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VOICE OF THE ENGINEER

FEB 17
Issue 4/2011
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DESIGNING OFFLINE AC/DC SWITCHING POWER SUPPLIES

BRICK BY BRICK

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ACCELEROMETERS AND TEMPERATURE SENSORS FIGHT SIDS

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EDN's 2010 INNOVATION AWARD FINALISTS

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Goodbye status-quo.

	Tektronix TDS2000C Series (DSO)†	Tektronix MSO/DPO2000 Series†
Bandwidth (MHz)	50, 70, 100, 200	100, 200
Max sample rate	2 GSa/s	1 GSa/s
Max memory depth	2.5 kpts	1 Mpt
Max update rate (waveforms/sec)	200**	5,000
Fully upgradable	No	No
Function Generator	No	No

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*All prices are in USD and subject to change

**Refer to Agilent Pub 5989-7885EN for update rate measurements

† Data for competitive oscilloscopes from Tektronix publications 3GW-25645-0 and 3GW-22048-1


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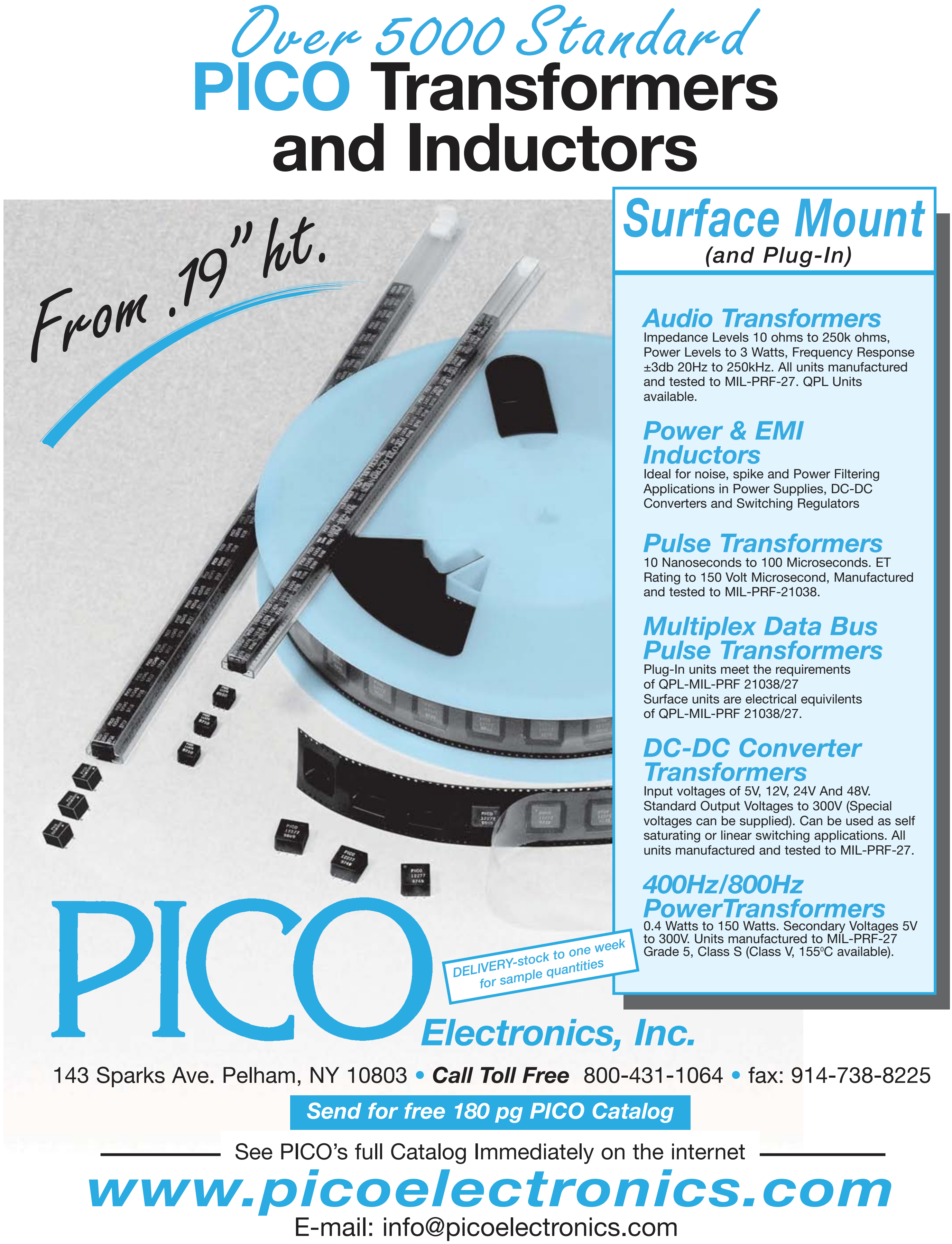

