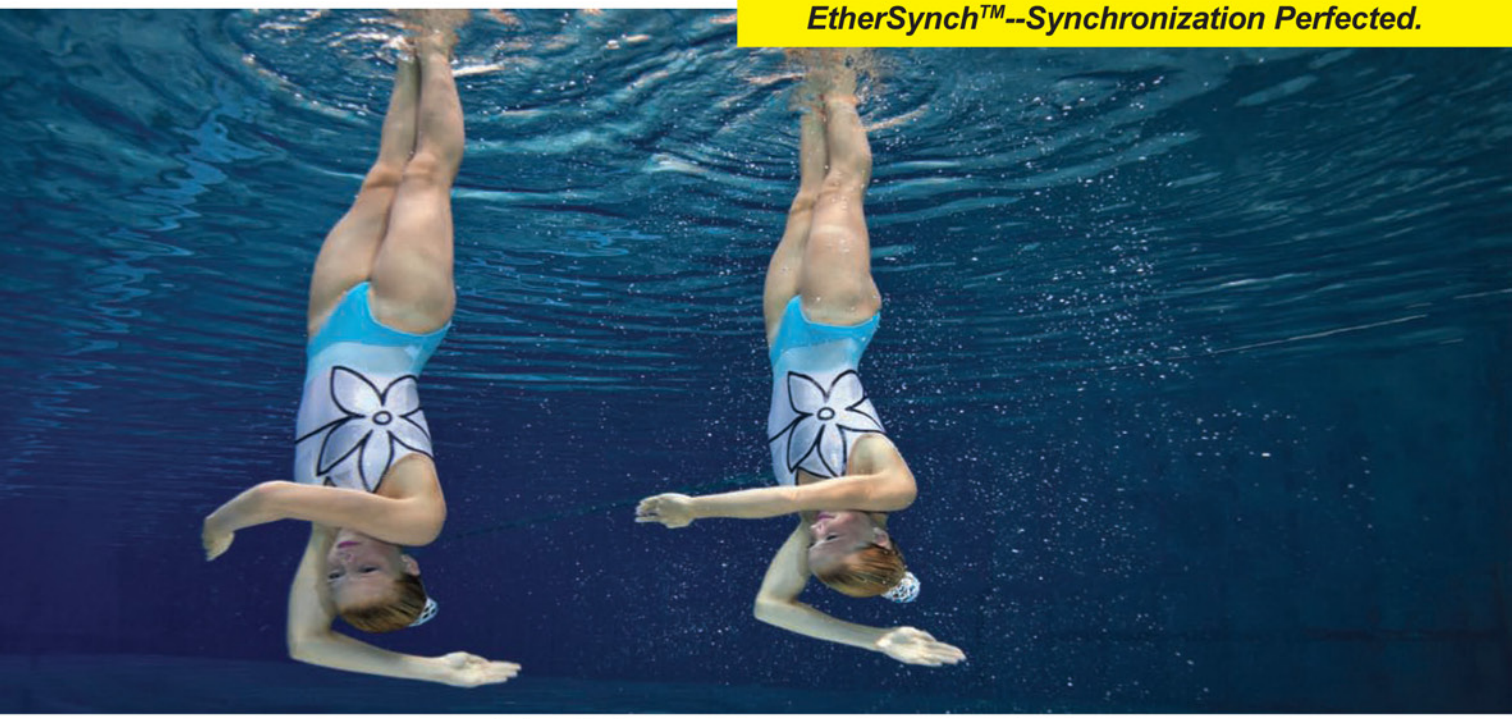

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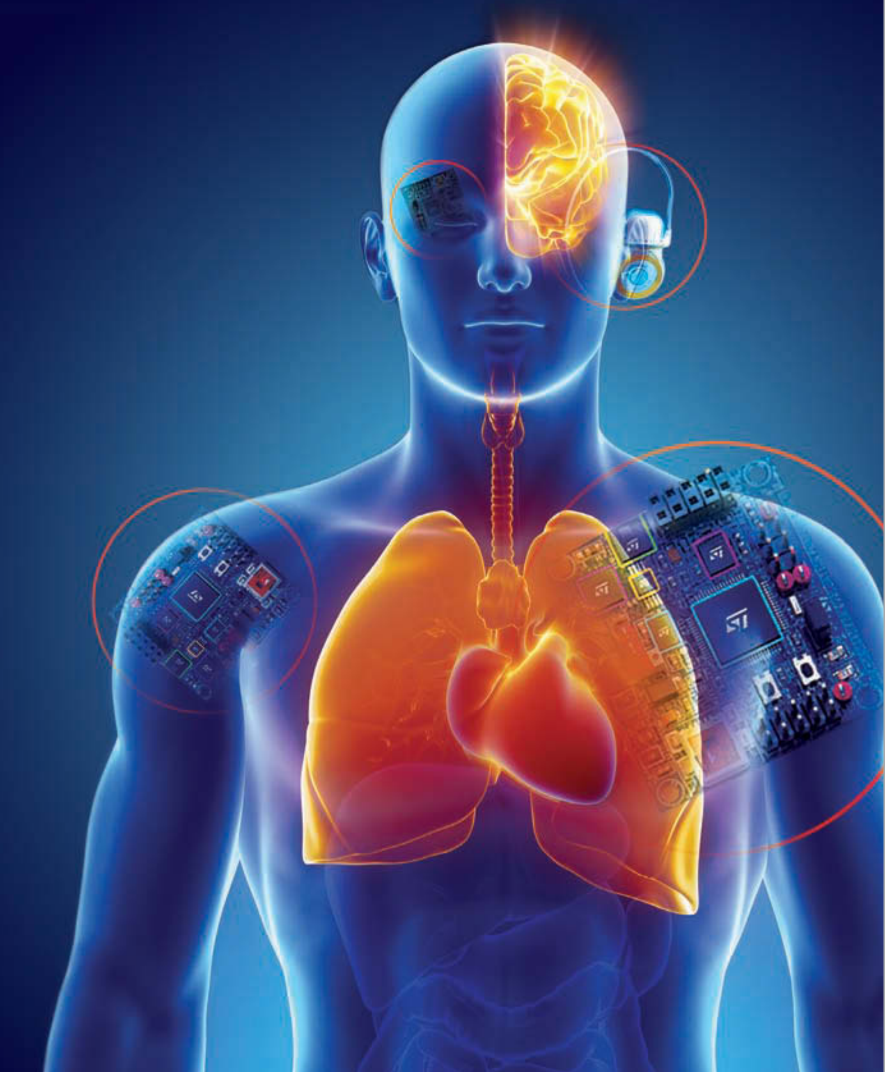

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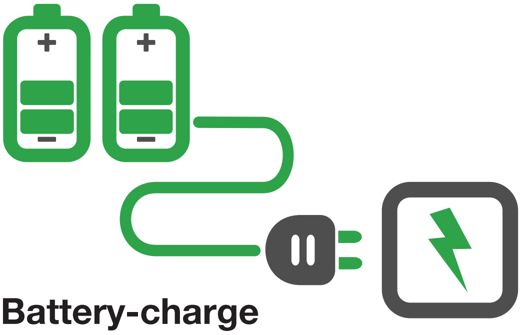
34 Eye, ear, lung, heart, and brain enhancements are now possible as modern electronics technology meets advances in medicine and biology.

by Steve Taranovich, Contributing Technical Editor



Battery-charge control: dedicated ICs or microcontrollers?

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43 Understand the role and implementation of the flyback topology in this application.

by Peter B Green, International Rectifier Corp

IMAGE(S): SHUTTERSTOCK; COURTESY OF MEDEL

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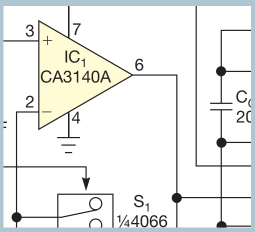

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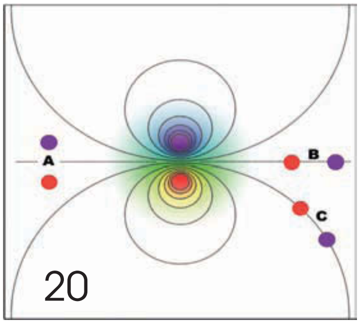
DEPARTMENTS & COLUMNS



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JOIN THE CONVERSATION

Comments, thoughts, and opinions shared by *EDN*'s community

The following two comments are in response to "School daze: Do you need a degree to be a real engineer?" In this editorial, Suzanne Deffree poses the headline's question to *EDN*'s audience. Readers have posted more than 100 comments in a lively conversation. Share your own comment here: http://bit.ly/ufNtR1.

Al W from Houston commented:

"I am frankly amazed at the many comments that implicitly assume that a degree equals education. By the same logic, anyone who has a driver's license must be an Indy 500 driver and anyone who doesn't must either not know how to drive or is a terrible driver. ...

"Here's a dirty secret: You can learn anything you want. It helps many people to have guidance from someone like a college professor, but that is only one way to learn. Perhaps many people who don't get a formal education don't take the trouble to get a full education, but some do, and it is silly to imply there is no way that could be true."

"KDC" from Kansas commented:

"Education is the most important step your children will take. It defines what doors will be open and the quality of life they will lead because it will determine their earning potential. Engineers without degrees typically do not have the technical background required to handle all of the problems and issues that come up in real-life engineering. I work at a plant where several nondegreed engineers work, all of them were promoted [due] to their performance. They usually are very good in a narrow field of interest. Their job prospects outside this plant are limited due to the lack of a degree, and this [lack] limits their earning potential."

EDN ***invites all of its readers to constructively and creatively comment on our content. You'll find the opportunity to do so at the bottom of each article and blog post. To review current comment threads on EDN.com, visit http://bit.ly/EDN_Talkback.***

CONTENT

Can't-miss content on EDN.com

PROGRESS IN SMALL LED LIGHTS: HIGH-VOLTAGE LEDs AND SECONDARY PHOSPHORS

Small lights represent a significant market in both the United States and Europe. LED-replacement lights compete on a level playing field for these devices because they don't face price-subsidized CFL products as they do in the Edison-bulb-replacement market. However, they can be, to put it delicately, unattractive in your light fixture. Here's how Cree is addressing the problem.

http://bit.ly/rGfxfq

PHOTOS: TOUR OF THE NASA AMES SUSTAINABILITY BASE GREEN BUILDING

EDN's Paul Rako recently took a tour of the environmentally conscious NASA Sustainability Base building, which the agency claims is like no other government building. In this blog post, Rako shares photos from the tour as well as comments on what he saw inside the building.

http://bit.ly/vMttXd

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DESIGNVISION AWARDS
• 2012 •

Submissions are now being accepted for the 2012 DesignVision Awards. Categories include PCB-design tools, semiconductor and IP, design-verification tools, interconnect technologies and components, IC-design tools, system-modeling and simulation tools, semiconductor components and ICs, and test-and-measurement equipment. Nominations will be accepted until Jan 6, 2012, and can be submitted here: **http://2012.designcon.com/designvision_awards**. Find more information on DesignCon at **http://www.designcon.com**.

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BY PATRICK MANNION, DIRECTOR OF CONTENT

3-D IC standards are great, but do we care?

Next month's DesignCon 2012, which will take place in Santa Clara, CA, will host many interesting panels, including "Why do we need 3-D design standards?" As cutting edge and exciting as that title sounds, it may be asking the wrong question, however. The right question may be, Do the economics of 3-D make sense, and who takes the fall when things go wrong?

Many people have written volumes about 3-D IC packaging; *EDN* also recently covered it (**Reference 1**). As the old saying goes, "When all's said and done, there's more said than done." With regard to 3-D ICs, alas, this saying is particularly true. Chi-Ping Hsu, PhD, senior vice president of Cadence's Silicon Realization Group, sums it up. Although acknowledging it makes sense in certain applications, such as mobile devices, and with vertically integrated manufacturers, such as Intel, Hsu suggests the problem elsewhere comes down to the almighty dollar—and the blame game.

"Why [do it]?" asks Hsu. "Who is accountable, and who makes the money and at what stage?" Knowing that different silicon sources have different ways of manufacturing TSVs (through-silicon vias), "who's fault is it when you have three dice, and it doesn't work?" he adds.

Other issues include handling fragile KGD (known-good die) and rework when things go awry. With multichip modules, the handling of KGD was a problem, but you could at least swap out a module if it were defective. That approach is more difficult with tightly packaged die with 10,000 interconnects per die. For now, according to Hsu, 2.5-D technology with bumped die on an interposer with associated logic is the way to go because it allows for rework and avoids the economics and the blame game.

Hsu's pragmatism quickly leads us to a brief discussion of more practical approaches to today's problems and to what may have been one of the least-hyped announcements of the year. While all media eyes this year were on 3-D IC design, Cadence was continuing to update Virtuoso IC 6.1, which includes the OA (Open Access) database. (Cadence developed OA and donated it to Si2, the Silicon Integration Initiative.) Users had previously been employing the CDB (Cadence database); the move to OA allowed design teams to save data in a format that other EDA vendors' tools could use.

According to Hsu, the move to OA is a move to a new generation of technology that shifts designers from connectivity-based design to intent-based design by abstracting them from the underlying details. "We want designers to focus on creativity versus engineering," he says. The end result is a 40% savings in project time, according to Hsu. The approach does raise questions, however, about what students preparing for the work force will require, but that topic is a separate discussion.

So, although 3-D may not be ready for prime time, and EDA companies—wisely, I might add—focus on problems resolvable and practical in the here and the now, the DesignCon panel does explore a key issue for 3-D enablement—namely, the need for IC standards to accelerate the adoption of 3-D design. It will look at how the standards can be implemented, the priority of those standards, the challenges, and how the industry is meeting those challenges.

Those ideas may whet your appetite for the rest of the conference, which features a track focusing on analog and mixed-signal design and verification and tracks on system chip, board, and package co-design and chip-level design for signal and power integrity. The panel on 3-D standards is part of the system-co-design track and features as speakers Sumit DasGupta from Si2, Liam Madden from Xilinx, and Raj Jammy from Sematech.

I'll be at this year's conference looking for both leading-edge explorations and practical approaches to real-world problems. See you there. **EDN**

REFERENCE

1 Demler, Mike, "EDA tools pave the path to 3-D ICs," *EDN*, June 9, 2011, pg 26, http://bit.ly/uKDUI6.

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SUDDEN SERVICE

GTRI opens compact range for antenna and radar-cross-section measurements

The Georgia Institute of Technology's GTRI (Georgia Tech Research Institute) has opened a compact range for radar-cross-section measurements and antenna testing, which can also be reconfigured to operate as an anechoic chamber. GTRI will use the EMI-shielded facility for defense-related research projects and collaborations with outside organizations.

The facility, in midtown Atlanta, has a test zone that is approximately six feet wide, four feet tall, and six feet deep. It can test at frequencies of 2 to 100 GHz and that extend down to 800 MHz. Metal walls and doors surround the new range and protect it from EMI from a broad range of sources.

The range's integrated mobile absorber wall covers the compact-range reflector, allowing the facility's use as an anechoic chamber. The facility also features a quiet zone; dual polarized, quasi-monostatic broadband feeds; a gated continuous-wave radar-cross-section and acquisition system; anechoic-absorber treatment with a Chebyshev patch; and overhead target-handling and radar-cross-section target support.

Compact ranges can test phenomena that would otherwise require much larger outdoor test facilities. For instance, radar-beam patterns normally take several miles to spread out and become flat once they leave a transmitter. The compact range's reflectron, in contrast, spreads out the pattern in a few dozen feet, allowing testing to take place indoors.

Foam absorbers that surround the interior of the facility attenuate signals and prevent them from scattering, meaning that signals from the transmitter return to the receiver only from the target and yielding clean measurements. "The design allows us to get a realistic picture of what the beam would look like if the transmitter were miles away," says Stephen Blalock, a GTRI senior research technologist who manages the facility. "This [ability] is essential for signature measurements, where we are trying to replicate what would be happening in a real-world scenario."

—by Fran Granville

▷**Georgia Institute of Technology**, www.gatech.edu.

Researchers adjust a target for testing in GTRI's new compact range (courtesy Gary Meek, Georgia Institute of Technology).

TALKBACK

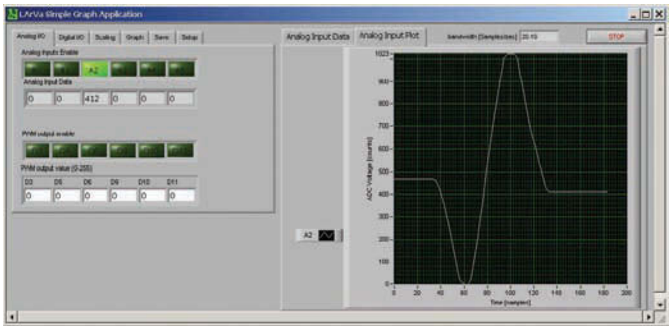
"Whether you have the sheepskin or not, what you learned in school is just the beginning. If you ever *stop* learning, you'll fail … whether you're 22, 42, or 62."

—Engineering fellow Alan Ritter, in *EDN*'s Talkback section, at http://bit.ly/tv2FL4. Add your comments.

Build a data-acquisition system for about $30

Many vendors offer development boards for Arduino, an open-source hardware microcontroller with its own development environment. The latest board, the Arduino Uno, costs less than $30 and is available from a variety of vendors. Hobbyists have developed most of the Arduino applications to date, but that situation may be changing. With six 12-bit ADCs; 14 digital-I/O pins, six of which can perform PWM output; simple serial communications over USB; and a low price tag, Arduino is now showing up in professional applications.

For example, Angstrom Designs has recently released a free driver that turns the Arduino into data-acquisition hardware. The LARVA (LabView Arduino) driver features automatic firmware uploading, onboard data averaging, and variable communication rates. It also accesses Arduino's ADCs, PWM, and digital-I/O pins. Angstrom offers a free LARVA simple graph application at www.angstromdesigns.com/larva/download. The installer includes the driver, the LabView source code, an executable file, and support files. You can use the source code as a starting point for projects, including data acquisition, temperature monitoring and control, and PWM motion control. Angstrom Designs also provides application notes on voltage and temperature data acquisition.



Analog Input Data: 0 0 412 0 0 0

PWM output value (0-255): D3 0, D5 0, D6 0, D9 0, D10 0, D11 0

The LARVA driver features automatic firmware uploading, onboard data averaging, and variable communication rates.

With a 16-MHz, 8-bit Atmel microcontroller at its core, Arduino isn't right for high-end test-and-measurement applications. With solid features and an affordable price, however, it meets the needs of many projects. It's too soon to tell, but Arduino may mark the introduction of open-source hardware into professional test-and-measurement systems. **—by Casey Hare**

▷**Angstrom Designs**, www.angstromdesigns.com.

14-bit capacitive-sensor conditioning IC supports a range of sensor types

ZMDI has expanded its family of capacitive-sensor signal-conditioning devices with the wide-dynamic-range ZSSC3123 IC. The chip delivers 14-bit resolution and 0.25% accuracy over a range of sensor capacitances and temperatures. Target applications include low-power-battery-driven sensor applications for humidity, weight scales, load and compression sensing, and tension control. The device suits MEMS-based sensor elements, such as pressure sensors for hydraulic-control systems, humidity sensors, and liquid-level gauges. The ZSSC3123 connects to microcontrollers, but you can also use it in stand-alone designs for transducer and switch applications.

The ZSSC3123 can be configured to interface with 0.5- to 260-pF capacitive sensors. At supply voltages of 2.3 to 5.5V, the device is accurate to 0.25% over the –20 to +85°C range and 0.5% accurate from –40 to +125°C.

You can use the device in both single- and differential-input sensor configurations. It features an operating current as low as 60 μA over 2.3 to 5.5V. A built-in sleep mode lowers the current consumption to less than 1 μA for temperatures as high as 85°C. The IC has sensitivity as low as 125 aF per digital bit.

The part provides SPI and I^{2}C interfaces as well as PDM or alarm outputs. It uses digital techniques to correct both first- and third-order nonlinearity errors. Third-order correction is especially useful in humidity and pressure applications. Programming and single-pass calibration of the capacitive sensor and the ZSSC3123 are accomplished through a standard PC environment using the TSSOP14 development board and calibration software.

The ZSSC3123 is available in die form and in a 14-pin TSSOP with a suggested retail price of $3.82 (1000). It operates over a –40 to +125°C temperature range. **—by Paul Rako**

▷**ZMDI**, www.zmdi.com.

DILBERT By Scott Adams

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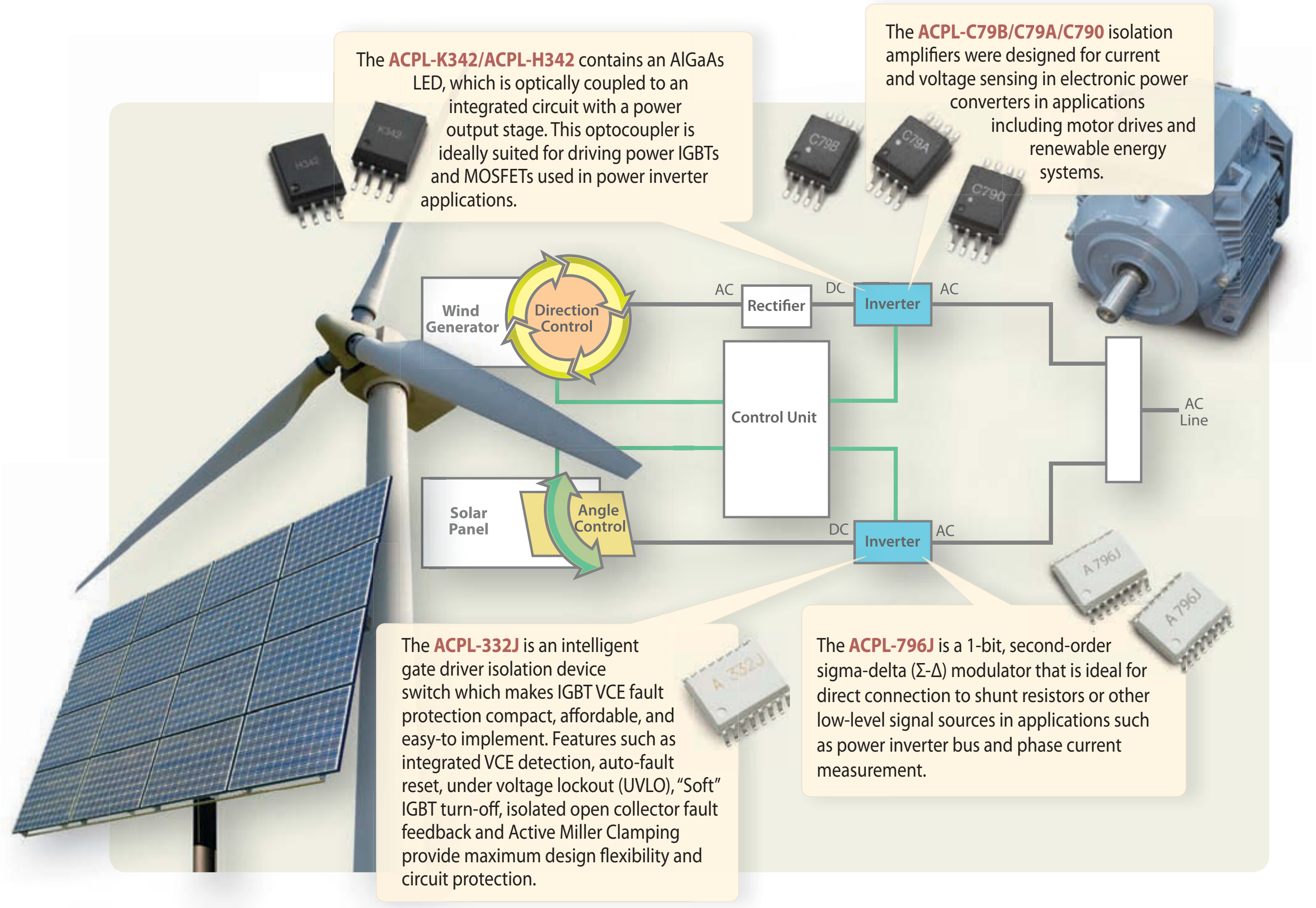

The **ACPL-K342/ACPL-H342** contains an AlGaAs LED, which is optically coupled to an integrated circuit with a power output stage. This optocoupler is ideally suited for driving power IGBTs and MOSFETs used in power inverter applications.

The **ACPL-C79B/C79A/C790** isolation amplifiers were designed for current and voltage sensing in electronic power converters in applications including motor drives and renewable energy systems.

The **ACPL-332J** is an intelligent gate driver isolation device switch which makes IGBT VCE fault protection compact, affordable, and easy-to implement. Features such as integrated VCE detection, auto-fault reset, under voltage lockout (UVLO), "Soft" IGBT turn-off, isolated open collector fault feedback and Active Miller Clamping provide maximum design flexibility and circuit protection.

The **ACPL-796J** is a 1-bit, second-order sigma-delta (Σ-Δ) modulator that is ideal for direct connection to shunt resistors or other low-level signal sources in applications such as power inverter bus and phase current measurement.

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PMC packs security in SAS controllers

PMC-Sierra Inc has rolled encryption technology into two new versions of its 6-Gbps SAS (serial-attached small-computer-system-interface) controllers. The Tachyon SPCve chips let storage-array designers provide embedded security as an alternative to external appliances, software, self-encrypting drives, or separate security chips.

> The chips work with hard drives or flash disks and have four engines that handle inline encryption and decryption of data at approximately 6 Gbytes/sec.

"We are in the datapath, and this [area] is the right place to handle security because the chips also can help control other storage functions, such as compression and de-duplication," says Kevin Burbank, director of marketing for enterprise storage at PMC.

The company announced eight- and 16-port versions of the security-enabled SAS controllers. Three years ago, PMC unveiled a similar set of Fibre Channel controllers with embedded security.

The new chips can work with hard drives or flash disks. They include four hardware-encryption engines that handle inline encryption and decryption of data at throughput of approximately 6 Gbytes/sec, about 90% of the maximum SAS data rate.

The chips have similar package and power requirements to those of controllers without security. They will sell for approximately 50% more than parts without security features. The new devices support the IEEE 1619 standard and 256-bit AES (Advanced Encryption Standard) encryption keys.

PMC provides security APIs and reference software along with the chips. The components ride an eight-lane PCIe 3.0 bus. The SPCve PM8009 and PM8019 devices are available for sampling, and production will begin in the first quarter of next year. **—by Rick Merritt**

▷**PMC-Sierra**, www.pmc-sierra.com.

The Tachyon SPCve chips let storage-array designers provide embedded security as an alternative to external appliances, software, self-encrypting drives, or separate security chips.

Boost-charger IC targets nanopower energy harvesting

12.01.11

Texas Instruments' bq25504 power-management ICs target use in nanopower energy harvesting from solar, thermoelectric, electromagnetic, and vibration systems and store the extracted energy in various storage elements, including lithium-ion batteries and supercapacitors. The bq25504 also includes circuitry to protect the energy-storage element from overvoltage and undervoltage conditions and to kick-start the system when the battery is deeply discharged. In a solar panel powering a handheld device that is operating in indoor light conditions, for example, the new boost charger increases the usable harvested energy by 30 to 70% compared with a linear regulator. This efficiency allows designers to reduce the size and the number of solar panels in their designs, thus reducing overall cost. The device can benefit wireless-sensor networks for area, industrial, water/waste, and structural monitoring, along with consumer, high-reliability, and medical applications.

The device has a typical quiescent current of 330 nA and conversion efficiency of greater than 80% MPPT (maximum power-point tracking) optimizes the energy the device extracts from dc harvesters, such as solar panels under varying light conditions and thermoelectric generators under varying thermal conditions. User-programmable settings allow you to use the boost-charger IC with a variety of energy sources and energy-storage elements, such as different battery chemistries or supercapacitors. A typical low cold-start voltage of 330 mV allows the bq25504 to start up from single-cell solar panels under low light, as well as thermoelectric generators with low temperature differences and other low-voltage sources. A battery-OK indicator allows conditional enabling of external loads and protects the storage element.

TI offers tools and support to speed the implementation of ultra-low-power energy harvesting, including the bq25504 evaluation module and an evaluation-module user's guide. The bq25504 is available in a 3×3-mm VQFN package and sells for $2.10 (1000).

—by Fran Granville

▶**Texas Instruments**, www.ti.com.


CENTELLAX ED32 Error Detector
CENTELLAX PG32 Pattern Generator
CENTELLAX SSB16000J

Kinetis microcontrollers operate at frequencies as high as 200 MHz

Freescale Semiconductor has introduced the Kinetis series of microcontrollers with an operating frequency as high as 200 MHz. Employing an ARM Cortex-M4 core and DSP and floating-point instructions, the X series includes 1 to 4 Mbytes of flash memory and 0.5 Mbyte of SRAM, with multiple off-chip memory options also available for expansion head room. The X series offers an advanced suite of connectivity, security, and HMI (human-machine-interface) peripherals, all with Freescale's bundled software enablement. This combination of processing performance, feature integration, and support makes the Kinetis X series optimal for automation applications, point-of-sale systems, medical instrumentation, test-and-measurement equipment, and systems with an HMI.

The Kinetis X series includes several hardware-acceleration techniques to maximize system performance by freeing the core from memory-access limitations and peripheral-servicing constraints. These techniques include large on-chip instruction and data caches that maximize CPU efficiency, 32 kbytes of tightly coupled SRAM for single-cycle access to scratchpad data, and a 64-channel DMA (direct-memory-access) controller that offloads general peripheral and memory-servicing tasks from the CPU. The X series also includes a 64-bit AXI (Advanced Extensible Interface) bus that increases concurrent data-transfer capabilities from several bus masters.

According to Geoff Lees, vice president of Freescale's industrial and multimarket-microcontroller business, factory automation is driving up performance. "We have seen some customers starting to look at application processors, but they realize that a Linux system does not provide the real-time capabilities," he says. Kinetis X allows you to address virtually any type of external memory, including NOR and NAND flash, serial flash, SRAM, and low-power DDR2 and DDR3. The devices also allow you to perform XIP (execute-in-place) functions from NOR or quad-SPI flash.

To enable the acquisition requires the secure, real-time process and display of a large number of system parameters. Kinetis X series addresses these requirements with Ethernet, high-speed USB OTG (On-The-Go), CAN (controller-area-network), I^{2}S (inter-IC-sound), and serial-communication interfaces, as well as cryptographic acceleration and tamper-detection units.

Applications that require a GUI (graphical user interface) can select from a low-power segment LCD or graphics-LCD controller. The on-chip SRAM supports graphics-LCD panels with resolution as high as 432×240 pixels without an external frame buffer. You can increase this resolution using external, 8-bit DRAM. To aid the development of embedded GUIs, the Portable Embedded GUI WindowBuilder suite and a low-resource eGUI LCD driver are available.

Software and tool support includes Freescale's MQX real-time operating system with integrated TCP/IP (Transmission Control Protocol/Internet Protocol) and USB stacks and support for low-cost or free graphics LCD and encryption plug-ins. The devices also bundle the Eclipse-based CodeWarrior 10.x integrated development environment with Processor Expert, providing a visual, automated framework to accelerate the development of complex embedded systems.

Kinetis Tower System modules and a growing range of Tower System peripheral modules, including Wi-Fi, sensing, and precision analog, also ease design. The ARM ecosystem, including development tools from IAR Systems, Keil, and Green Hills, also provides support. Freescale plans to introduce a software-development platform before the arrival of silicon to reduce customers' software-development-cycle time. This announcement follows a similar one that accompanied the introduction of a platform that integrated ARM Cortex-M4 and -A5 cores. A bundle includes Freescale or third-party tools, and testing for compatibility is under way. **—by Colin Holland**

▷**Freescale**, www.freescale.com.

> “Hardware-acceleration techniques maximize system performance.

Hot-swap I^{2}C-bus buffers provide high noise margins

The high-noise-margin LTC4313 and LTC4315 buffers provide capacitance buffering and bus extension to I^{2}C, SMBus (system-management-bus), and PMBus (power-management-bus) systems. The devices have a guaranteed minimum logic-input voltage of 0.3 times the common-collector voltage, allowing them to operate with noncompliant I^{2}C devices that drive a high logic-low output voltage. You can connect a number of the devices in series, improving the reliability of communications in large, noisy systems.

The LTC4313 and LTC4315 suit use in computing, networking, and data-storage systems that use multiple I/O cards with different supply- and bus-voltage levels. They provide automatic level translation from systems with voltages as low as 1.4V to systems with voltages as high as 5.5V.

The high-noise-margin LTC4313 and LTC4315 buffers provide capacitance buffering and bus extension to I^{2}C, SMBus, and PMBus systems.

The LTC4315 has a second supply pin, allowing the use of separate input- and output-bus-pullup supplies. Rise-time accelerators provide pullup currents during bus rising edges that reduce rise time, resulting in reduced power consumption and improved logic-low noise margins. The LTC4313 provides a strong slew-limited switch or a 2-mA-current-source rise-time-accelerator current. The LTC4315 provides a pin-selectable, strong slew-limited switch rise-time-accelerator current.

The LTC4313 comes in an eight-pin, 3×3-mm DFN package or an eight-lead MSOP, and the LTC4315 comes in a 12-pin, 4×3-mm DFN package or a 12-lead MSOP. Prices start at $2.40 (1000).

—by Fran Granville

▷**Linear Technology Corp**, www.linear.com.

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BY HOWARD JOHNSON, PhD

Quadrature-via layout

Figure 1 illustrates the pattern of magnetic fields emanating from a pair of vias carrying a purely differential signal. The **figure** looks down on a multilayer PCB in plan view, showing the two signal vias, purple and red, in the center. The curving lines represent magnetic lines of force trapped between solid reference-plane layers.

If you place a second via pair anywhere on the diagram, the degree of differential crosstalk that the second pair receives varies according to the number of magnetic lines of force that pass between the two elements of the second pair. For example, consider the straight horizontal line running through the center of the diagram. It passes directly between the two vias on the left that form via Pair A. According to Faraday's law, that magnetic line of force creates crosstalk at A.

Because the diagram shows only a few field lines, some areas appear completely devoid. This lack of lines does not make crosstalk zero within those zones. If you imagine a diagram with hundreds or thousands of lines, you can see that the crosstalk is never zero at any point, but it is substantially less in areas in which the lines have more distance between them, and it varies smoothly from point to point.

Imagine sliding via Pair A to the right, halving its distance to the central pair. In that new position, three field lines penetrate the space between the purple and the red elements of Pair A, substantially increasing the crosstalk it perceives. As you push more to the right, further decreasing the distance, crosstalk increases markedly. In general, differential-to-differential crosstalk varies inversely with the square of distance, much like the differential-to-differential crosstalk between PCB traces (**Reference 1**).

Now consider via Pair B on the right side of the **figure**. The axis of this pair lies parallel to the magnetic lines of force so that no lines penetrate between its purple and its red elements. Fabulous! With this orientation, the central via produces no differential-mode crosstalk at B. In a long row of differential via pairs, turning every other pair in this way suppresses all nearest-neighbor differential crosstalk—a good plan and one that I am surprised I don't see more often.

Quadrature layout is not a new idea. If you look at multichannel analog circuitry from the mid-20th century, such as telephone exchanges or high-fidelity recording equipment, you'll see oodles of audio transformers, mounted in rows, with every other transformer turned 90° with respect to its nearest neighbor. Such physical arrangements successfully mitigate differential crosstalk from nearby aggressors. Quadrature layout does nothing to mitigate common-mode crosstalk, but at least it nails the differential mode.

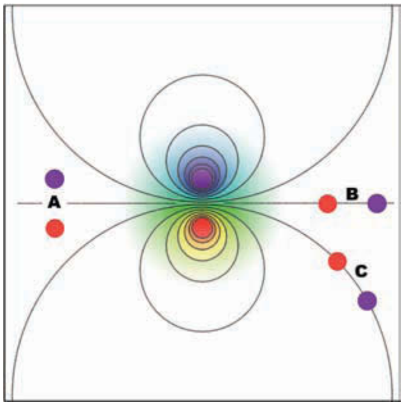

Figure 1 A pair of vias in differential mode creates a highly predictable pattern of crosstalk.

The magnetic-field diagram admits one additional interpretation: the 2-D scaler magnetic potential. This concept applies to all situations involving parallel conductors, such as long cables, PCB traces, and arrays of vias. The 2-D potential interprets the magnetic-field diagram as a topographic contour plot, with the purple signal via perching atop a hill and the red signal via sitting down in a valley. The lines of magnetic force represent contours of constant height, or potential. The key insight you can derive from this method is simple: Any two elements on the same contour, or at the same potential, exhibit zero differential crosstalk between them. At position C, for example, the two vias lie along the same line of magnetic force. That alignment eliminates differential-mode crosstalk from the central source (**Reference 2**). The way the contours work, no matter where you place a differential via pair, you can always rotate its alignment to mitigate crosstalk from a troublesome differential source. EDN

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Howard Johnson, PhD, of Signal Consulting, frequently conducts technical workshops for digital engineers at Oxford University and other sites worldwide. Visit his Web site at www.sigcon.com.