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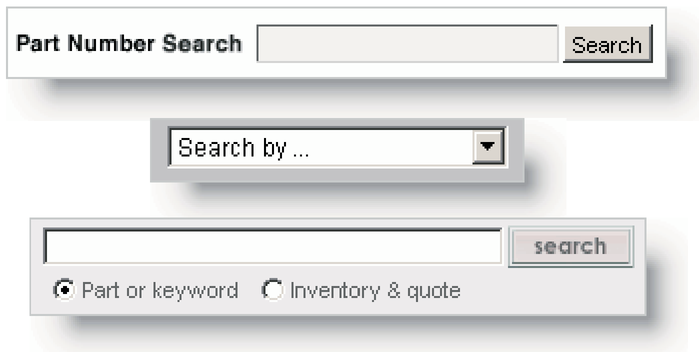
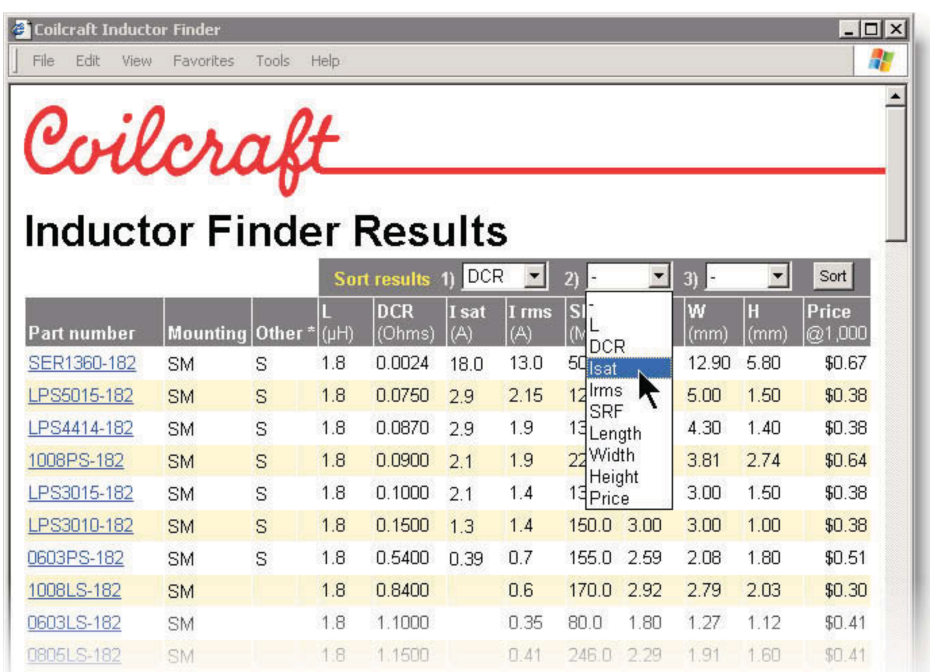


Their sites have search engines. Ours has a find engine.



Part number	Mounting	Other *	L (µH)	DCR (Ohms)	I sat (A)	I rms (A)	SI (M		W (mm)	H (mm)	Price @1,000
SER1360-182	SM	S	1.8	0.0024	18.0	13.0	50		12.90	5.80	$0.67
LPS5015-182	SM	S	1.8	0.0750	2.9	2.15	12		5.00	1.50	$0.38
LPS4414-182	SM	S	1.8	0.0870	2.9	1.9	13		4.30	1.40	$0.38
1008PS-182	SM	S	1.8	0.0900	2.1	1.9	22		3.81	2.74	$0.64
LPS3015-182	SM	S	1.8	0.1000	2.1	1.4	13		3.00	1.50	$0.38
LPS3010-182	SM	S	1.8	0.1500	1.3	1.4	150.0	3.00	3.00	1.00	$0.38
0603PS-182	SM	S	1.8	0.5400	0.39	0.7	155.0	2.59	2.08	1.80	$0.51
1008LS-182	SM		1.8	0.8400		0.6	170.0	2.92	2.79	2.03	$0.30
0603LS-182	SM		1.8	1.1000		0.35	80.0	1.80	1.27	1.12	$0.41
0805LS-182	SM		1.8	1.1500		0.41	246.0	2.29	1.91	1.60	$0.41

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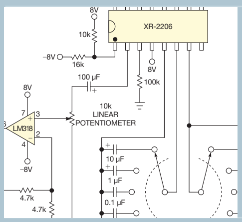
DESIGNIDEAS



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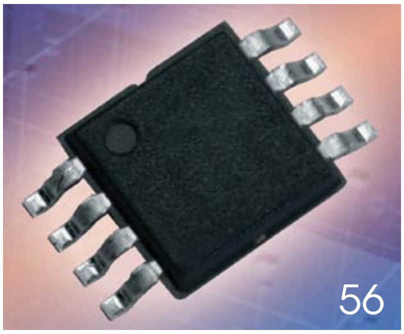

DEPARTMENTS & COLUMNS

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INNOVATION VOTE NOW!

Take a look at page 46 in this issue to see a list of the innovative engineers and products our editors selected as finalists in the 21st annual *EDN* Innovation Awards. After perusing the candidates, head to the Web to view a write-up of each finalist and help us honor electronic innovation by using the easy electronic ballot to make your voice heard.
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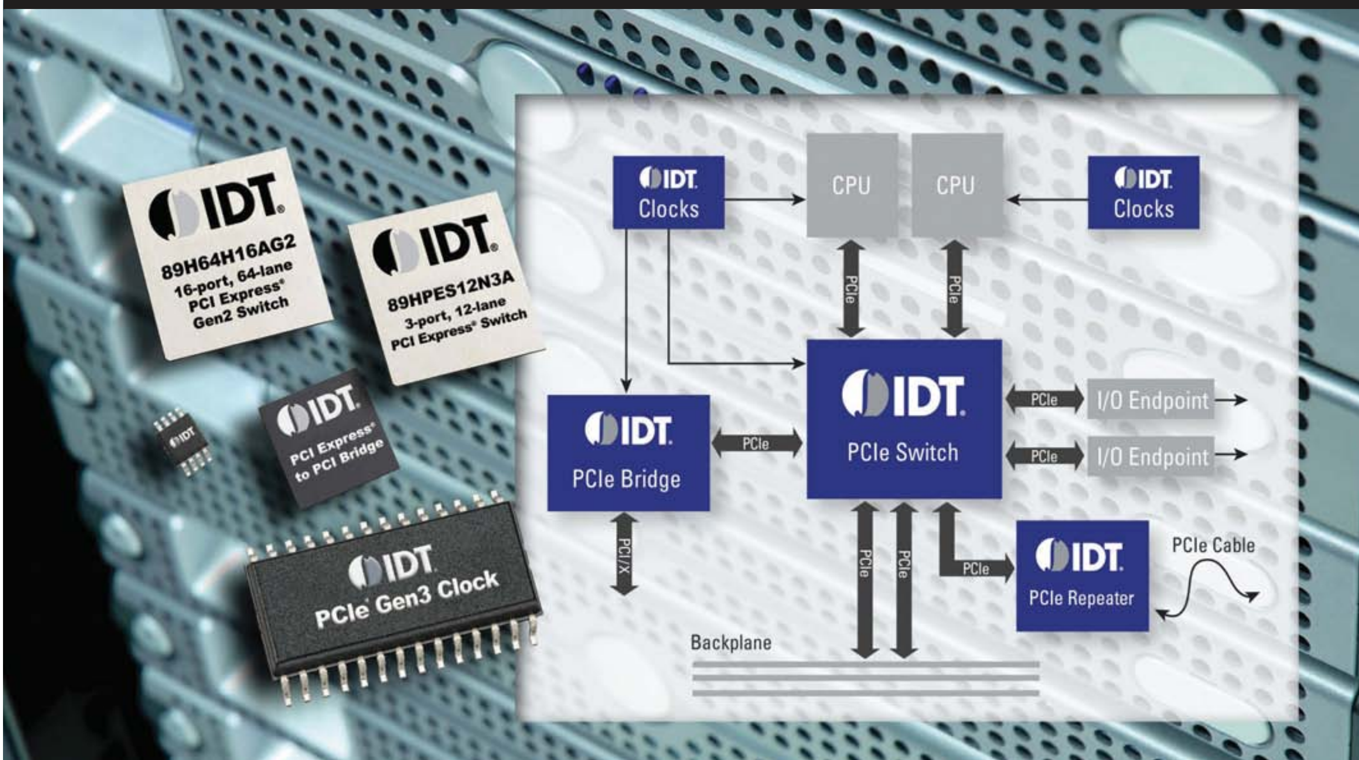