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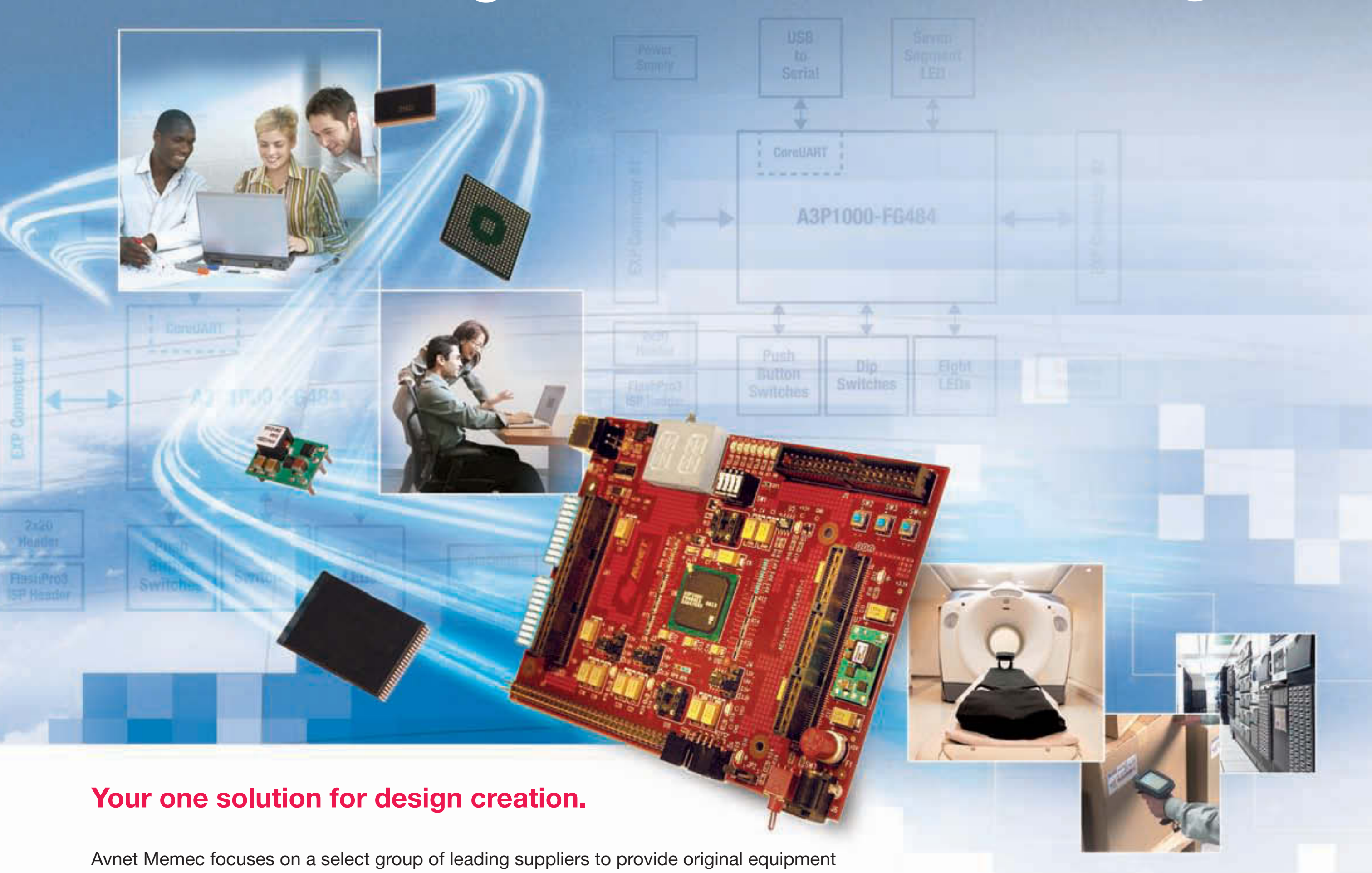

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BY PALLAB CHATTERJEE, CONTRIBUTING TECHNICAL EDITOR

Driving toward millivolt electronics

Thanks to new behaviors and the characteristics of materials at small geometries, nanotechnology has the potential to introduce great change to the electronics arena. The University of California—Berkeley's Center for E^{3}S (Energy Efficient Electronics Science) is working to develop fundamental devices that will result in a millionfold reduction in power for future generations of electronic systems.

The overall goal of the center, which receives its funding from the National Science Foundation, is to develop high-performance devices and circuits that require low power to run. Current electronics nominally operate at 1.25 to 5V. The E^{3}S Center is researching devices that can operate at millivolts. The more-than-1000-mV reduction in required power would result in a power-reduction factor of 1 million, assuming that power is proportional to voltage squared.

Eli Yablonovitch, PhD, leads the research group, which focuses on nanoelectronics, nanomechanics, nanophotonics, nanomagnetics, and system integration (**Figure 1**). The nanoelectronics program focuses on eliminating the voltage mismatch between devices, allowing circuits to operate on just a few millivolts of supply power and still have a large enough noise margin. The group is investigating switches—from the level of modulating thermionic-emission current over a barrier to the level of modulating the tunneling current through a barrier. The challenges include modeling and tuning tunneling probability and identifying and manufacturing materials exhibiting the desired band-edge-energy alignment.

Tsu-Jae King Liu, PhD, leads the nanomechanics research team in addressing the off-state leakage in CMOS switches, which sets a lower limit in energy per operation. Mechanical switches have zero off-state current. The mechanical switches have a speed limitation of reaching saturation at the speed of sound at approximately 340m/sec in air. When the switches use a diamond-substrate architecture, they have a saturation point close to that of an electron, which is comparable to that of a CMOS switch. The researchers are addressing the complexity of manufacturing the devices and creating higher-density circuits.

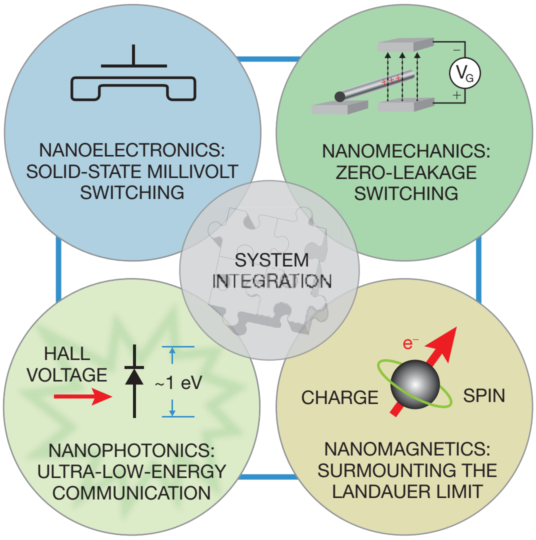

Figure 1 The University of California—Berkeley's Center for E^{3}S develops fundamental devices that will result in the next 1-million-times reduction in power for future generations of electronic systems. The research group focuses on nanoelectronics, nanomechanics, nanophotonics, nanomagnetics, and system integration.

Ming C Wu, PhD, is leading the nanophotonics research group, which focuses on circuit and data communication using light rather than electrons. Photons can consume less energy for longer links, and recent demonstrations have shown optical interconnects achieving 10^{-12}J of energy per bit. The challenge includes the creation and identification of fundamentally new approaches for transmitters and detectors to get the operating energy to the goal of communicating with one optical bit using 10^{-17}J of energy.

Jeff Bokor, PhD, leads the nanomagnetics researchers, who are investigating nanomagnetics devices for logic functions rather than memories. Nanomagnetic logic allows a spin degree of freedom with low energy dissipation—even less than the Landauer Limit—on each transition. (The Landauer Limit is the minimum possible amount of energy necessary to change 1 bit of information.) Theoretically, a room-temperature circuit or memory operating at the Landauer Limit could change at a rate of 1 Gbps and expend only 2.85 trillionths of 1W of power. Scientists have recently challenged this principle, and the circuits in this research program are using energy below this threshold.

The last area of focus is the development of systems that use these devices and techniques to allow for the realization of known common circuit functions. These circuits would use models that only nanotechnology can realize. **EDN**

Pallab Chatterjee is on the IEEE Nanotechnology Council.

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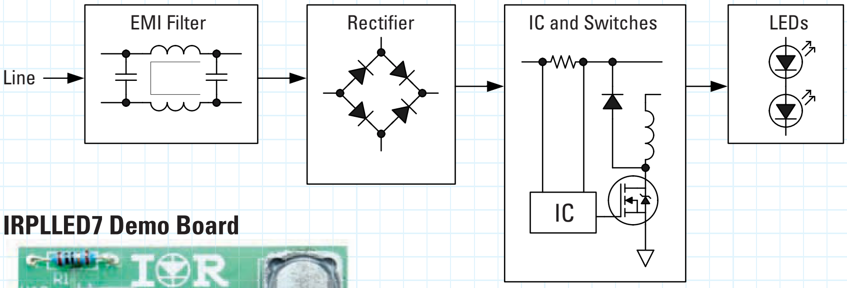
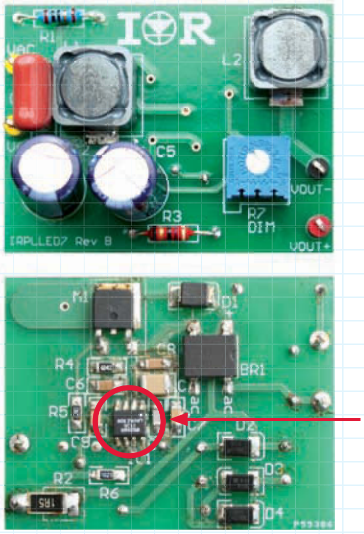


IRPLLED7 Demo Board



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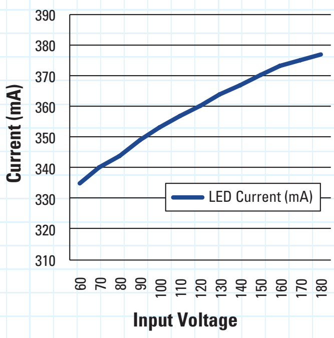

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Part Number	Package	Voltage	Load Current Regulation	Startup Current	Frequency
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IRS25401S	SO-8	200V	+/-5%	<500 µA	<500 kHz
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BATTERY-CHARGE CONTROL: DEDICATED ICs OR MICROCONTROLLERS?

CONSIDER THE TRADE-OFFS WHEN CHOOSING BETWEEN MICROCONTROLLERS AND DEDICATED CHARGE-CONTROL ICs FOR BATTERY-CHARGE CONTROL.

DAVID GUNDERSON • MICRO POWER ELECTRONICS INC

Battery-charger-control designers face a fundamental choice: to use a part from the rich selection of dedicated charge-control ICs available from many vendors or to use a programmable microcontroller. Because battery-charge control is a slow process, you can use inexpensive microcontrollers with embedded ADCs, signal conditioning, and PWM modules to directly control the charger's power-conversion circuits. You can also use a microcontroller for charger-to-battery-management-system communication and interaction, such as in a smart charger; flexible user interfaces, such as those in charge-status displays; battery-conditioning control; and other flexible features. However, microcontroller circuits and firmware are normally more expensive to design and test and often cost more to produce than chargers employing dedicated charge-control ICs.

IMAGE: SHUTTERSTOCK

AT A GLANCE

- Lithium-chemistry cell types have better volumetric and weight energy density than any other commercially available rechargeable cells.
- Designers typically implement single-cell battery chargers with dedicated charge-control ICs.
- Charging lithium-chemistry cells requires that the charger controls both charge current and battery voltage.
- To reduce current requirements, designers of batteries for electric vehicles, large-system back power, and other high-power-requirement applications build batteries from high-series-count cell stacks.
- Many microcontrollers have the built-in ADC, signal conditioning, and PWM control for a battery-charge-control design.

CHARGING REQUIREMENTS

Most recent battery-charger-design activity is for lithium-chemistry batteries. Lithium-ion, lithium-polymer, lithium-iron-phosphate, and related cell types have better volumetric and weight energy density than any other commercially available rechargeable cells. This feature makes them highly desirable for use in portable power systems, including electric vehicles; portable computing and communication devices, such as smartphones, PDAs, tablets, and laptop computers; military computer-assisted warrior systems; and medical-parameter monitors. Nickel-chemistry batteries are still in use, but they are rapidly being replaced by lithium-chemistry devices.

Charging lithium-chemistry cells requires that the charger controls both charge current and battery voltage. The initial part of a charge sources a CC (constant-current) mode into the cells until the battery voltage rises to the "float" voltage. Once the cell reaches the float voltage, the charger's output voltage remains at the float value in CV (constant-voltage) mode until the charge current decreases to a fixed low value. Once the battery reaches the low current, the charger turns off (**Figure 1**). Unlike nickel- and lead-chemistry batteries, lithium-chemistry batteries are usually not trickle-charged after charge termination. Maintaining a low current after charge termination can actually damage some lithium cells.

You can derive a close estimate of the charge time of a lithium-chemistry battery using the standard CC/CV algorithm by dividing the battery capacity in ampere-hours by the constant-current-mode charge current in amperes and multiplying that figure by the charge time, 1.3 hours. With proper design and intelligent tuning of the CC/CV-mode algorithm, you can do a closer calculation than this one, but it's a good starting point. You can also do much worse if the CC-to-CV-mode transition occurs too early due to poor design or inaccurate battery-voltage measurement.

The minimum requirement for a lithium-chemistry battery charger is that it must be able to control both the current into the battery and the voltage at the battery-charge terminals. For safety purposes, most lithium-chemistry battery chargers can disable charge if the battery temperature is too high or too low. In many cases, the charger can reduce the charge current when the battery voltage is low to safely recover an overdischarged battery.

The standard shorthand for the cell configuration in a lithium-chemistry battery is NSMP (N cells in series/M cells in parallel). When designing a charger, remember that the series number is critical because it determines the battery voltage. The parallel number determines battery capacity, and you use it only to calculate charge time at a specific charge current.

Battery-charger conversion efficiency is becoming a major issue due to regulations that the US DOE (Department of Energy) and other countries' regulatory agencies are putting into place. As these new regulations go into effect, high efficiency will become a primary converter-type selection criterion.

DEDICATED CHARGE ICs

All dedicated charge-control ICs convert a dc voltage input—typically from an ac/dc power supply—to the required current and voltage for battery charging. Most dedicated charge ICs for lithium batteries support the previously noted requirements: CC- and CV-mode control, battery temperature enable/disable, and reduced-current low-voltage battery recovery. Examples are the large selections from Texas Instruments, which offers approximately 160 parts; Linear Technology, which lists approximately 60 parts; Maxim, which offers about 70 devices; and Intersil, with approximately 50 parts. Other companies offering more limited selections of charger ICs include Fairchild, Analog Devices,

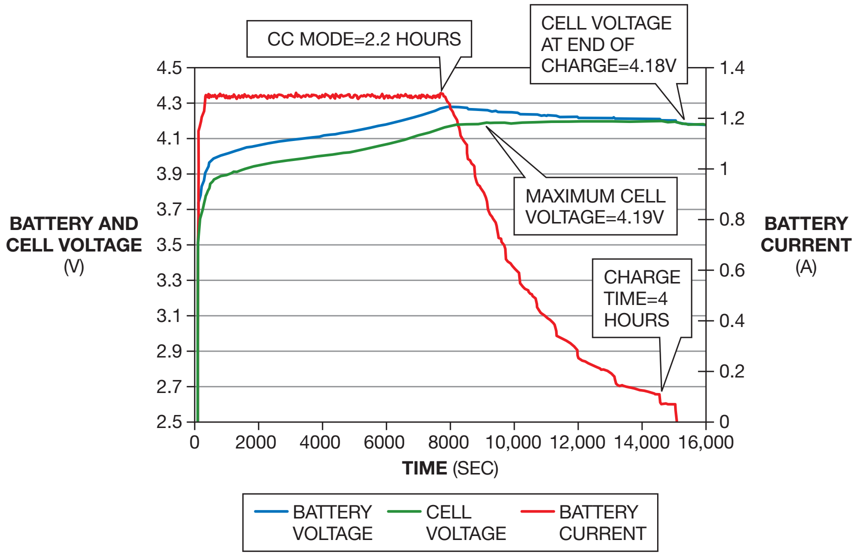

Figure 1 Once the cell reaches the float voltage, the charger's output voltage remains at the float value in CV mode until the charge current decreases to a fixed low value. Once the battery reaches the low current, the charger turns off.

Freescale, Micrel, On Semiconductor, and Torex Semiconductor.

When selecting a dedicated charge-control IC, you normally start with the battery chemistry; the number of serially connected cells, or maximum battery voltage; the desired charge current; and whether the device requires charge enable/disable on temperature. You must also consider whether the power source is a USB interface, along with the maximum and minimum input dc voltages. Most IC vendors have parametric-selection tools on their Web sites to narrow your choices once you make these selections.

Almost all dedicated charge-control ICs implement buck-type converters, in which the input voltage is higher than the maximum battery voltage. A few ICs support buck/boost-type voltage conversion. The head room required between the minimum input voltage and the maximum battery voltage is also an important selection consideration.

The two broad types of dedicated charge-control ICs are linear converters and switched-mode converters. Linear converters usually have less than 1A charge current and operate only in situations with similar input and output voltages. Otherwise, the power loss in the converter becomes unmanageable without expensive heat removal in the form of heat sinks, fans, or similar units. However, linear converters are inexpensive, small, and easy to design (**Figure 2**).

Switch-mode converters are more complex to design and implement but can support an almost-unlimited range of I/O voltages and charge current. Modern switch-mode converters run at such high switching frequencies that they can use small external inductors and ceramic capacitors, making the circuit small and relatively simple. You can use a switch-mode converter instead of a linear type to provide better conversion efficiency (**Figure 3**).

USING A MICROCONTROLLER

At this point, you may wonder why you should not just select a dedicated charge-control IC in all cases instead of doing the expensive embedded firmware development and circuit design for using a microcontroller in a battery-charge-control application. Many microcontrollers have the built-in ADC, signal conditioning, and PWM control required for a battery-charge-control design. Examples include the PSoC line from Cypress, the MSP430 line from TI, PIC processors from Microchip, AVR processors from Atmel, and many others.

You can design a battery-charge controller using a cheap, relatively low-power microcontroller because charge control, unlike general-purpose power-supply control, is slow due to the battery's electrochemical nature. Nothing much happens in a battery in less than a few hundred milliseconds other than protection trips, and battery chargers should never trip the protection. As a result, a software-implemented control loop works well for battery-charge control. You can implement the CC/CV-protocol charge control for lithium-ion battery charging in a few hundred lines of C.

The only required hardware-support circuits are voltage- and current-measurement amplifiers, an ADC, a PWM output, and a few general-purpose I/O ports; most available microcontrollers integrate many of these components. These processors often also include an I^2C or an SMbus (system-management-

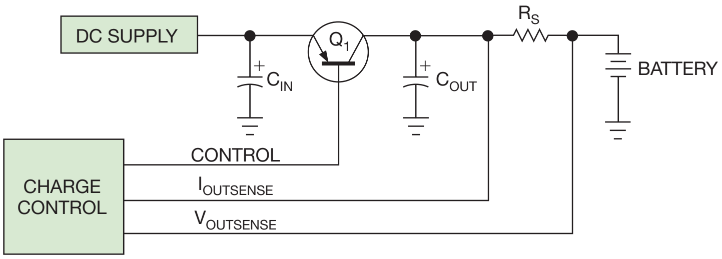

Figure 2 Linear converters are inexpensive, small, and easy to design.


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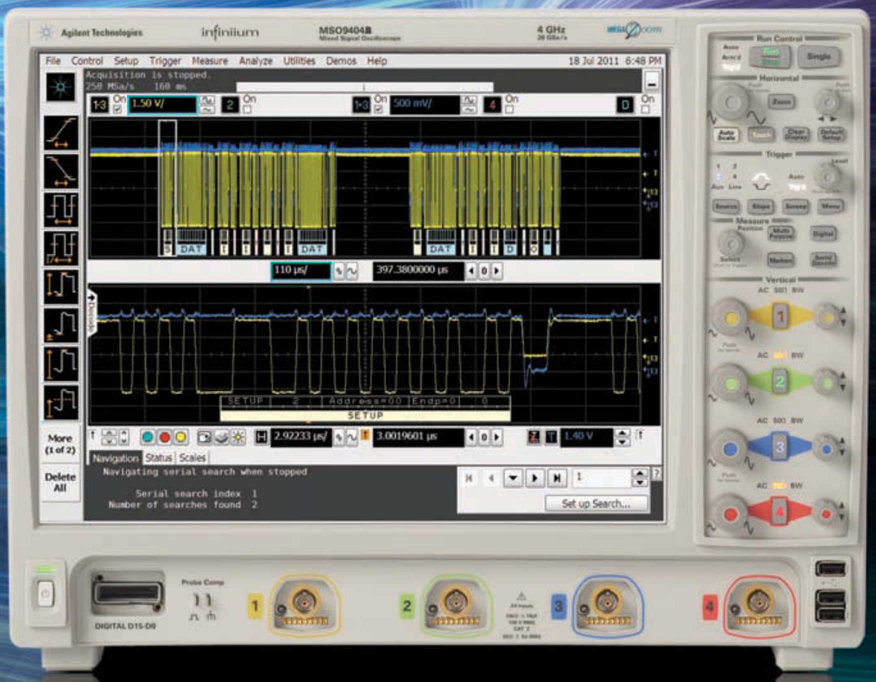
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bus) interface for designs requiring communication with the battery's fuel gauge.

Vendors publish extensive application notes on how to use their products as battery-charge controllers. Some even offer evaluation systems for this application that can help you to start your circuit and firmware design. In most cases, microcontroller-based charge controllers are more costly to design and produce than designs that use dedicated controllers. Why go to all the cost and trouble?

SINGLE-CELL BATTERIES

Charging a battery with a single series cell requires the simplest charge-control design. A large selection of dedicated charge-control ICs are available that handle as much as 3A charge current, have internal switching MOSFETs, and require few external parts. It is becoming common for designs to charge batteries using the 5V-dc, 500-mA-maximum, source on a USB interface. Single-series-cell batteries almost always use this approach, and a selection of dedicated linear and switch-mode controller ICs for this application is available.

Single-cell charging algorithms normally require no communication between the battery and the charger. As a result, designers typically implement single-cell battery chargers with dedicated charge-control ICs. Examples include cell-phone chargers, shaver chargers, and charger docks for smartphones and tablet computers. The core voltages of these portable devices are low enough that a single lithium-chemistry cell can supply their approximately 3V minimum input voltage from the battery. Many of these devices can be charged off USB power.

In some cases, however, a multibay charger better suits the application. These cases include medical and military applications in which several batteries are always on charge at a central site. Microcontrollers can often control more than one battery-charger bay because the required control algorithm is slow. The microcontroller's ability to control multiple bays can yield a production-cost advantage, but it also complicates the firmware and makes the charger more difficult to design and test. Vendors such as Micro Power offer chargers with as many as four charge bays, which one inexpensive PSoC microcontroller can control.

TWO- TO FOUR-CELL DEVICES

When the portable device requires more power than a single-cell lithium-chemistry battery can provide, you need to consider a battery with two to four cells in series. Charging these batteries is a more complex design problem because of cell balancing and CC/CV-algorithm tuning requirements. Higher-cell-count batteries must be charged so that the maximum cell voltage—not the battery voltage—is less than the specified float voltage. If the charger continues to push current into the battery when one or more cell voltages are too high, cell damage can result, reducing the life of the battery and even causing a safety issue in the most extreme case.

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You can design batteries with internal cell-balancing circuits that either shunt current around some of the cells or push additional current into selected cells to keep the cells in balance. However, it's sometimes necessary for the charger to participate in balancing, and to achieve this task, the charger must communicate with the battery-management system. Dedicated charge-control ICs typically don't support this sort of interactive charge control, so the task requires a microcontroller.

To optimize charge time, you should tune the charge-control algorithm for battery temperature, internal battery voltage, and other parameters that only the battery-management system knows. For example, to optimize charge time,

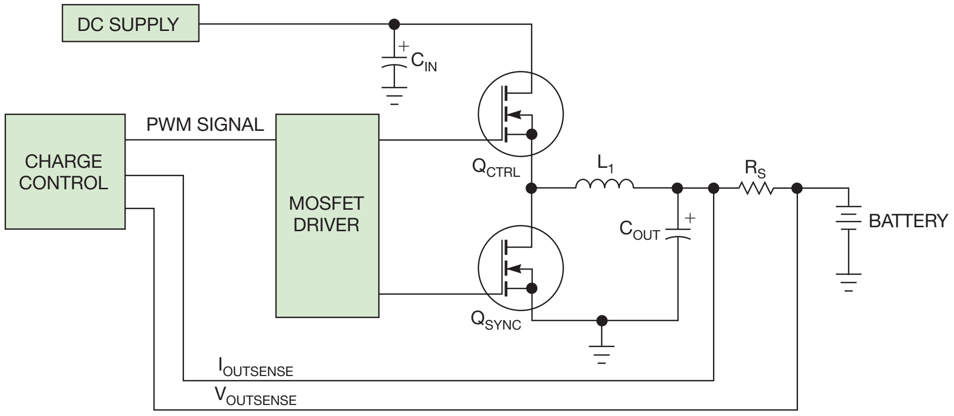

Figure 3 Modern switch-mode converters run at such high switching frequencies that they can use small external inductors and ceramic capacitors, making the circuit small and relatively simple.

the charger should stay in CC mode for as long as possible. However, the battery-charge current path sometimes contains an antireverse diode, preventing the charger from measuring the actual cell-stack voltage. The battery-management system can measure the cell stack's voltage in the battery and communicate that measurement to the charger, which can use the more accurate voltage in the CC-to-CV-mode-transition algorithm and keep the battery in CC mode for a longer time. This approach can significantly reduce the charge time.

A charger for a more complex battery usually has a status display, such as an LED bar graph or an LCD, for example. Implementing this feature usually requires a microcontroller because dedicated charge controllers have simple status-display support.

High-end chargers for the complex batteries in military and medical applications sometimes contain microcomputer systems for storing and communicating information—typically through a USB interface to a PC—about individual batteries. You can use this information for preventive maintenance and battery-fleet-status reporting.

HIGH-VOLTAGE BATTERIES

To reduce current requirements, designers of batteries for electric vehicles, large-system back power, and other high-power-requirement applications build batteries from high-series-count cell stacks. Electric-vehicle battery systems also support regenerative braking systems, active cooling and heating, and other advanced battery-management systems. As you might expect, high-cell-count batteries require complex cell-balancing circuits and algorithms. These complex, high-voltage batteries require the full integration of the battery-management system and the charging systems. Integrating the charger with the battery-management system into one system usually requires computer control for much of the battery-management-system function because dedicated charge-control ICs are too inflexible.

Battery-fleet management is common in these complex systems, so the charger/battery-management system must acquire and maintain information about battery health and histo-

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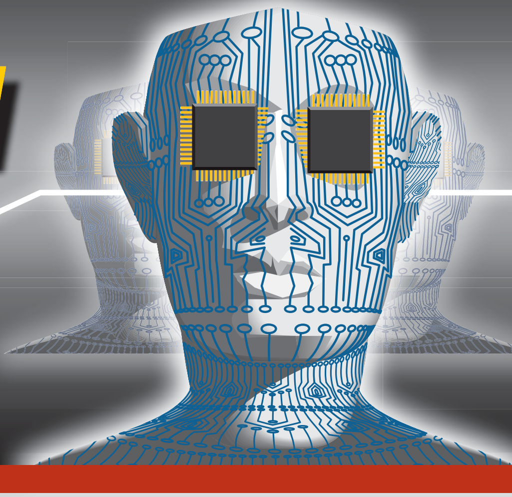

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IF AN ADVANCED USER INTERFACE IS REQUIRED, CONSIDER A MICROCONTROLLER.

ry. The distributed energy storage in electric-vehicle and household- and business-backup power systems will likely find use for power-grid peak-load management when the nationwide smart grid becomes a reality. This situation will require that the charging system synchronize with the grid inverter so that the battery can both source and consume power to and from the grid. These integrated systems will require robust communication through the charger with the battery-management system so that the smart grid can maintain information about battery status and capabilities. All of these developments shift the charger away from acting as a simple current-controlled voltage converter to acting as a subsystem in a complex, computer-controlled energy-management system.

MAKING A DECISION

Making a decision on the type of charge controller to use for a specific application goes as follows: If the battery is a one-cell lithium-chemistry type and the charge current is less than 500 mA or if charging from USB power is necessary, use a dedicated, linear or a minimum-function switch-mode charge controller, such as the TI bq24100 series. If the battery is a one- to three-cell, single-bay lithium-chemistry type and the charge current is less than 3A, use a dedicated, switch-mode charge controller, such as a TI bq24105 or bq24170. However, if the application requires charger-to-battery communication, an advanced user interface, or communication with a host computer, consider the use of a microcontroller. If the battery is a one- to three-cell, multibay lithium-chemistry type and the charge current is less than 3A, trade off the costs for a switch-mode charge controller with those of a microcontroller controlling more than one bay.

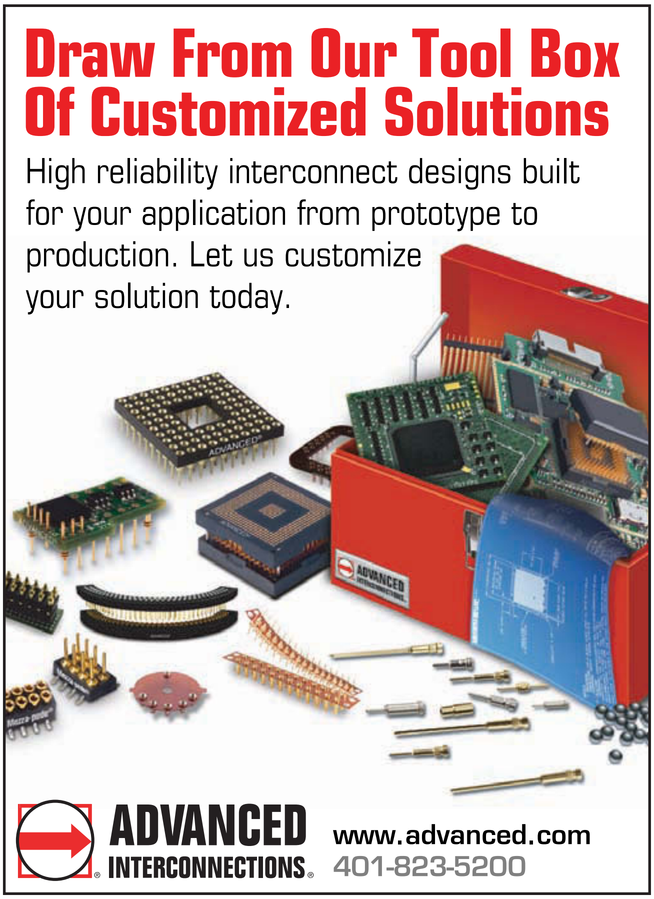
Batteries requiring more than 3A charge current or having more than three cells almost always require a switch-mode converter using a microcontroller because communication between the charger and the battery-management system is usually necessary for safety and optimal charge time. No matter how many cells the battery has, applications requiring battery-history and -status recording and communication must use a microcontroller or even a microcomputer in the charger.**EDN**

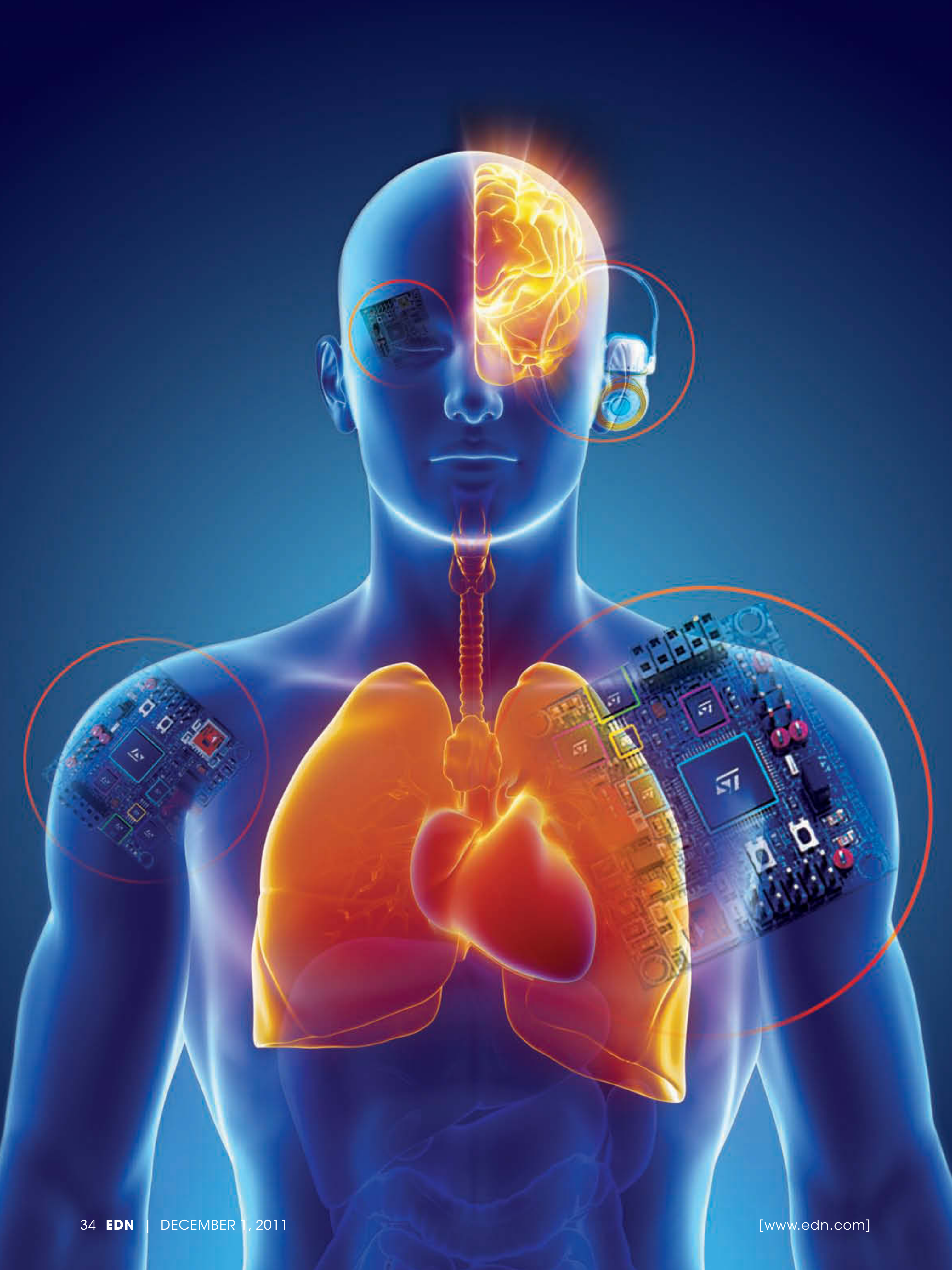
ACKNOWLEDGMENT

This article originally appeared on EDN's *sister site*, SmartEnergy Designline, *http://bit.ly/tS3ZS0*.

AUTHOR'S BIOGRAPHY

David Gunderson is a senior electronics engineer at Micro Power Electronics. He is responsible for design electronics and embedded software for batteries and chargers. Gunderson holds a bachelor's degree in electrical engineering, and his interests include composing and performing music and playing with his grandchildren.





MEDICAL SENSORS ENCOMPASS BIOMEDICAL ELECTRONICS

EYE, EAR, LUNG, HEART, AND BRAIN ENHANCEMENTS ARE NOW POSSIBLE AS MODERN ELECTRONICS TECHNOLOGY MEETS ADVANCES IN MEDICINE AND BIOLOGY.

BY STEVE TARANOVICH • CONTRIBUTING TECHNICAL EDITOR

Almost 40 years after the popular sci-fi show *The Six Million Dollar Man* made its debut on TV, science fiction is becoming a reality as modern electronics technology merges with nanotechnology, advanced implants, solar- and light-powered devices, and major sensor advances in medicine and biology. Innovative marvels are transforming sensor-based electronics in human-body enhancements and replacements. These electronics include WBANs (wireless body-area networks) and enhancements and replacements for eyes and ears. Part one of this article describes innovative sensor technology and the miniaturized, implantable, and wireless-electronics-interface methods—from the sensor to the microcontroller. Part two, which you can access at www.edn.com/111201cs, discusses the lungs, heart, and brain.

IMAGE(S): SHUTTERSTOCK; COURTESY OF MEDEL

The advanced developments in sensors and wireless-communications devices have enabled the design of miniature, cost-effective, and smart physiological sensor nodes. One innovation is the development of wearable health-monitoring systems, such as WBANs. The IEEE 802.15.4 standard for this technology stipulates a low-power, low-data-rate wireless approach in relation to medical-sensor body-area networks. STMicroelectronics this year contributed to this futuristic "cyborg" technology with its sensors and MEMS and the iNEMO (inertial-module-evaluation-board) node (**Figure 1**).

Among other vendors in this field, Analog Devices also offers some advanced activity-monitoring solutions and sensor-interface components, and Texas Instruments offers a development kit with Tmote Sky, a next-generation "mote," or remote, platform for extremely low-power, high-data-rate sensor-network applications, which is designed with the dual goal of fault tolerance and development ease. TI's Tmote Sky kit boasts a 10-kbyte on-chip RAM, the largest size of any mote; an IEEE 802.15.4 radio; and an integrated onboard antenna providing a range as far as 125m.

AT A GLANCE

- Modern electronics technology is merging with nanotechnology, advanced implants, solar- and light-powered devices, and major sensor advances in medicine and biology.
- Retinal-prosthesis development can help restore sight to people who have retinal-degenerative diseases, such as macular degeneration.
- Cochlear-implant systems need to intelligently separate information from noise.

HELPING THE BLIND TO SEE

Retinal-prosthesis development can help restore sight to people who have retinal-degenerative diseases, such as macular degeneration, which can cause blindness (**Reference 1**). Researchers doing preclinical implantation studies have verified that these prostheses ultimately assist an eye's lost functions with an implant, containing a 15-channel stimulator chip, discrete power-supply components, and the power- and data-receiving coils that conform to the outer wall of an eye. In the study, researchers at the Boston Retinal Implant Project implanted an array in the subretinal area of a pig but affixed most of the prosthesis—a titanium, hermetically encased electronics assembly—to the outer surface of the sclera, or the white of the eye. A serpentine electrode array extends from the case to the superior temporal quadrant of the eye (**Figure 2**). The system has an external video-capture unit and a transmitter that wirelessly sends image data to the implanted portion of the device (**Figure 3**). A custom ASIC then translates the image into biphasic current pulses of programmable strength, duration, and frequency to the electrode array (**Figure 4**). Minco also offers advanced-design, flexible circuitry for implants that could help bring this project to reality for the approximately 1.7 million people who suffer from this eye condition.

Since the researchers performed this clinical study two years ago, many improvements in electronics technology have emerged that enhance miniaturization, decrease power consumption, and increase integration within this effort before it eventually becomes a product that the FDA (Food and Drug Administration) will approve for use on humans. Examples of these technological advancements include Texas Instruments' Wireless Power

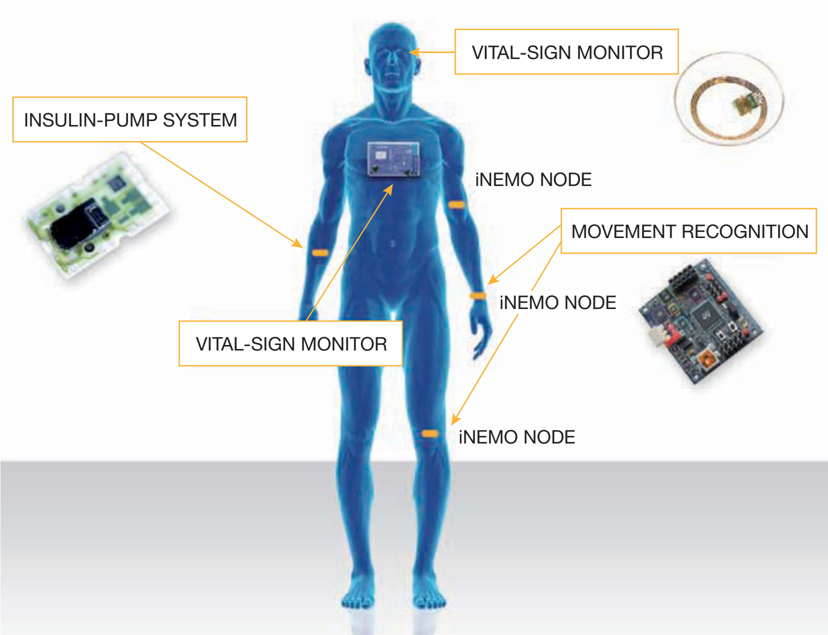


Figure 1 STMicroelectronics has developed applications employing sensors for personal and diagnostic use.