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BY RON WILSON, EDITORIAL DIRECTOR

Stuxnet and the Internet of Victims

In marketing speak, it is the Internet of Things. Just as in the first decade of this century the Internet connected the world's people, so—the pundits tell us—in this decade, the Internet will connect the world's man-made objects. The toaster will talk to the television, and the light switch will lie down with the lamp. Without debating the wisdom of this scenario for global unification, we feel the need to offer it a hurled monkey wrench and then to observe the consequences.

Our spanner comes in the form of that recently famous computer virus, Stuxnet. As you may recall, no one has admitted to being the source of the virus. But it appears that some organization opposed to Iran's nuclear program launched Stuxnet onto the Internet to attack the software that controls Iran's uranium-enrichment centrifuges. Unfortunately, Stuxnet seems to have attacked many other instances of this widely used software, as well, making it perhaps the first act of global cyberterrorism.

It won't be the last.

And that brings us to the point. Every node on the Internet of Things can be either the target of a malicious attack or the collateral damage from one. Your toaster may burn breakfast because your junior-hacker nephew is bored. Or the traffic light you are approaching may turn green in all directions because someone wants to disrupt an election in Athens.

Connectivity brings with it vulnerability. And when you make the things with which we live vulnerable, you must defend them. This observation has implications for how we design, test, and maintain embedded systems. Given the realities of human nature, there may be implications for the future of the entire Internet.

PHOTO-ILLUSTRATION BY TIM BURNS. TOASTER: BARIS SIMSEK/ISTOCKPHOTO.COM

The implications for design are disturbing. A network-connected embedded controller capable of defending itself certainly must have authentication and encryption technology. If interactions with the Internet are intense, the node will need a dedicated cryptography engine. Experience has shown, however, that high security cannot rely on passive defenses. Mission-critical systems—such as the traffic signal—may need a full hardware-based firewall, especially if these systems will do code updates.

And what about the code? We will certainly need a secure kernel and probably full virtualization. From experience with PCs and smartphones, we already know that security means not just secure design: It means a continuous battle of countermeasures against an unseen foe. So, yes, there will be code updates. And the need for updates means that the node must remain tethered to its developer as long as it is in service.

Every node on the Internet of Things can be either the target of a malicious attack or the collateral damage from one.

If you add all this up—hardware requirements, secure virtualized software, frequent updates over the whole product life—you get to the bottom line. Security, not performance, will set the minimum cost of a node. Ignore security, and the Internet of Things becomes the Internet of Victims. **EDN**

Contact me at ron.wilson@ubm.com.

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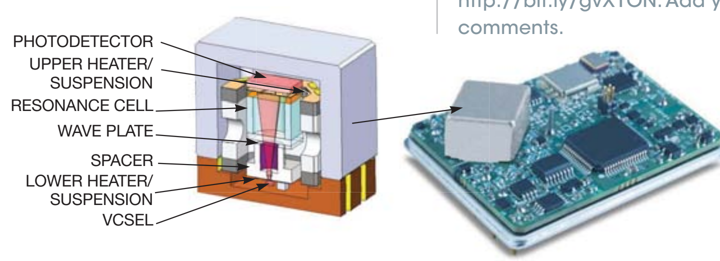
Chip-scale atomic clock survives 500g shock on any axis

Symmetricom's new SA.45s chip-scale atomic oscillator outputs a 10-MHz, 3.3V square wave and a 400-nsec, 1-pulse/sec signal. You can use an RS-232 interface to the device's internal DSP to provide status and modify the pulse output. The SA.45s has a center-frequency accuracy of $\pm 5\times10^{-11}$ and can survive 500g shock on any axis. It occupies 16 cc of volume, weighs 35g, and requires 115 mW of power. Allan-deviation stability is 2×10^{-10} over a tau of 1 sec. The device features SSB (single-sideband) RF-output phase noise at 1 Hz of less than –53 dBc (decibels referred to carrier)/Hz. With a 110-second warm-up, the oscillator has MTBF (mean time between failures) of greater than 100,000 hours.

This oscillator finds use in applications such as dismounted IED (improvised-explosive-device) jammers, UAVs (unmanned aerial vehicles), next-generation man-pack radios, military handheld GPS (global-positioning-system) units, and geophysical sensors. It comes in a 1.6×1.39×0.45-in., hermetically sealed package. Option 001 operates from –10 to +70°C, and Option 002 operates from –40 to +85°C. The SA.45s sells for $1500 (small quantities).**—by Paul Rako**

▷**Symmetricom**, www.symmetricom.com.



The physics package in the Symmetricom atomic clock has a microwave oscillator on the PCB (printed-circuit board) that modulates a VCSEL (vertical-cavity surface-emitting laser). The Q (quality factor) of the cesium resonance cell is greater than 10 million.

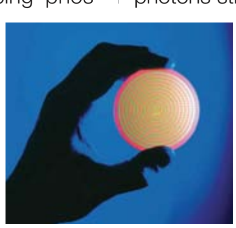
TALKBACK

"Everything has capacitance, all wires have resistance, and most people don't get engineering humor. These rules always matter."

—Engineer Ken Thornton-Smith, in *EDN*'s Talkback section, at http://bit.ly/gvX1ON. Add your comments.

Secondary phosphors simplify white-LED-lighting design

Intematix hopes to separate LED emitters from their white-light-producing phosphors and simplify the design of LED lighting by selling solid forms of phosphors, or secondary phosphors, which designers can assemble separately from the LED as part of the light itself. In traditional white-LED design, using primary phosphors is the most familiar approach. A white LED is essentially a blue LED with a dollop of phosphor directly on the die. This phosphor emits white light when the LED's blue-wavelength photons strike it; the phosphor emits white light in response.



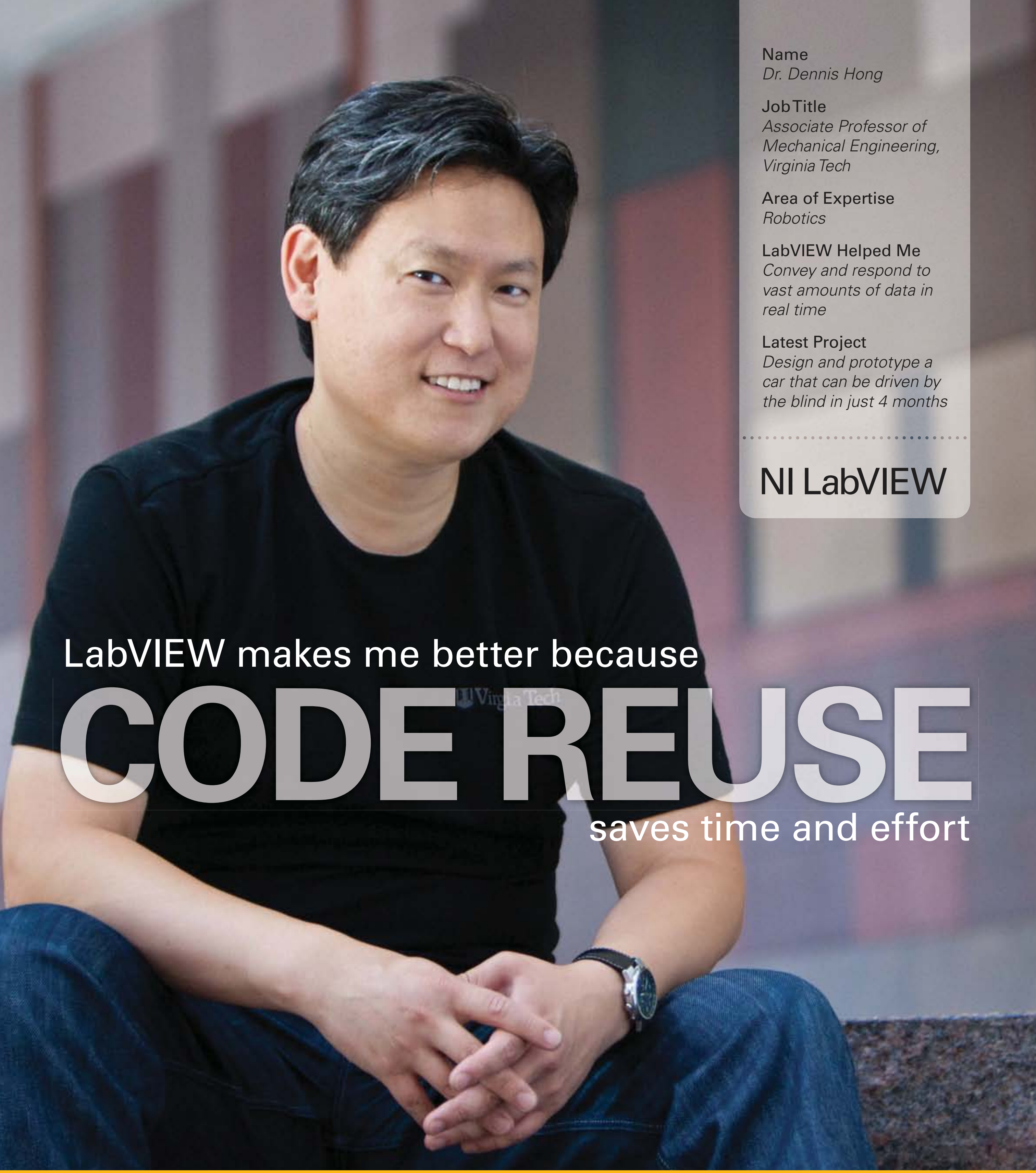
With Intematix's ChromaLit secondary-phosphor approach, the phosphor is separate from the blue-light source.

Matching LEDs to phosphors can be tricky. LED manufacturers make the decision during the design of the LEDs, and the designers of end-lighting systems can't tweak these designs for their applications.

Intematix's approach is not new: You can think of fluorescent lights as having secondary phosphors because the initial wavelength in the fluorescent tube is ultraviolet and becomes white only after striking the internal phosphor coating, which in turn emits the white fluorescent light.