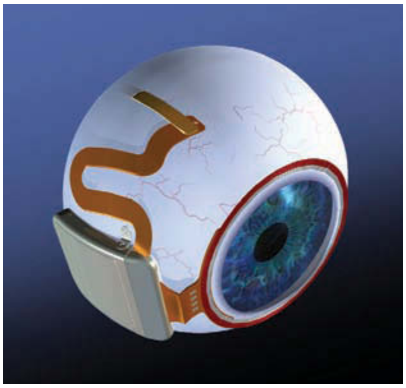
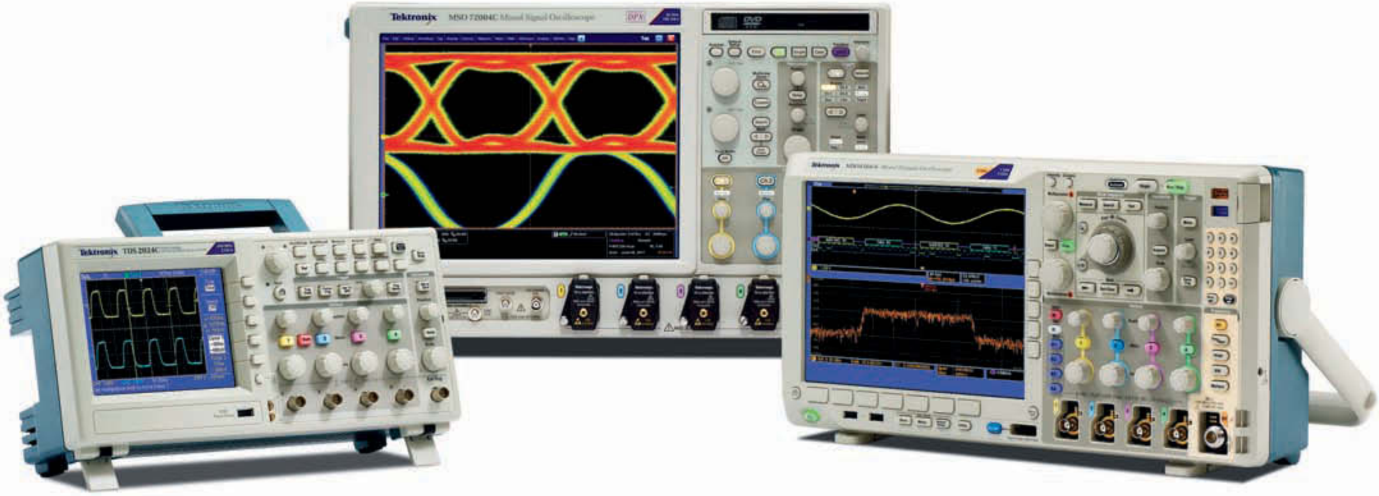
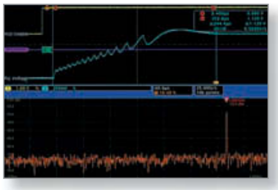


Figure 2 Researchers at the Boston Retinal Implant Project implanted an array in the subretinal area of a pig but affixed most of the prosthesis—a titanium, hermetically encased electronics assembly—to the outer surface of the sclera. A serpentine electrode array extends from the case to the superior temporal quadrant of the eye (courtesy Veterans Administration Boston Healthcare System and the Boston Retinal Implant Project).





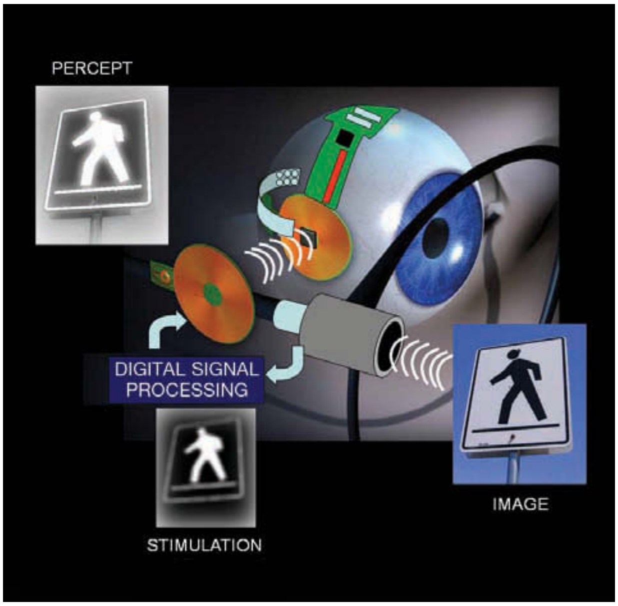


Figure 3 This system has an external video-capture unit and a transmitter that wirelessly sends image data to the implanted portion of the device (courtesy Veterans Administration Boston Healthcare System and the Boston Retinal Implant Project).

Consortium Qi-compliant wireless receiver and transmitter technology. The company offers compliant communication for wireless-power transfer, ac/dc-power conversion, output-voltage conditioning, and dynamic-rectifier control for an improved load system. You can design complete contactless power transfer and charging with TI's wireless-power products and development kits. Freescale and Analog Devices also offer low-power wireless products for this segment.

Another clinical study using photodiode circuits shows promise for the development of high-resolution retinal prostheses. In this study, researchers at Stanford University are investigating actively biased photoconductive and passive photovoltaic circuits (**Reference 2**). According to Daniel V Palanker, associate professor in the Department of Ophthalmology and in the Hansen Experimental Physics Laboratory at the university, a pocket PC processes a data stream from a videocamera, and a micro-LCD, similar to video goggles, displays the resulting images. An approximately 900-nm, nearly IR (infrared) light illuminates the LCD at 0.5-msec intervals, corresponding to approximately 30° of visual field. This pulsing projects the images through the eye optics into the retina. Photovoltaic pixels then receive the IR image in a subretinally implanted, 3-mm-diameter chip, corresponding to 10° of visual field. Each pixel converts the pulsed light into a proportionally pulsed biphasic electric current that introduces visual information into diseased retinal tissue.

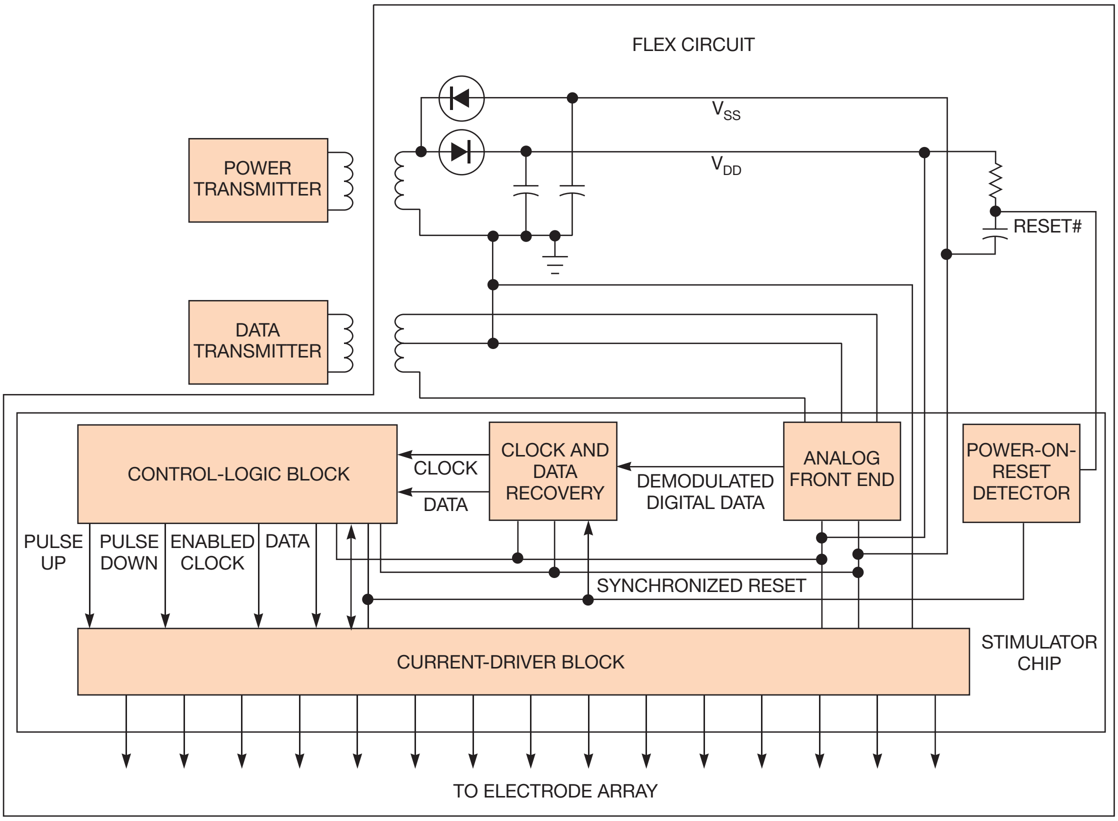


Figure 4 A custom ASIC translates an image into biphasic current pulses of programmable strength, duration, and frequency to an electrode array (courtesy Veterans Administration Boston Healthcare System and the Boston Retinal Implant Project).

The absence of an additional power supply in a photovoltaic system can greatly simplify prostheses design, fabrication, and the associated surgical procedures compared with photoconductive systems, which require an active bias voltage. The researchers plan future studies to determine the responses of the various retinal neurons to such stimulation.

HELPING THE DEAF TO HEAR

Another area of advancement in biomedical science covers cochlear implants. The primary goal of these implants is to use electrical stimulation safely to provide or restore functional hearing (**Reference 3**). The implants comprise a behind-the-ear processor in the external unit and a battery that uses a microphone to pick up sound, convert the sound to the digital realm, process and encode the digital signal into an RF signal, and then send it to the antenna in the headpiece (**Figure 5**). A magnet attracted to the internal receiver, which physicians surgically place just beneath the skin behind the ear, holds the headpiece in place. A hermetically sealed stimulator contains active electronic circuits that derive power from the RF signal, decode the signal, convert it into electric currents, and send them along wires threaded into the cochlea. The electrodes at the end of the wire stimulate the auditory nerve that connects to the central nervous system, which interprets electrical impulses as sound.

An external speech processor comprises a DSP, a power

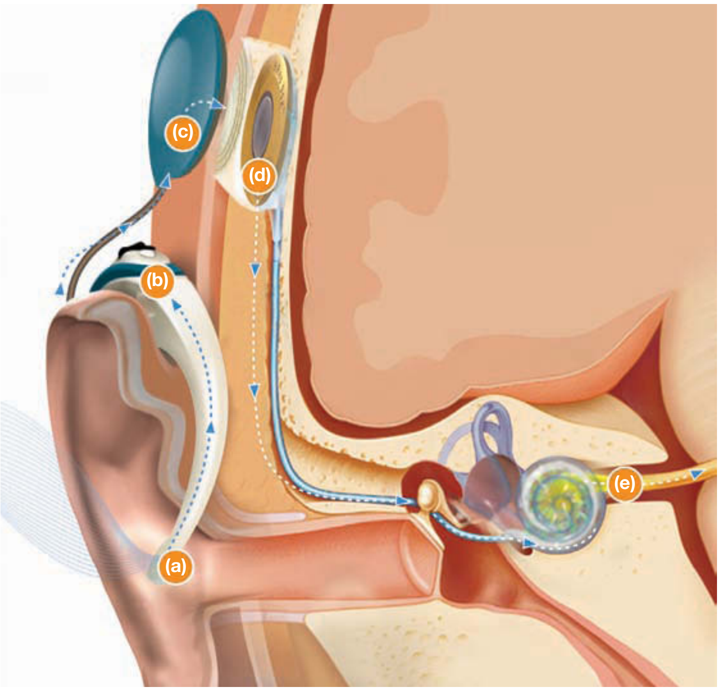


Figure 5 A cochlear implant converts sound to electric impulses for delivery to the auditory nerve. A microphone captures sound on the sound processor (a). A sound processor converts sound into detailed digital information (b). A magnetic headpiece sends the digital signals to the cochlear implant (c). The cochlear implant sends electrical signals to the hearing nerve (d). The hearing nerve (e) sends impulses to the brain, which interprets the sound as sound (courtesy Advanced Bionics).

amplifier, and an RF transmitter. The DSP extracts features in the sound and converts them into a stream of data that the RF transmitter will transmit. The DSP also contains patient information in a memory map. An external-PC fitting program can set or modify the maps and other speech-processing parameters.

The internal unit has an RF receiver and a hermetically sealed stimulator. This internally implanted unit has no battery power, so the stimulator must derive its power from the RF signal. The charged stimulator then decodes the RF bit stream and converts it into electric currents for delivery to appropriate electrodes at the auditory nerve. A feedback system monitors critical electrical and neural activities in the implants and transmits these activities back to the external unit (**Figure 6**).

Advanced Bionics has developed an implantable electronics platform that benefits patients by offering more channels and the ability to generate virtual channels through current steering. According to Lee Hartley, vice president of R&D at the company, one of the biggest challenges in developing sophisticated sound-processing sensors is improving the ability to hear in noisy listening environments. "Cochlear-implant recipients have a reduced ability to discriminate loudness levels and distinct frequency channels," he says. "This [reduced ability] heightens the challenge of improving speech understanding and music appreciation; we need to intelligently separate information from noise."

The next major areas for significantly improving cochlear-implant systems and performance, says Hartley, include ubiquitous wireless connectivity to commercial devices, increasingly intelligent scene-analysis algorithms running at low power, and technologies that enable patients to receive cochlear-implant services from clinicians regardless of the patients' or clinicians' location. "Technology trends in the industry are moving toward system architectures and service models that will minimize the visibility of the entire cochlear-implant system," he explains. Hartley expects advances in IC technology to afford the delivery of wireless features and system-power reductions: "I see system design continuing to be modular in that recipients will customize their experience based on their changing needs."

Signal processing has greatly improved the performance of cochlear implants. Sound can be modeled either as a periodical source for voice sounds or as a noise source for unvoiced sounds. The resonance properties in the vocal tract filter the sounds' frequency spec-

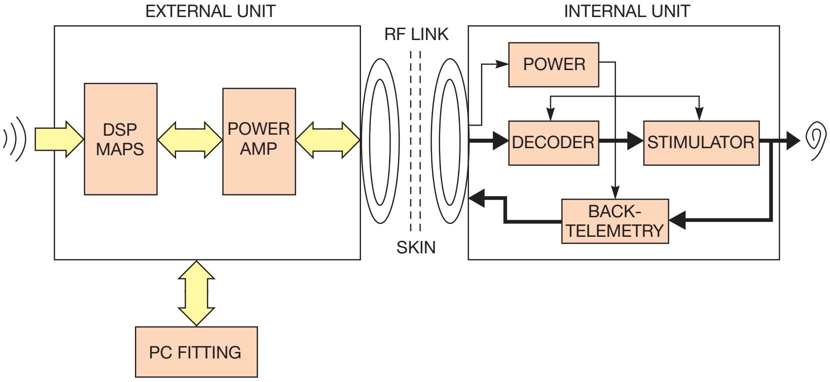


Figure 6 A feedback system monitors critical electrical and neural activities in the implants and transmits these activities back to the external unit (courtesy IEEE).

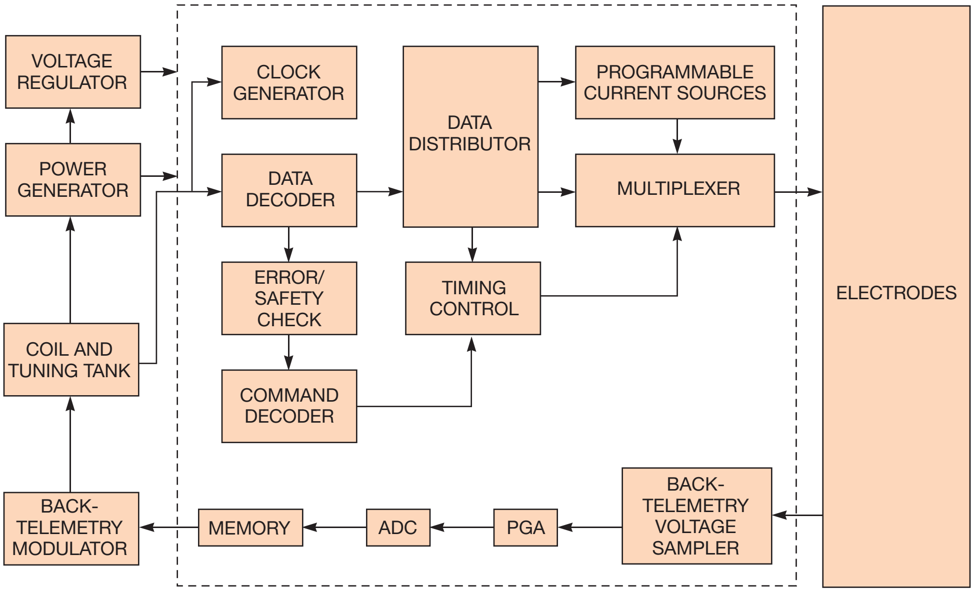


Figure 7 A receiver and a stimulator in an internal unit act as the engine of a cochlear implant (courtesy IEEE).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trum. Alternatively, the source can be modeled as a carrier while the vocal tract acts as a modulator, reflecting the opening and closing of the mouth or the nose. The source typically varies rapidly, whereas the filters react more slowly (**Reference 3**).

The internal unit in all modern cochlear implants connects to the external unit by a transcutaneous RF link for the safety and convenience of the user. The RF link uses a pair of inductively coupled coils to transmit not only data but also power. The RF-transmission unit has some challenging tasks, such as efficiently amplifying signals and power and maintaining immunity to EMI. Its secondary functions are to provide reliable communication protocols, including a signal-modulation method; bit coding; frame coding; synchronization; and back-telemetry detection.

The RF design of cochlear implants presents many conflicting challenges that require careful compromises. For example, to extend battery life, the power transmitter must be a high-power, efficient design. Thus, most modern implants use a highly efficient Class E amplifier. Class E amplifiers are nonlinear, however, and their distorted waveform limits the data-transmission rate. Another challenge is the need for power-efficient transmitting and receiving coils. Operating the RF system at its resonant frequency, or at a narrow bandwidth, maximizes power, but the RF system must have unlimited bandwidth for data transmission. And, although these devices call for high transmission frequency, this requirement dictates a large coil. In a practical, usable design, however, the size of the transmitting and the receiving coils must be small and cosmetically acceptable.

The receiver and stimulator in the internal unit act as the engine of the cochlear implant (**Figure 7**). The ASIC (shown in dashed box) performs the critical function of ensuring safe and reliable electrical stimulation. It has a forward pathway with a data decoder that recovers the digital information from the RF signal, an error and safety check that ensures proper decoding, and a data distributor that sends the decoded electrical-stimulation parameters to the programmable current source by switching the multiplexers on and off. The backward pathway includes a back-telemetry voltage sampler that reads the voltage for a time on the recording electrode. The PGA (programmable-gain amplifier) then amplifies voltage, the ADC converts it to the digital domain and stores it in memory, and the back-telemetry technology sends it to the external unit. The ASIC also has many control units, which range from the RF signal generated from the clock to the command decoder. The ASIC cannot easily integrate some functions, such as the voltage regulator, the power generator, the coil and RF-tuning tank, and the back-telemetry data modulator, but advances are occurring in these areas.

The current-source circuit, comprising a DAC and current mirrors, generates the stimulating current according to the amplitude information from the data decoder. This current source must be accurate and involves challenges. For example, due to process variations, the relationship between the source and the drain of the MOSFET is not constant, yet the voltage difference between the gate and the source controls the amount of current in the drain. For this reason, the circuit requires a trimmer network to fine-tune the reference current. New designs combine multiple DACs to obtain the desired accurate current, thereby eliminating the need for a trimmer. An ideal current source also has infinite impedance, so some designers use cascoded current mirrors at the expense of reduced voltage compliance and increased power dissipation.

You must carefully consider and implement these compromises. Some cochlear-implant products have multiple current sources, and older devices required a switching network to connect one current source to multiple electrodes. Recent designs use multiple current sources sequentially or simultaneously, however. In these designs, both the P- and the N-channel current sources generate positive and negative phases of stimulation. The challenge is to match the P- and the N-channel current sources to ensure balancing of the positive and the negative charges. Adaptive compliance voltages can reduce power consumption and maintain high impedance.

Engineers prefer ASK (amplitude-shift-keying) modulation over FSK (frequency-shift-keying) modulation because of ASK's simple implementation scheme and low power consumption with the high-frequency RF signal. Thanks to persistent and collaborative work by teams of engineers, scientists, physicians, and entrepreneurs, safe and charge-balanced stimulation has restored hearing to more than 120,000 people worldwide. These prostheses serve as models to guide development of other neural prostheses to improve the quality of life for millions of people. **EDN**

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Flyback topology offers superior balance in LED drivers

UNDERSTAND THE ROLE AND IMPLEMENTATION OF THE FLYBACK TOPOLOGY IN THIS APPLICATION.

LED-based light fixtures and bulb replacements are now rapidly replacing incandescent, halogen, and CFL (compact-fluorescent-lamp) light sources in many general-lighting applications. Flyback dc/dc converters are the power-supply topologies of choice for a large segment of the LED-driver market because these devices allow electrical isolation between the LEDs and the ac line, which is a safety requirement in most LED lamps.

Almost all LED-based-light-bulb replacements include a large, aluminum heat sink shaped to fit the design, with many fins to maximize the surface area. High-brightness LEDs generate heat, which must radiate out into the ambient air to prevent overheating and to lengthen lifetimes.

Although the LEDs themselves are not accessible, they often electrically connect to the heat sink because any insulator between the two imposes a thermal barrier. Designs using insulators need thin heat sinks to minimize this barrier and thus cannot offer reliable electrical isolation. For this reason, engineers often favor isolated flyback driver circuits over the simpler but nonisolated buck topology. Flyback LED drivers also offer simplicity; low cost; the ability to achieve a high power factor; and, with some additional circuitry, compatibility with common TRIAC (triode-alternating-current)-based dimmers.

The core element of a flyback LED-driver circuit is a coupled inductor (**Figure 1**). A high-voltage MOSFET switches the primary of the inductor across the dc bus. When the switch is on, current rises in the inductor and energy is stored in the magnetic field. For this scenario to occur, the inductor cores require an air gap. Switching off the MOSFET interrupts the primary current; therefore, current must flow in the secondary winding instead of through the diode and into the output capacitor and load. During this phase, the energy in the inductor transfers to the output. Because current does not flow to the output when the MOSFET is on, a storage capacitor at the output is necessary to provide continuous current in the LEDs.

The inductor's turns ratio provides neither a step-down nor a step-up function as in a transformer; instead, it must be derived by considering the reflected voltage that appears at the primary winding when the MOSFET is off. The voltage

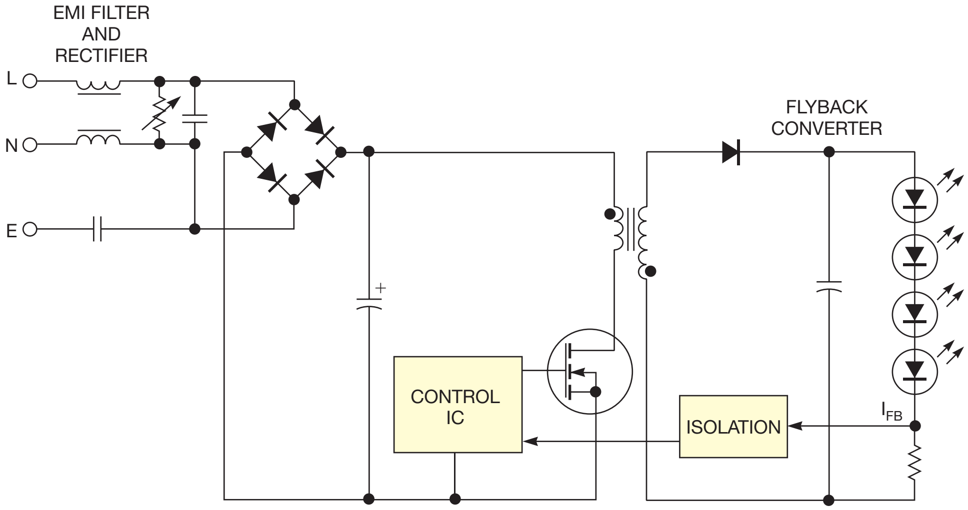

Figure 1 The core element of a flyback LED-driver circuit is a coupled inductor.

Figure 2 The flyback approach most suits power levels lower than 50W, which covers all screw-in, LED-based light-bulb-replacement products and many downlights and luminaires.

appearing at the drain of the MOSFET must not exceed its maximum drain-to-source-voltage rating under conditions of peak line voltage and maximum LED-output voltage. This voltage is equal to the dc-bus voltage plus the LED-output voltage, multiplied by the turns ratio, which is the reflected voltage. For a 120V-ac circuit, the MOSFET should have a 400V voltage; for a 277V-ac or wide-input-range circuit, the MOSFET should have a 650V voltage. These voltages allow for a practical inductor design that requires fewer turns on the secondary.

Flyback converters continuously store and transfer energy through the inductor. Thus, the inductor operates in only one quadrant of the flux-density-versus-magnetic-field-strength curve. As a result, the core must be larger to transfer a given power than it is in some other more-complex power-supply topologies, which use the cores more efficiently. The flyback approach most suits power levels lower than 50W, which covers all screw-in, LED-based light-bulb-replacement products and many downlights and luminaires (**Figure 2**). Flyback designs can also operate at higher power levels; however, these designs are more complicated and often use multiple-inductor and MOSFET-interleaved circuits.

As performance standards emerge to cover LED-lighting products, environmental considerations, such as high power factor, also become requirements. A flyback LED driver can provide a power factor of approximately 0.9 using passive-circuit techniques without any preregulating stage, which would add significantly to the cost and size.

To provide a high power factor, you can run the flyback circuit from a full-wave-rectified dc bus with only a small capacitor for high-frequency coupling, or you can add a simple, passive valley-fill circuit comprising two capacitors and three diodes (**Figure 3**). The first method is cheaper but requires a larger holdup capacitor at the outputs to prevent the LED's current from dropping out close to the ac line's zero crossings. As a result, this method is feasible only when the LED current is 350 mA or less. The second and more common method adds some cost but overcomes the limitation of the first method.

The next important issue to consider is how to regulate the LED current. You can achieve this regulation by using a secondary voltage- and current-sense circuit with an optoisolator to transfer the feedback signal back to the primary-side control IC. Alternatively, you can regulate the primary-side peak current in the MOSFET only and not directly sense the LED voltage or current. Another option is to use a primary-sensing method that provides some current regulation and overvoltage protection but without the need for an optoisolator.

Using a secondary voltage- and current-sense circuit is the most accurate method, but it requires the use of an optoisolator and an output-sensing and regulation circuit, all of which affect space and cost. Regulating the primary-side peak current in the MOSFET eliminates a significant number of components but offers a less accurate form of control, which can provide the correct output current to the LEDs at only a specific line input and LED-output voltage. Although this approach may be acceptable in some low-end applications, it offers no protection against an open-circuit condition. The output of a flyback converter can produce high voltages if the load becomes open circuit—for example, when one LED in the chain fails in an open-circuit state—because the voltage continues to rise until the inductor can discharge its stored current.

Manufacturers are now employing the primary-sensing method in smart flyback-control ICs that can sense the current and voltage at the primary side of the circuit and use an algorithm to determine the output current without directly sensing it. An LED driver employing one of these controllers

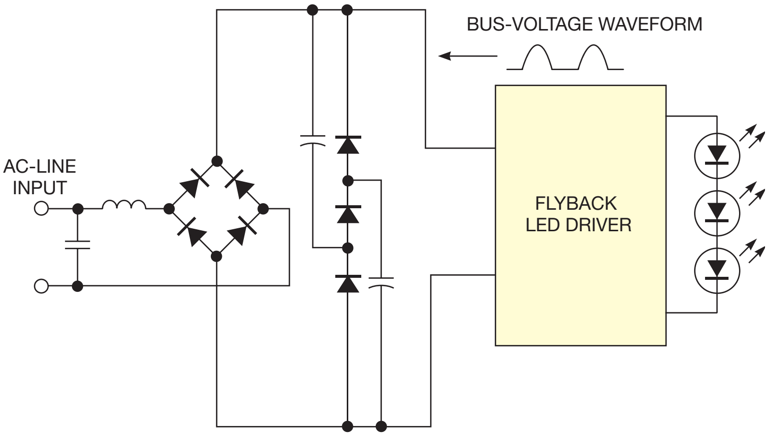

Figure 3 To provide a high power factor, you can run the flyback circuit from a full-wave-rectified dc bus with only a small capacitor for high-frequency coupling, or you can add a simple, passive valley-fill circuit comprising two capacitors and three diodes.

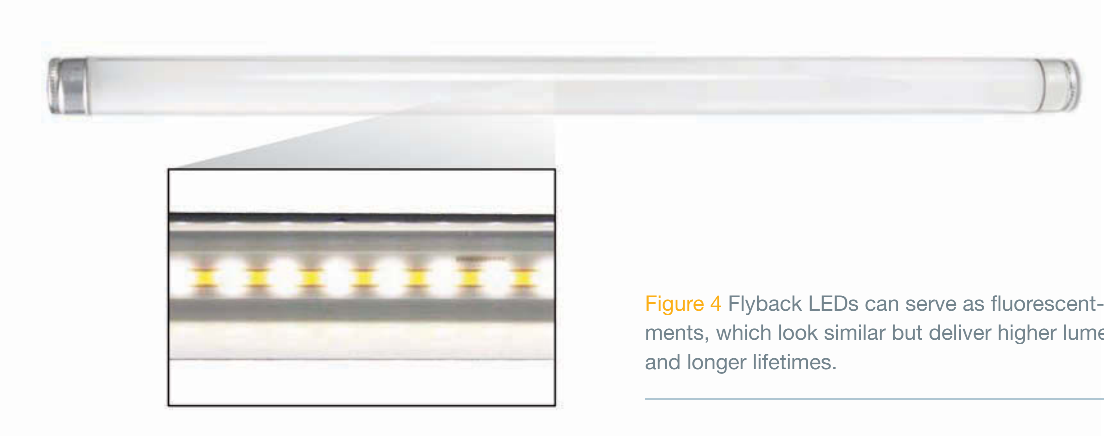

Figure 4 Flyback LEDs can serve as fluorescent-tube replacements, which look similar but deliver higher lumens per watt and longer lifetimes.

can provide a regulated output current over a range of input-voltage variation, although it still needs to be set to operate for a specific number of LEDs at the output because it cannot adjust for voltage variations. Such controllers can also include circuitry for detection of open-circuit conditions; thus, they limit the output voltage. This method is more accurate than regulating the primary-side peak current in the MOSFET because the controller integrates the added complexity, but it is still less accurate than using a secondary voltage- and current-sense circuit with an optoisolator.

A FLYBACK LED DRIVER CAN PROVIDE A POWER FACTOR OF APPROXIMATELY 0.9 USING PASSIVE-CIRCUIT TECHNIQUES WITHOUT ANY PREREGULATING STAGE.

A flyback driver in an LED-based-light-bulb replacement could use any combination of these PFC techniques. However, the current trend is toward products that users can dim from currently installed TRIAC-based dimmers. This approach adds another degree of complexity to the LED-driver design. TRIAC-based dimmers generally work poorly with capacitive loads, such as solid-state power-converter circuits, because, once the TRIAC fires, it continues to pass current only while the current remains above a defined threshold. In LED drivers, some additional circuitry is usually necessary to guarantee the same activity. Without the extra circuitry, the TRIAC tends to fire erratically, which results in flickering.

After addressing this issue, you must then enable the LED driver to adjust the LED's output current depending on the dimmer's position. The most-basic circuit relies on the drop in bus voltage as the dimmer's level decreases to provide a reduction in output current. However, this approach produces limited performance and operates only over a portion of the adjustment range of the dimmer. It probably makes more sense to design better dimmers that can work with LED drivers rather than to design more complicated LED drivers to work with dimmers that originally operated with incandescent light bulbs. Although this approach seems technically logical, the market is not currently going in that direction.

Many designs now produce good dimming control by adding circuitry that detects the firing angle of the TRIAC and converts it to a dc-control voltage, which then adjusts the output current accordingly. Such implementations, however, currently require many components because they use the method of regulating the primary-side peak current in the MOSFET, often requiring multiple optoisolators. As a result, such products often sell for at least $30. The next generation of dimmable flyback-based designs will most likely use the primary-sensing method as new and more intelligent control ICs enter the market.

Besides finding use in luminaires and downlights, flyback LEDs also serve as fluorescent-tube replacements, which look similar but deliver higher lumens per watt and longer lifetimes (**Figure 4**). You can, for example, use these LEDs in series in a long chain to give the appearance of a continuous light source. The 24W LED-based product in the **figure** replaces a 32W T8 fluorescent lamp. At this level, a flyback design provides the best option for a low-cost driver that complies with safety and performance requirements.

Compatibility with TRIAC dimmers is generally unnecessary in this type of LED lighting, which often operates using 0 to 10V analog dimming control or digital-control schemes such as DALI (Digital Addressable Lighting Interface) in more advanced applications. This approach eliminates many of the problems of dimming and allows more precise control of the light output because this scheme can incorporate PWM, linear dimming, or both.EDN

ACKNOWLEDGMENT

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AUTHOR'S BIOGRAPHY

Peter B Green is LED-group manager at International Rectifier, where he has worked for 10 years. His responsibilities include LED-driver-IC-product-line definition and specification, working with IC designers and application engineers to design new LED-driver controllers and supporting demo boards and writing application notes. Green has a bachelor's degree in electrical engineering from Queen Mary College, University of London. His personal interests include electronics, computers, popular science, history, and travel.

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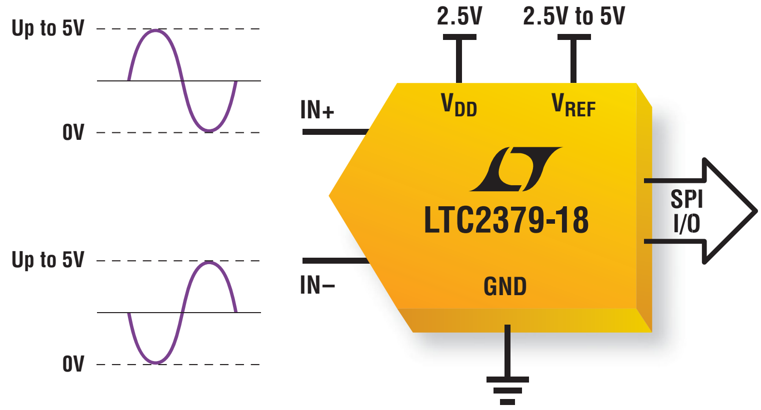

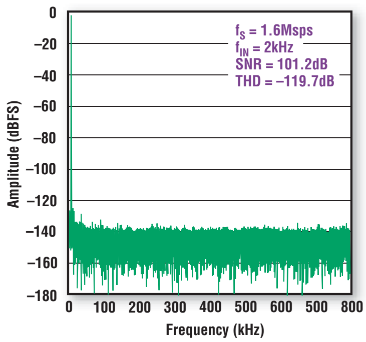

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Inexpensive VFC features good linearity and dynamic range

Jordan Dimitrov, Toronto, ON, Canada

VFCs (voltage-to-frequency converters) were favorite circuits of the late analog gurus Bob Pease and Jim Williams (**references 1** to **5**). In tribute to them, this Design Idea reveals a circuit that provides good performance at a low price. You can obtain all of the parts for a few dollars from a local electronics shop.

The circuit has high input impedance, works with a single power supply, and connects directly to microcontrollers. The linearity error is less than 0.1% for frequencies as high as 700 kHz, and the dynamic range is 60 dB. The circuit exploits the integrator, comparator, and one-shot architecture (**Figure 1**). The output frequency is proportional to the input voltage: $f=(1/V_{CC}t_{OS})V_{IN}$, where V_{CC} is the power supply, 5V, and t_{OS} is the duration of the pulse that the one-shot generates, according to the **equation** $t_{OS}=0.7\times R_{OS}\times C_{OS}$. You must filter and regulate the power supply, V_{CC}. If the magnitude of the power supply changes, the slope of the calibration curve also changes. The components you use for the integrator, C_{INT} and R_{INT}, do not participate in the **equation** so they need not be either accurate or stable. However, capacitors C_{INT} and C_{OS} must have low dielectric absorption.

You build a start-up circuit with switch S_1 and the timing network comprising R_1, C_1, and R_2. This step ensures that the circuit will oscillate with any value of input voltage. After you turn on the power supply, the switch stays closed for approximately 1 sec, keeping C_{INT} completely discharged. When the switch opens, C_{INT} starts charging by a fixed current, which the magnitude of the input voltage defines. The result is a rising ramp at the integrator's output. When the ramp reaches 2.5V, IC_2 generates a pulse because 2.5V is the threshold level of the Schmitt trigger at the 1B input of IC_2. Because the pulse magnitude is larger than the input voltage, the current through C_{INT} reverses, and C_{INT} partially discharges (**Figure 2**).

When the pulse is over, the integrator starts another rising ramp, and the cycle repeats. Because of the built-in Schmitt trigger, the circuit requires no separate comparator IC. Most applica-

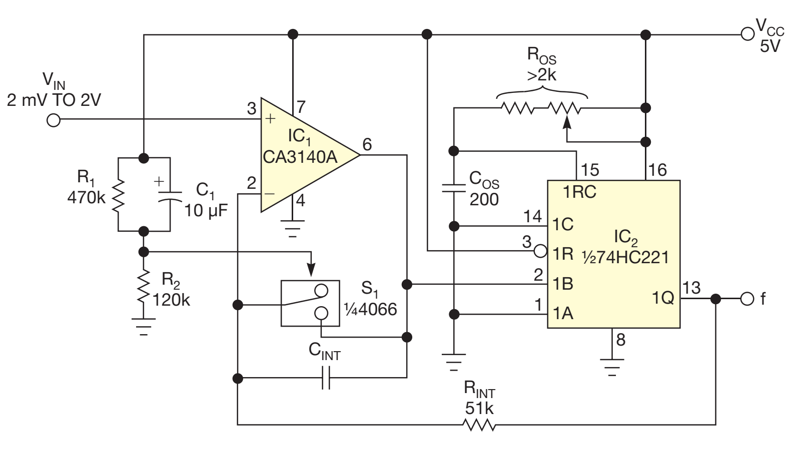

Figure 1 Three inexpensive ICs and a few passive components make a VFC with good linearity, speed, and dynamic range.