The phosphors are available in the ChromaLit development kit, which implements precision optics manufacturing and Intematix's phosphor technology to enable lighting manufacturers to create lighting systems in any shape and color. You can customize ChromaLit products in geometry, color temperature, color-rendering index, and substrate material, thus offering creative opportunities.**—by Margery Conner**

▷**Intematix**, www.intematix.com.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Two entry-level scope series offer mixed-signal capability, built-in waveform generator

Agilent Technologies has expanded its MSO (mixed-signal-oscilloscope) and DSO (digital-storage oscilloscope) portfolios with two affordable entry-level InfiniiVision X series that together comprise 26 models, including units that have two and four analog channels. The 2000 X series offers bandwidths of 70 to 200 MHz and boasts 50,000-waveform/sec update rates. Maximum sampling rate is 1G sample/sec, which doubles when you use only half of the channels. Waveform-memory depth is 100,000 points/channel.

The scopes include optional eight-channel MSO capability and optional built-in 20-MHz sine-, square-, ramp-, triangle-, pulse-, dc-, and noise-waveform generation. The 3000 X series offers 100- to 500-MHz bandwidths and a waveform-update rate of 1 million waveforms/sec.The 2G-sample/sec maximum sampling rate and the waveform-memory depth of 1 million (optionally, 2 million) points/channel double when you use only half of the analog channels. Options include a 16-channel MSO capability, the built-in waveform generator, and hardware-accelerated serial-protocol decoding.

The InfiniiVision X-series scopes include a custom 90-nm CMOS ASIC with 6 million gates and embedded memory. This MegaZoom IV single-chip architecture enables the integrated logic-timing analyzer; function generator; and, in the 3000 X series, protocol analyzer. The scopes also allow you to see more of the signal more of the time because the MegaZoom IV technology delivers 3000 X-series update rates to 1 million waveforms/sec, minimizes blind time, and maintains responsiveness with deep memory enabled.

All models come with an 8.5-in.-diagonal, 800×480-pixel WVGA (wide-video-graphics-adapter) display, which offers twice the viewing area of other popular scopes. X-series units weigh only 8.5 lbs and conserve bench space with a footprint approximately 15 in. wide by less than 6 in. deep.

The scopes offer optional integrated MSO capability for time-aligned digital- and analog-signal viewing and an optional integrated WaveGen function generator. The 3000 X-series units also offer optional hardware-accelerated serial-protocol analysis. Upgrade options provide investment protection: The fully upgradable (including bandwidth within the series) X-series scopes allow you to purchase what you need today and add capability as your performance needs evolve. Optional measurement-software packages, which add functions either at purchase or as needs arise, include segmented memory for analysis of laser pulses, radar bursts and serial packets, and hardware-accelerated mask testing to quickly perform pass/fail analysis using known-good waveforms.

The 1M-waveform/sec update rate, optional built-in waveform generator, and moderate price are among the features that distinguish the MSO-X 3054A 500-MHz-analog-bandwidth mixed-signal scope. With the optional double-depth memory and two analog channels in use, the scope acquires 4M-sample records at 4G samples/sec/channel.

> "The scopes offer optional MSO capabilities and an integrated WaveGen function generator.

The 3000 X series also offers hardware-accelerated serial decoding and trigger enabling to allow rapid analysis of I^2C (inter-integrated-circuit), SPI (serial-peripheral-interface), CAN (controller-area-network), LIN (local-interconnect-network), I^2S (I^2C sound), RS-232, and other UART (universal asynchronous receiver/transmitter)-based networks.

US suggested retail prices range from $1234 for a two-channel, 70-MHz DSOX2002A to $13,520 for a four-channel, 500-MHz MSOX3054A with 16 logic-analysis channels; optional double-depth waveform memory; a built-in waveform generator; and one hardware serial-triggering option. Discounts are available for educational users.

—by Dan Strassberg

▷**Agilent Technologies**, www.agilent.com/find/infiniivisionx-series.