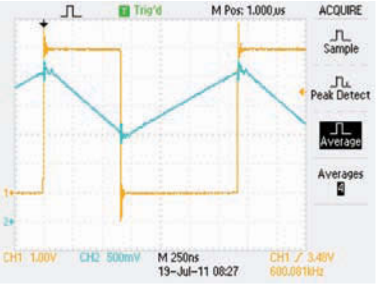

Figure 2 Because the pulse magnitude is larger than the input voltage, the current through C_{INT} reverses, and C_{INT} partially discharges.

tions can go without any adjustment. You adjust the full-scale frequency using only the trimming potentiometer, which is part of R_{OS} in **Figure 1**.

You can select different frequency spans (**Table 1**), each requiring its own values for C_{INT} and R_{OS}. The spans have different linearity. The **table** shows the linearity error as a percentage of the full-scale frequency for 11 equally spaced values of the input value in a range from 2 mV to 2V. **EDN**

TABLE 1 PERFORMANCE AT DIFFERENT FREQUENCY SPANS

Maximum frequency (kHz)	**Duration of t_{os}** (μsec)	**R_{OS} value** (kΩ)	**C_{INT} value** (pF)	**Linearity** (% of full-scale)
50	8	57.2	400	±0.044
100	4	28.6	200	±0.056
200	2	14.2	100	±0.021
400	1	7.15	50	±0.031
600	0.67	4.77	33	±0.066
800	0.5	3.58	25	±0.11
1000	0.4	2.86	20	±0.42

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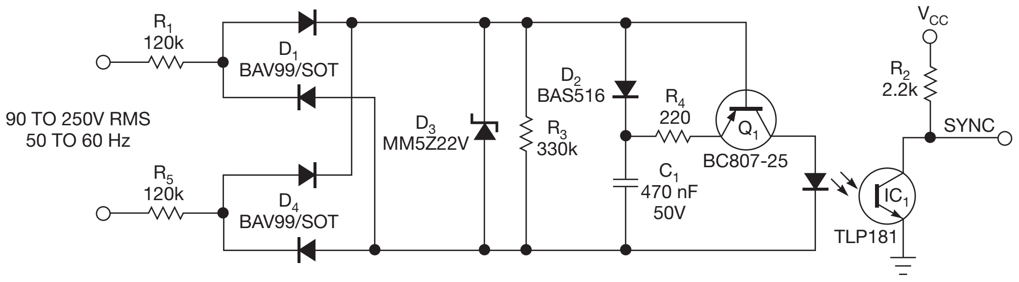
Mains-driven zero-crossing detector uses only a few high-voltage parts

Luca Matteini, Agliana, Italy

The circuit in this Design Idea generates a zero-crossing pulse off the ac mains and provides galvanic isolation. The falling edge of the output pulse happens at approximately 200 μsec before the zero crossing. You can use the circuit to safely stop the triggering of a thyristor gate, giving it time to properly turn off. The circuit generates short pulses only when the mains voltage is approximately 0V, thereby dissipating only 200 mW at 230V and a 50-Hz input.

The circuit charges capacitor C_1 up to the limit that 22V zener diode D_3 creates (**Figure 1** and **Reference 1**). You limit the input current with resistors R_1 and R_5. As the input-rectified voltage drops below the C_1 voltage, Q_1 starts conducting and generates a pulse a few hundreds of microseconds long. The coupling of IC_1 makes the response of Q_1 squarer. The rms operating voltage dictates the only requirement for R_1 and R_5. SMD, 1206-size resistors typically withstand 200V-rms operation. This design splits the input voltage between R_1 and R_5, for a total rating of 400V rms. D_3 limits the voltage across the bridge to 22V so that all of the sub-



NOTES:
YOU CAN LOWER D_3 TO AN 18 TO 20V PART, PERMITTING A LOWER VOLTAGE RATING, SUCH AS 25V, FOR C_1.
R_1 AND R_5 MUST BE 1206-SIZE PARTS TO WITHSTAND THE RMS VOLTAGE ACROSS THEM; 1206-SIZE PARTS ARE USUALLY RATED FOR 200V.

Figure 1 This zero-crossing detector uses low-voltage parts and consumes little power.

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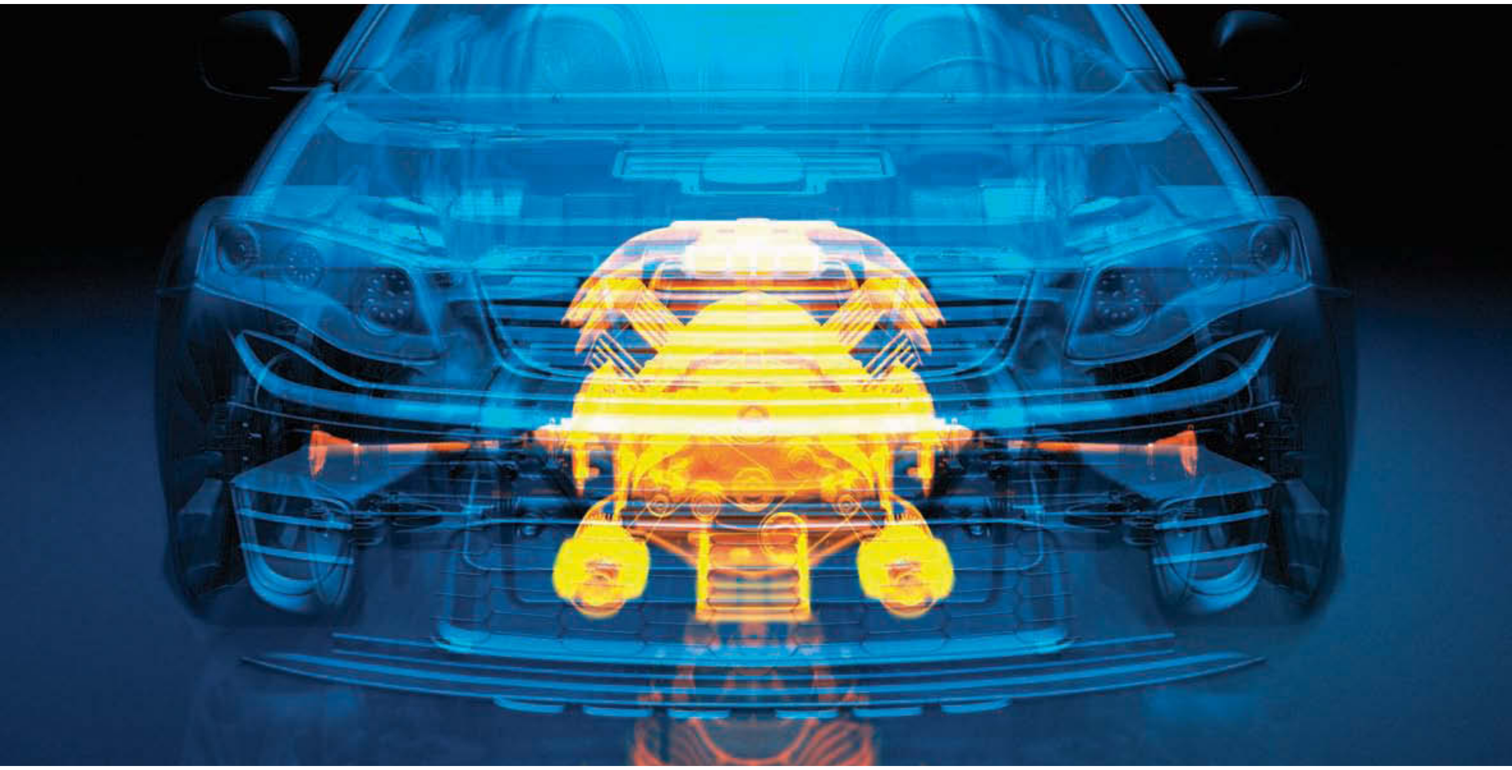

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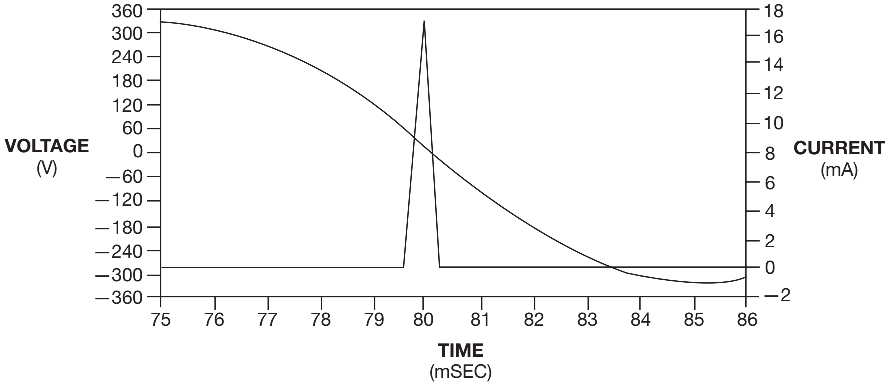

Figure 2 In this LTspice simulation, as the input voltage drops through 0V, the LED current makes a pulse whose edges lead and lag the crossing point. The peak optocoupler-LED current is 17 mA.

WITH A 230V INPUT AT 50V, THE LTSPICE SIMULATION SHOWS A 17-mA PEAK IN THE OPTOCOUPLER LED.

sequent components can have lower voltage ratings. A 22V zener diode can clamp as high as 30V, so this design uses a 50V, 470-nF ceramic capacitor. Ceramic capacitors have better reliability than electrolytic or tantalum capacitors, especially at higher temperatures. If you prefer a cheaper and smaller 25V part, you can change the zener diode's voltage to 18V and still have a good margin for safety. Use R_4 to limit the peak current in the LED. The primary limit on the LED current is the slope of the rectified ac input. The gradual slope doesn't let Q_1 generate current spikes when it discharges C_1's stored energy.

You can simulate the operation of the circuit in LTspice Version IV (**Figure 2** and **Reference 2**). With a 230V input at 50 Hz, the simulation shows a 17-mA peak in the optocoupler LED. The simulation gives good results with inputs of 90 to 250V, both at 50 and 60 Hz. At 110V and a 60-Hz input, the LED current peak is 8.5 mA, so IC_1 still works. If you need higher LED-drive currents, you can reduce the value of R_3 or increase the value of C_1.

Testing a physical circuit shows good correlation with the simulation (**Figure 3**). Driving the isolated output from a 5V logic supply yields a good pulse waveform (**Trace 1**). The mains input is fed to the scope with a 15V isolation transformer for safety (**Trace 2**). You can use the persistence feature of the oscilloscope to show the zero-crossing point when zooming in to the transition (**Figure 4**). This approach allows you to accurately measure the pulse timing relative to the input zero crossing. **EDN**

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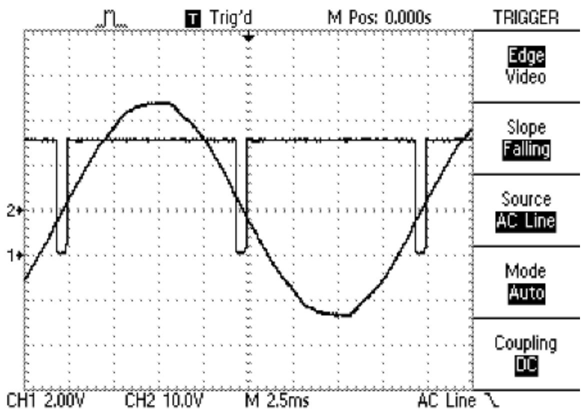


Figure 3 Results for a prototype circuit correlate well with the simulation.

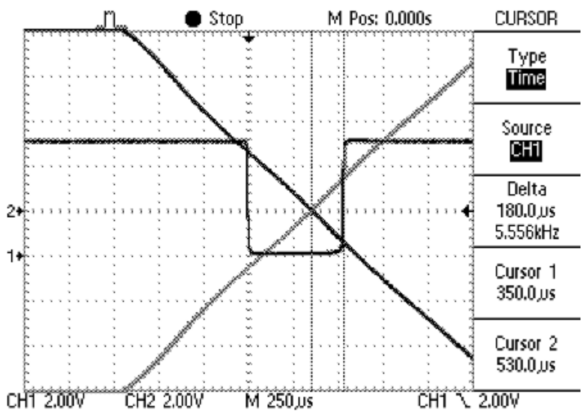


Figure 4 You can use the oscilloscope's persistence function to relate the exact zero-crossing point to the output-pulse timing.

Build an op amp with three discrete transistors

Lyle Russell Williams, St Charles, MO

You can use three discrete transistors to build an operational amplifier with an open-loop gain greater than 1 million (**Figure 1**). You bias the output at approximately one-half the supply voltage using the combined voltage drops across zener diode D_1, the emitter-base voltage of input transistor Q_1, and the 1V drop across 1-MΩ feedback resistor R_2.

Resistor R_3 and capacitor C_1 form a compensation network that prevents the circuit from oscillating. The values in the **figure** still provide a good square-wave response. The ratio of R_2 to R_1 determines the inverting gain, which is –10 in this example.

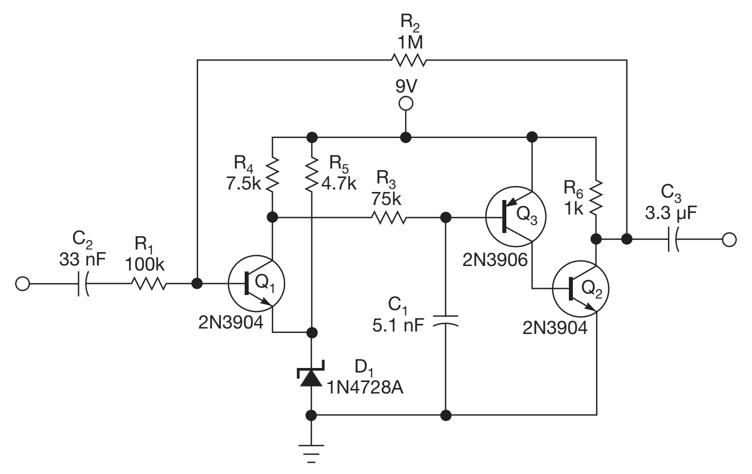


Figure 1 This ac-coupled inverting op amp has an open-loop gain of 1 million. R_1 and R_2 set a closed-loop gain of –10.

You can configure this op amp as an active filter or as an oscillator. It drives a load of 1 kΩ. The square-wave response is good at 10 kHz, and the output reduces by 3 dB at 50 kHz. Set the 50-Hz low-frequency response with the values of the input and the output capacitors. You can raise the high-frequency response by using faster transistors and doing careful layout. **EDN**

A diode ladder multiplies voltage under software control

William Grill, Riverhead Systems, Greeley, CO

The circuit in this Design Idea uses a Microchip 12F10 controller to drive a voltage multiplier ladder and a single pin to output status and to input a trigger signal you supply (**Figure 1**). When you trigger the signal, the software turns on a MOSFET to connect the multiplier output to a load. The microcontroller has an internal comparator with a 0.6V trip point. The circuit attenuates and feeds back the output voltage to this comparator.

Listing 1, which is available at www.edn.com/111201dia, shows the controller-based software, which stops the oscillator, driving the voltage multiplier when the internal comparator indicates that the output voltage has reached an upper limit. This circuit works in a wireless-monitor design, increasing the voltage, power, and range of a small periodic transmitter. It can provide 12 to 15V and 9 to 11 mA.

Processing begins when power is applied. The controller qualifies its Port 3 input on Pin 4. When at a logic high, logic is true, and the software code generates complementary PWM outputs on ports 4 and 5, which are pins 3 and 4, respectively.

These oscillations charge the ladder network. The controller outputs a low on the Port 2/Pin 5 status line, indicating that charging is under way. You choose the ratio of R_1 and R_2 so that the center node of the ladder is at 0.6V when the output voltage reaches the desired value. When the output reaches the final value, the controller puts the status pin in tristate mode, and the 20-kΩ resistor pulls the pin up to the power-rail voltage. Port 2 on Pin 5 then becomes an input.

When you pull this pin low, the microcontroller asserts Port 1 and Pin 6 high, turning on the P-channel MOSFET through Q_2, and applies the output voltage on C_4 to the load. Meanwhile, Port 1 and Pin 6 go high, shifting the lower pin of output capacitor C_4 from ground to the power rail and adding a few volts to the output of the voltage ladder.

The program drives the complementary outputs at pins 2 and 3 with a 700-µsec PWM period with a 50% duty cycle. You can change the software code to vary these parameters. The controller has an internal 4-MHz oscillator and supports a user-settable reference block. The code continues to monitor the enable pin, C_4's voltage feedback, and the pump operation during the discharge to the load. You must set certain bits in the processor configuration for this code to work (**Figure 2**). **EDN**

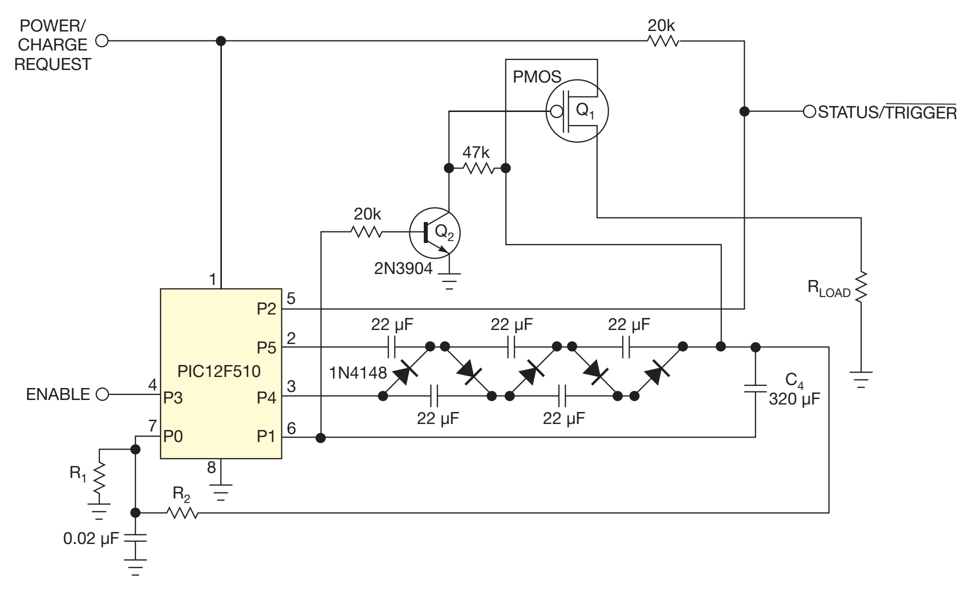
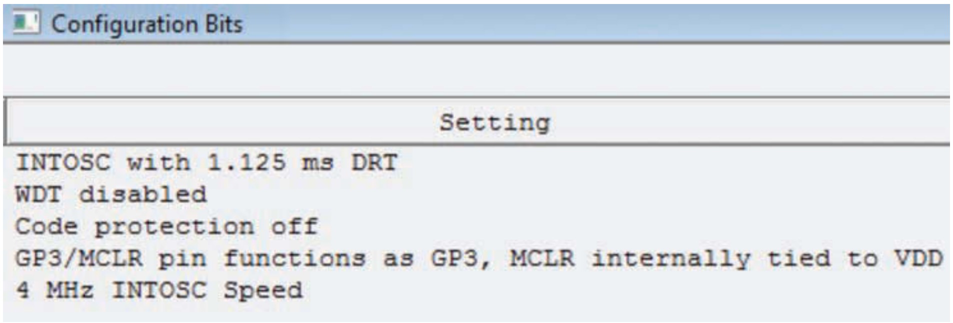


Figure 1 This circuit boosts 3V to a regulated 12V and connects the multiplied voltage to a load under software control.



```
Setting
INTOSC with 1.125 ms DRT
WDT disabled
Code protection off
GP3/MCLR pin functions as GP3, MCLR internally tied to VDD
4 MHz INTOSC Speed
```

Figure 2 Set these configuration bits for proper operation of the software code in the microcontroller.