DILBERT By Scott Adams

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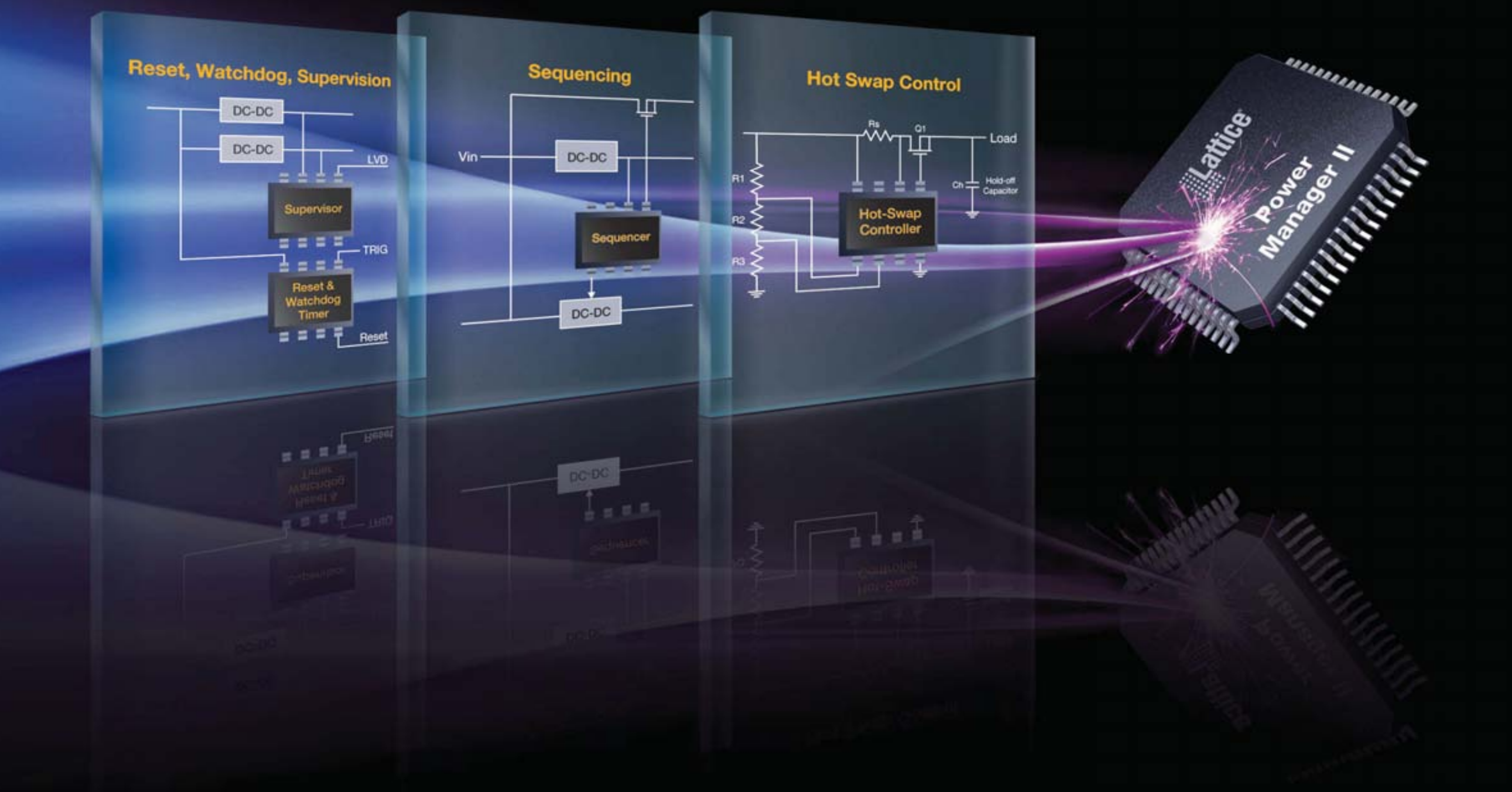

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1-GHz DSP core targets low-cost, high-definition audio applications

Ceva's new TL3211 DSP core is code-compatible with the company's TeakLite-III architecture. The core addresses the requirements of 2 and 3G (second- and third-generation) modems in low-cost smartphones and supports HD (high-definition) audio features for DTVs (digital televisions), set-top boxes, and Blu-ray Disc players.

Ceva manufactured the core in a 40-nm CMOS process, achieving a silicon footprint of 0.2 mm^2 and operation at a 1-GHz clock rate. A complete audio circuit in the 40-nm process includes 24k words of data memory, 8k words of code memory, memory controllers, and the AXI (Advanced Extensible Interface), with a chip area of 0.6 mm^2.

The 32-bit TL3211 audio-DSP core has a single-cycle 32×32-bit multiplier, a 32-bit register file, 64-bit-wide memory bandwidth, and 72-bit accumulation for wide dynamic range and efficient bit manipulation. It supports as many as three instructions running in parallel and single- and double-precision FFT (fast-Fourier-transform) instructions for efficient codec implementations.

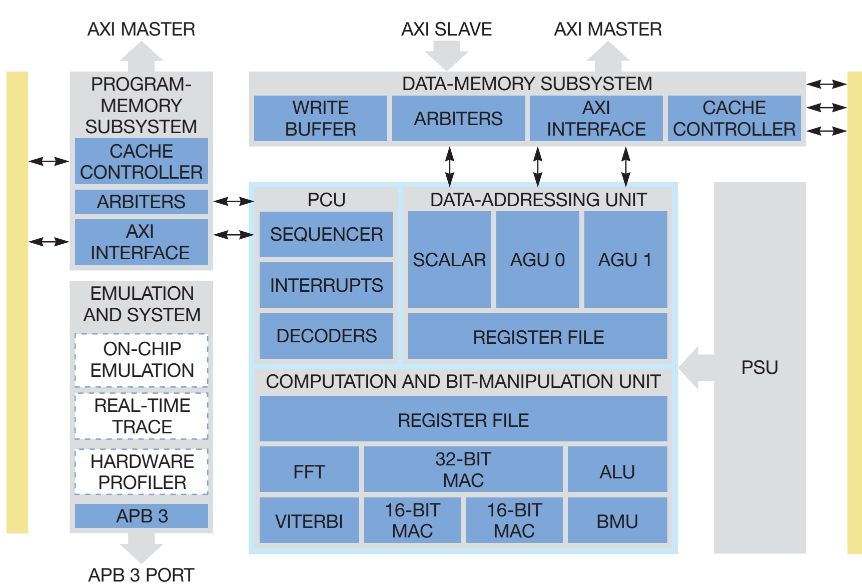
For mobile devices, the TL3211 enables integration of baseband processing with application processing for HD audio, supporting voice enhancements, such as noise cancellation, speech recognition, and beam forming. Ceva offers more than 90 audio and voice codecs, including MP3, AAC (advanced audio coding), HE-AAC (high-efficiency advanced audio coding), WMA (Windows media audio), WMA Pro, and RealAudio. Ceva also provides a suite of fully certified Dolby (www.dolby.com) codecs, including Digital, Digital 5.1 encoder, Digital Plus, TrueHD, and ProLogic IIx, and DTS (Digital Theater System, www.dts.com) codecs, including the DTS core decoder, DTS 5.1 encoder, DTS-HD LBR (low bit rate), DTS-HD Master Audio, and DTS Neo 6.

The TL3211 includes Ceva's PSU (power-scaling unit), which applies clock frequency and voltage scaling to reduce power consumption, allowing for lower-cost IC packaging. It also includes two 16-bit MAC (multiply/accumulate) units, a 32-bit MAC unit, Viterbi functions, an ALU (arithmetic-logic unit), a BMU (bit-manipulation unit), two AGUs (address-generation units), a PCU (power-control unit), and full-duplex APBs (advanced peripheral buses).

The Ceva-Toolbox provides a software-development and -debugging environment for the TeakLite-III family. The development environment fully simulates the TL3211's cached memory subsystem. The TL3211 core and Ceva-HD-Audio are now available for licensing.

—by Mike Demler

▷**Ceva**, www.ceva-dsp.com.



Ceva's TL3211 core includes program- and data-memory subsystems, a bit-manipulation unit, a power-control unit, a power-scaling unit, and Viterbi and FFT functions.

02.17.11

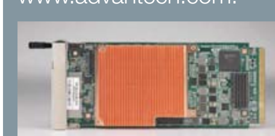
COMPACTPCI SINGLE-BOARD COMPUTER USES INTEL CORE PROCESSOR

The MIC-5603 AMC (advanced-mezzanine-card) CompactPCI (Peripheral Component Interface) single-board computer incorporates the second-generation Intel (www.intel.com) Core i7 processor and targets applications requiring graphics or vector processing and computationally intensive tasks.

An optional front-panel HDMI (high-definition multimedia interface) connects to the processor's on-chip controller, offering integrated Intel HD (high-definition) graphics DX10.1 and OpenGL (graphics-library) capabilities. The system includes as much as 8 Gbytes of 1333-MHz DDR SDRAM with ECC (error-correcting-code) suiting use in applications requiring low-latency memory access. The device achieves external Ethernet connectivity through two dedicated GbE (gigabit-Ethernet) front-panel ports.

—by Fran Granville

▶**Advantech**, www.advantech.com.



The MIC-5603 single-board computer incorporates Intel's second-generation Core i7 processor family for performance enhancements and scalability in graphics-processing applications.

Rarely Asked Questions

Strange stories from the call logs of Analog Devices

Considerations on High-Speed Converter PCB Design, Part 2: Using Power and Ground Planes to Your Advantage

Q. What are some important PCB layout rules when using a high-speed converter?

A. Part 1 of this RAQ discussed why splitting AGND and DGND is not necessary unless circumstances within the design force you to make that choice. Part 2 discusses the design of a power delivery system (PDS) for the printed circuit board (PCB). Often overlooked, this task is critical for analog and digital designers working at the system level.

The PDS design goal is to minimize the voltage ripple that occurs in response to supply current demand. All circuits require current, some more than others and some at faster rates than others. A low-impedance power or ground plane with adequate decoupling and a good PCB stack will minimize the voltage ripple that occurs as a result of the circuit's current demands. For example, if a design has 1-A switching currents and the PDS has 10-mΩ impedance, the maximum voltage ripple will be 10 mV.

First, design a PCB stack that supports a large plane capacitance. For example, a six-layer stack may comprise top signal, ground1, power1, power2, ground2, and bottom signal. Specify ground1 and power1 to be close in the stack—separating them by 2 mils to 3 mils forms an inherent plane capacitor. The best part about this capacitor is that it is free; just specify it in the PCB fabrication notes. If the power planes must be divided, with multiple VDD rails on the same plane, use as much of the plane as possible. Don't leave voids, but be mindful of sensitive circuitry as well. This will maximize the capacitance for that VDD plane. If the design allows extra layers—from six to eight in our example—put two extra ground planes between power1 and power2, doubling the inherent capacitance in the stack given the same 2-mil to 3 mil core spacing.

With the perfect PCB stack, use decoupling at both the entry point where the power plane originates and around the DUT. This will ensure a low PDS impedance across the entire frequency range. Use a handful of capacitor values from 0.001 µF to 100 µF to help cover this range. It isn't necessary to sprinkle capacitors everywhere, and butting them right up against the DUT breaks all kinds of manufacturing rules. If these kinds of drastic measures are required, then something else is going on in the circuit.

To Learn More About High-Speed Layout
http://dn.hotims.com/34921-101

Contributing Writer Rob Reeder is a senior converter applications engineer working in Analog Devices high-speed converter group in Greensboro, NC since 1998. Rob received his MSEE and BSEE from Northern Illinois University in DeKalb, IL in 1998 and 1996 respectively. In his spare time he enjoys mixing music, art, and playing basketball with his two boys.

Have a question involving a perplexing or unusual analog problem? Submit your question to: www.analog.com/askrob

VOICES

Emerging power technology: silicon carbide

John Palmour, co-founder of Cree and chief technology officer for the company's power and RF products, sees SiC (silicon carbide) as a viable competitor to silicon devices for high-power switches. Silicon wafers have formed the basis of virtually all digital-computing wizardry and many power devices, as well. However, new wafer technologies are emerging to challenge silicon's domination in the power arena. Palmour sees SiC as a challenger that will emerge from and transcend the niche power market to rival silicon in high-power devices. According to Palmour, using SiC-based devices results in an efficiency increase of more than two percentage points over competing components. For more on this technology, see "SiC power MOSFET pushes past Si-based MOSFETs/IGBTs with lower losses, lower capacitance, easier drive," *EETimes*, Jan 17, 2011, http://bit.ly/fboYvC.

Your new silicon-carbide MOSFET switches command a stiff price premium. Do you see them as products for a niche market?

A No, we see it as a mainstream high-voltage technology; 30 years ago when vendors introduced the first HEXFETs [hexagonal FETs], they sold for approximately $100 each. Now, they're about $2. Like the first HEXFETs, these SiC devices are not easy to make, but there's a lot of opportunity to shrink the devices, simplify the process technology, develop device architectures, and go to larger die sizes: Today, we're on 4-in. wafers, and we'll move up to 6 in. in the next 18 months.

One of the reasons that silicon technology dominates in new-device development is its ready availability; there are lots of silicon foundries and designers. Cree has been in the SiC market for a long time and has a lot of patents protecting its technology. Are you concerned about stifling innovation in a new technology?