Originally published in the February 7, 1985, issue of *EDN*

Charger extends lead-acid-battery life

Fran Hoffart, National Semiconductor Corp, Santa Clara, CA

A circuit that properly charges sealed lead-acid batteries ensures long, trouble-free service. **Fig 1** is one such circuit; it provides the correct temperature-compensated charge voltage for batteries having from one to as many as 12 cells, regardless of the number of cells being charged.

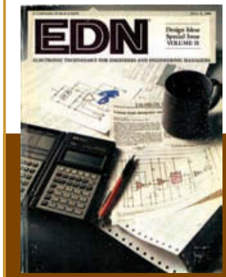
The **Fig 1** circuit furnishes an initial charging voltage of 2.5V per cell at 25°C to rapidly charge a battery. The charging current decreases as the battery charges, and when the current drops to 180 mA, the charging circuit reduces the output voltage to 2.35V per cell, floating the battery in a fully charged state. This lower voltage prevents the battery from overcharging, which would shorten its life.

The LM301A compares the voltage drop across R_1 with an 18-mV reference set by R_2. The comparator's output controls the voltage regulator, forcing it to produce the lower float voltage when the battery-charging current passing through R_1 goes below 180 mA. The 150-mV difference between the charge and float voltages is set by the ratio of R_3 to R_4. The LEDs show the state of the circuit.

Temperature compensation helps prevent overcharging, particularly when a battery undergoes wide temperature changes while being charged. The LM334 temperature sensor should be placed near or on the battery to decrease the charging voltage by 4 mV/°C for each cell. Because batteries need more temperature compensation at lower temperatures, change R_5 to 30Ω for a TC of –5 mV/°C per cell if your application will see temperatures below –20°C.

When the circuit charges more than six cells, the additional voltage across the LM334 increases self-heating, so use a small heat sink and increase the resistance of R_6. Likewise, use higher resistances in series with the LEDs to avoid overloading the LM301A.

The charger's input voltage must be filtered dc that is at least 3V higher than the maximum required output voltage: approximately 2.5V per cell. Choose a regulator for the maximum current needed: LM371 for 2A, LM350 for 4A, or LM338 for 8A. At 25°C and with no output load, adjust R_7 for a V_{OUT} of 7.05V, and adjust R_8 for a V_{OUT} of 14.1V. **EDN**



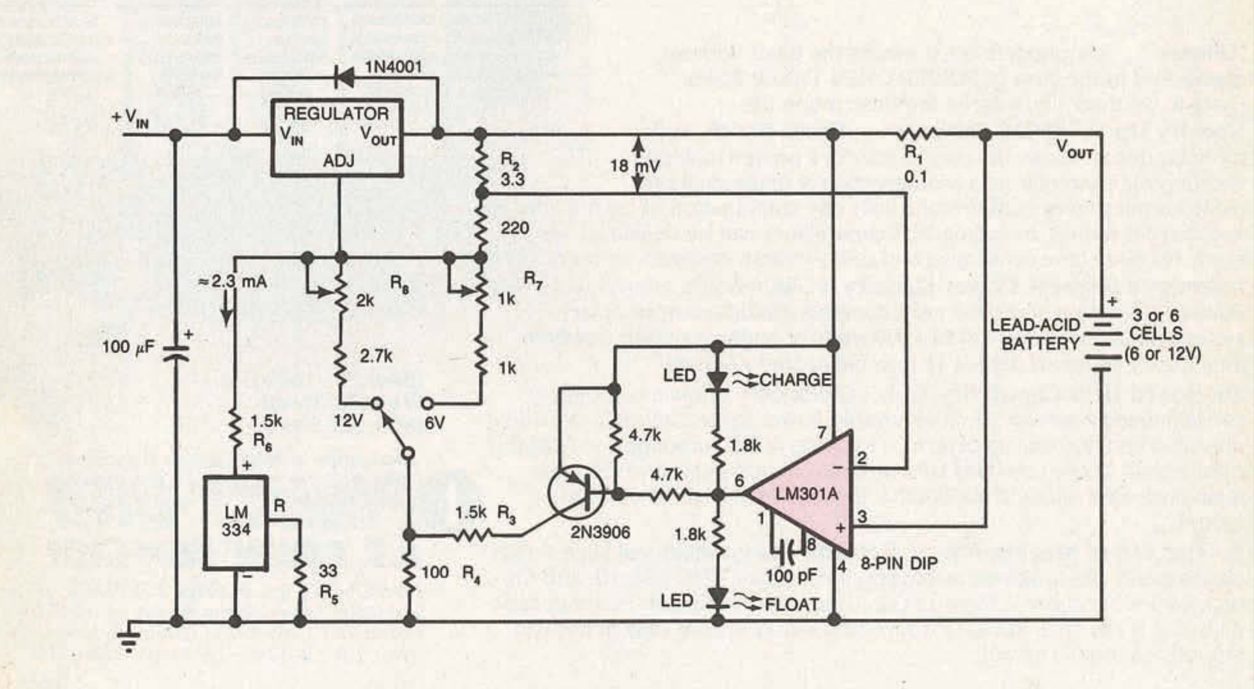


Figure 1 This circuit charges lead-acid batteries by applying 2.5V per cell (at 25°C) and floats them at 2.35V when they are fully charged. Use an LM371 regulator for a 2A rating, an LM350 for 4A, or an LM338 for 8A.

Counterfeit components cost more than US dollars, SIA testifies

US semiconductor companies face more than $7.5 billion in counterfeiting costs each year, but that loss is not the biggest that this illegal practice forces, according to recent Senate testimony by Brian Toohey (**photo**), president of the SIA (Semiconductor Industry Association). Toohey aims to aid the Senate's investigation into counterfeit electronic parts in the DOD (Department of Defense) supply chain.

Counterfeit versions of electronics and semiconductors are well-known threats in the electronics supply chain, and they put the health and safety of both the military and civilians at risk. That threat is growing, the SIA says, especially as microelectronics are finding use in an increasing number of mission-critical applications, such as lifesaving medical devices; automotive-safety systems; airplanes; and the tools, systems, and communications equipment that the US military relies on. “The catastrophic-failure risk inherently found in counterfeit semiconductors places our citizens and military personnel in unreasonable peril,” said Toohey, testifying on behalf of the industry before the Senate Armed Services Committee in November. “A counterfeit semiconductor is a ticking time bomb.”

> “Our industry takes this threat very seriously, and we are committed to doing everything within our power to stop counterfeits from entering our military and civilian supply chains.

Speaking about the economic impact of counterfeit parts on the electronics supply chain, Toohey added, “Counterfeiters violate American companies' intellectual-property rights and cost Americans jobs. We estimate that counterfeiting costs US-based semiconductor companies more than $7.5 billion each year.”

The SIA recommended to the committee a multipronged approach to effectively curtail counterfeit electronics. First, the government should support and continue partnerships among the industry, the DOD, and the DOJ (Department of Justice) to develop a more robust and effective authentication system. The government should also strengthen procurement procedures at the DOD for mission-critical components, including purchasing exclusively from authorized distributors, and ensure that the industry can fully partner with CBP (Customs and Border Patrol) officials to stop suspected counterfeits at the border by ending CBP's redaction policy. In addition, the government should aggressively prosecute counterfeit traffickers and provide stronger enforcement of intellectual-property rights internationally.

“Our industry takes this threat very seriously, and we are committed to doing everything within our power to work with the DOD and other government agencies to stop counterfeits from entering the US and our military and civilian supply chains,” said Toohey.

You can view Toohey's full testimony at http://1.usa.gov/t5E6Pc.

—by Suzanne Deffree

OUTLOOK

MORE CARS EMPLOY PREMIUM AUDIO SYSTEMS

Global sales in 2011 of premium audio systems for automobiles should reach 7.9 million units, up 14% from 6.9 million units last year, according to IHS iSuppli, which expects such sales to climb to 13.3 million units by 2015. According to the market-research company's estimates, the 2011 sales will show worldwide revenue of $7.3 billion, up 11% from $6.6 billion in 2010. The company expects unit-sales expansion of 12 to 18% during the next three years for premium audio systems, which include surround sound, eight or more speakers, 400W or more of power, or any combination of these features. The segment also includes branded audio in speaker grates, amplifiers, and head units.

Many automotive-infotainment functions are migrating from built-in car electronic systems and into portable devices, such as smartphones, says Mark Boyadjis, senior analyst and regional manager for automotive-electronics research at IHS iSuppli. “Music remains a basic feature that all vehicles must have,” he adds. “Audio systems that can produce high-quality sound will continue to be in demand.”

—by Suzanne Deffree


UBM
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“Universal” Memory? Not Exactly...

productroundup

CONNECTORS

Weidmüller introduces modular M23 connectors

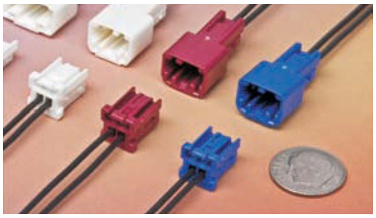
The modular M23 connector family features compact and robust circular connectors for signal-, power-, and hybrid-system applications. They target use outside cabinets in machine and industrial automation systems. The family includes signal connectors with six to 19 poles and a hybrid connector with four power contacts and four signal contacts. Gold-plated contacts ensure more than 1000 mating cycles and currents of 8 to 28A at voltages of 100 to 800V. Crimping contacts feature spring-loaded-socket technology. The connectors also feature the Euro-Lock system, which has an integrated locking clip that securely locks the contacts into the insert, allowing for easy assembly and disassembly without special tools. The connectors operate at −40 to +125°C.

Weidmüller, www.weidmuller.com

JST XMA series connectors offer wire-to-wire positive locking

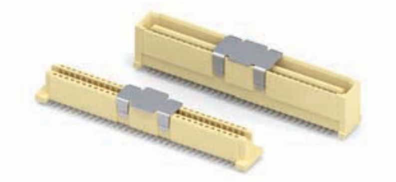
The XMA series of 2.5-mm-pitch, wire-to-wire, crimp-style connectors have a positive-locking feature when mating to prevent contacts from making connection until the mating halves fully mate and lock together. Optional secondary retainers ensure that the contacts are fully seated and locked into the housings to prevent accidental release. The receptacle housings have a tapered lead-in to prevent the pin and receptacle contacts from stubbing. Three optional housing and keying patterns are also available. The connectors come with two to six circuits rated 3A ac/dc (using #22 AWG; sizes AWG #26 to #22 are accommodated) at 250V and operate at −25 to +85°C. Contacts are made of a tin-plated, copper-alloy base material.

JST Corp, www.jst.com



Mill-Max offers 1-mm-pitch 891 and 893 series connectors

The 64-position, 1-mm-pitch 891 and 893 mezzanine connectors target use in parallel-board-stacking interconnections. The connectors meet EIA-700 AAAB specifications for the IEEE 1386 industry standard for adding general functions to motherboards. The surface-mount connectors have a mated height of 10 mm. The 1-mm pitch pro-

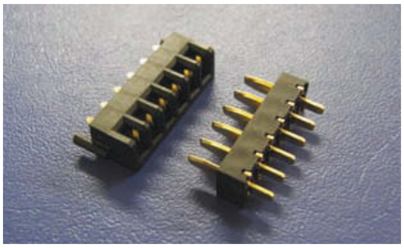


EDN ADVERTISER INDEX

vides high-density packing for saving space on PCBs. The connectors' housing includes locating posts to promote accurate placement on the PCB.
Mill-Max Manufacturing Corp,
www.mill-max.com

Yokowo's two-piece battery connector features two-way insertion

This two-piece battery connector allows both horizontal- and vertical-blade insertion. The connector's receptacle side features a dual-beam contact in both insertion directions. Two tabs on the receptacle provide a secure grip around the blade upon insertion. Biaxial torsion and a floating function absorb the battery gap and reduce the risk of intermittent power outages, even if a user drops the device. The connector targets use in devices requiring uninterrupted power, including data-collection terminals, medical equipment, military devices, aerospace equipment, and systems operating in harsh environments. Current ranges as high as 3A. The connector features a 30-mΩ maximum contact resistance, a −40 to +85°C operating temperature, 12V-ac/dc voltage, and 2000-cycle operational durability. Each blade has six 3-mm-pitch contacts.
Yokowo America Corp,
www.yokowoconnector.com

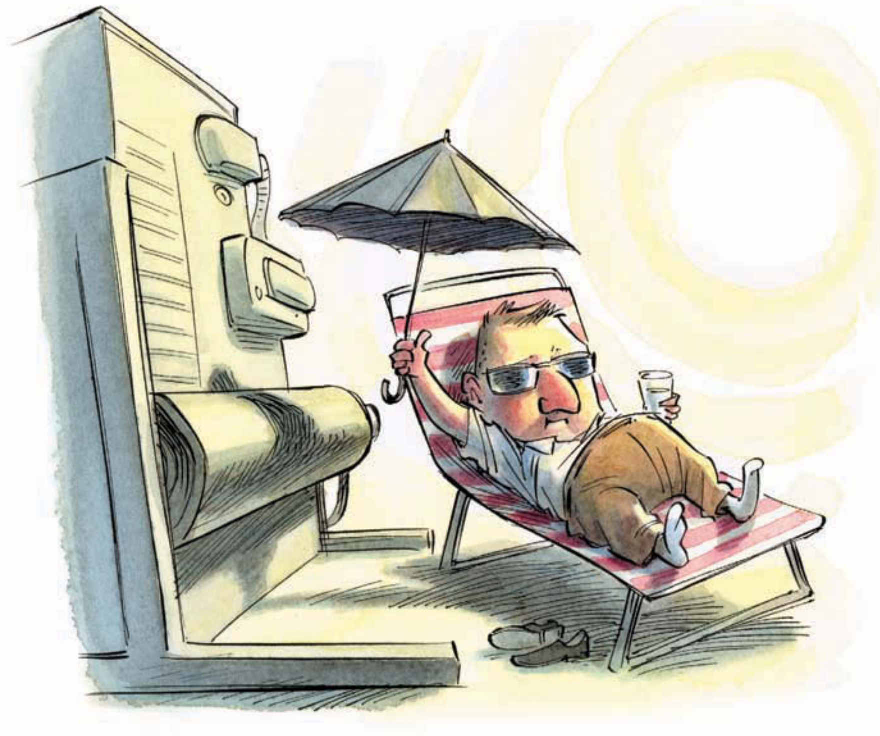


FCI's high-reliability Micro HDMI connector targets consumer applications

FCI's HDMI D-type connector complies with the physical, electrical, and environmental requirements of the HDMI standard. It can handle video signals up to 1080p, providing state-of-the-art HD resolution to handheld devices and featuring a full 19-pin array. It is a suitable option for next-generation compact audio/video data PCB layout targeting HDMI Rev 1.4 and 3-D signal transmission. The Micro HDMI connectors are available in a DIP+SMT legs version (10118241-001RLF) and a full DIP legs version (10118242-001RLF) with SMT solder tails. Each connector offers durability of 5000 cycles. Passive latching technology prevents unintentional cable release. The company also offers an HDMI A-type receptacle to enable linkage of HDMI A-type and D-type connectors in a host system.
FCI, www.fciconnect.com

CLARK S ROBBINS • GS ENGINEERING

The sun will screw up tomorrow



DANIEL VASCONCELLOS

Some time ago, I was involved in a project that used signals from various sensors to provide action inputs to a new electronically controlled hydraulic system that was part of a large industrial machine. Because of cost and design constraints, we had to use existing signals when possible. We slightly modified some of these signals to more closely meet our needs. Because these sensor signals were critical to the operation and success of the hydraulic-control system, we assimilated those people responsible for these other signals into a cohesive team. All subsystem and component owners had to report on a regular basis about the design and test progress relative to the new durability and reliability goals for their sensor subsystems. Initially, all tests went successfully with no unanswered questions from incidents that occurred during the testing.

After we committed to producing the system, however, a few puzzling incidents occurred. The safe operation of the hydraulic-control system required that we had to monitor a couple of the sensor signals 100% of the time for continuity, condition, and validity. The problem was that the system had detected the loss of a sensor signal for a longer time than the minimum allowable. We did in-depth testing and analysis of the sensor, the amplifier, the wiring, and the connections but could find nothing wrong and could not reproduce the problem. The sensor-subsystem team assumed a nonreproducible fault that would be of no concern. I disagreed with the findings but could offer no alternative cause or theory.

After we went into production, the same problem occurred but on only a few of the machines. However, because we had no root cause, we could not fix the problem and guarantee that those few machines would not have the problem again, so we had to replace each machine exhibiting the problem—an expensive approach.

An intermittent connection was obviously causing this sensor problem because the diagnostics reported the fault as a loss of continuity. According to the system's specifications, pin and sleeve connectors at the sensor amplifier and at the hydraulic-controller input could not be the source of the problem.

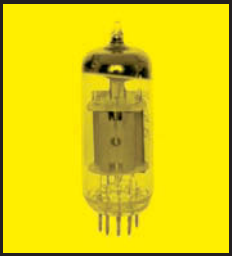
The project used some of these machines outdoors and sometimes from night into day. One of the machines had the problem a number of times on the same day, but the machine was sitting idle with energized controllers. When the problem occurred, the operator reset the fault because the machine was supposed to be up and running at a moment's notice. When I queried the operator about what had happened and when it had happened, he told me that the problem occurred whenever the sun was shining on the machine for a period of time. If clouds obscured the sun, the problem did not occur. The sensor amplifier's connector and surrounding support structure were facing directly into the sun.

It was now painfully obvious that thermal deformation of the support structure was moving the sensor amplifier and the pin and sleeve connector. A close examination of the pin- and sleeve-connector terminals showed that the pin was slightly undersized; under certain conditions, it could lose contact.

You might be able to guess where this story is heading. The connector manufacturer admitted that it occasionally produced slightly under-tolerance pins, citing a study that indicated that this condition would not create a noticeable problem with any of the systems using this connector. Although that claim may have been true for other systems that were using this connector, it was a problem for our hydraulic-control system, which could not tolerate the loss of that signal beyond a short time. **EDN**

Clark S Robbins is a software-application engineer at GS Engineering (Houghton, MI).

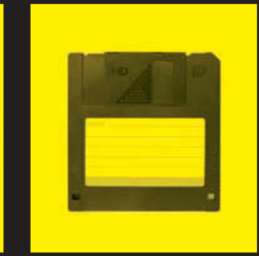
OPTOCOUPLERS ARE OLD TECHNOLOGY



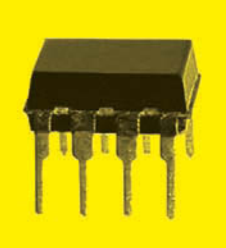
VACUUM TUBES
1910–1958

ROTARY PHONES
1920s–1980s

VHS TAPES
1970s–1990s



FLOPPY DISKS
1980s–1990s



OPTOCOUPLERS
1960s–2009

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[1] Intel, 2011. [2] Wincor-Nixdorf 2009. [3] Shinhan Bank ROI Study 2009.

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