A We sell wafers to anyone who wants to buy them. We're not the only one investing in the technology. The Japanese have been spending a tremendous amount of money to develop SiC, from crystal growth right up through device technology. We don't expect to be alone in this [market].

In the 600 to 1200V range of silicon carbide, the real competitor seems to be IGBTs [insulated-gate bipolar transistors]. Yet, SiC MOSFETs currently have 20A specifications, well below those of IGBTs, whose specs can range higher—into the hundreds of amperes. How can they compete?

A You can buy IGBTs typically capable of as much as 200A in die size, and you can buy modules of paralleled die that do 1000A. We can likewise parallel SiC devices to 1000A, although we don't currently offer anything as high current as an IGBT chip. We do want to go up in current because it makes life easier for the module guys. One of the things about SiC is that it's easy to parallel because it has a [positive]-temperature coefficient so [the chips] share current well [in a module].

What about other emerging technologies? Manufacturers have also recently introduced GaN [gallium-nitride]-on-silicon wafers as a way to leverage GaN on the more common silicon-manufacturing process.

A GaN on silicon is currently at a much lower voltage range—in the low hundreds of volts. One company offers a 200V HEMT [high-electron-mobility-transistor] device. Silicon carbide is at six times the voltage and two to three times the current range of an HEMT device. In power devices, leakage currents, reliability, and avalanche capability are extremely important. We firmly believe that SiC is a much better choice than GaN. GaN has a million times higher defect, or dislocation, density than does SiC. All those dislocations lead to leakage current that prevents you from taking a power device to avalanche. Then, if you grow your process on silicon, there's another factor of 10 times more defects. Regarding the argument that you can use cheap 6-in. wafers for GaN; we're soon moving our 4-in. SiC process to 6 in.

I think, though, that GaN on silicon makes a lot of sense for lower voltages. It doesn't stack up well in the 600V and higher voltage range. If you look back, Cree started with a focus on SiC and GaN. The company has grown around it as a focus. You can do amazing things with focus—and a little bit of money.

What if alternative-energy applications, such as large-scale solar inverters, dc-voltage backbones for servers, and wind generators, don't take off? Are you willing to bet that they will?

A Yes, we're willing to make that bet, but the good news is that we don't have to. Beyond alternative energy are large motor-drive-business and traction applications, such as trains and trams, as well as the electric- and hybrid-vehicle market. SiC is a generally applicable, superior power semiconductor. [SiC's advantage is not at a] part-to-part price comparison; it can save you money at the system level. You get to throw away snubber circuits, shrink heat sinks, downsize switches, and [still] get higher efficiency. In the long term, we expect this technology to be a ubiquitous power semiconductor.

—interview conducted and edited by Margery Conner

BY BONNIE BAKER

Photosensing with ambient background

Trying to shield ambient light from your photo circuit is not a trivial task. You would think that you could just cover your circuit with your hands, but that is not a solution: Pulse oximeters depend on the translucency of flesh. Covering the photosensor with black electrical tape doesn't work, either, because light is somehow able to get through even that material.

So it is fair to say that ambient light can be a problem in some light-sensing applications. **Figure 1**'s oscilloscope photo of A_1, a dual-supply, transimpedance amplifier, shows a square-wave light signal in the presence of background light. This environment creates a dc offset voltage of approximately 3.5V referred to the output. The transimpedance amp has a built-in offset due to the fact that the photodiode can conduct current in only one direction. The combination of ambient light and the amplifier's built-in offset makes a total offset of about 7.5V, which you may be able to calibrate from your system. However, you are using only one quadrant of the amp's output range. Further, when the measured light signal increases to maximum intensity, the amplifier's output starts to saturate.

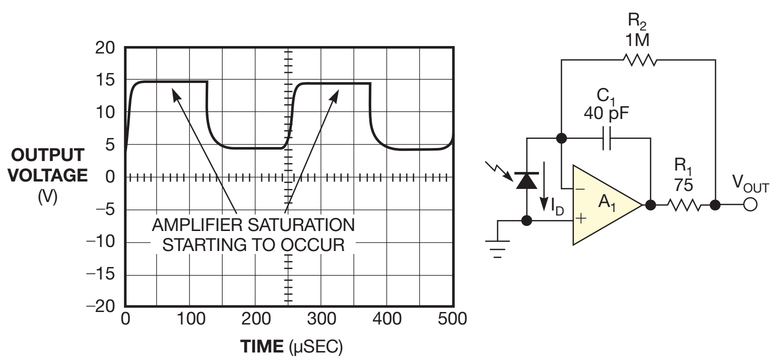


Figure 1 The output range of a transimpedance amplifier spans only one quadrant.

A dc-restoration circuit, A_2, comprises a noninverting integrator driving the summing junction of the transimpedance amplifier through R_5 (**Figure 2**). The current through R_5 cancels the current from the photodiode at frequencies below the integrator's signal-zero frequency. In **Figure 2**, the signal-zero frequency from the dc-restoration circuit is $R_2/[R_5(2\pi R_4C_4)]$. You adjust this zero by changing R_5. This dc-restoration circuit requires that the portion of the signal zero that R_3 and C_3 generate matches that of R_4 and C_4. The transimpedance amplifier's output signals above the signal-zero frequency do not feed directly back into the transimpedance amp's summing junction.

The value of R_5 depends on the relationship between the signal-zero frequency and the signal-pole frequency. The signal-pole frequency in this circuit is $1/(2\pi R_2C_2)$. If the output of the dc-restoration amplifier is 10V, a higher-than-100-kΩ resistor value for R_5 decreases the signal-zero frequency and increases the dc-restoration range. Combining the signal-pole and signal-zero frequencies distorts the output signal with R_5 values below about 10 kΩ.

By using the dc-restoration circuit, the transimpedance amplifier's output reaches approximately 0V. The dc-restoration circuit also brings the transimpedance amplifier's output signal into the linear region of A_1's operation. EDN

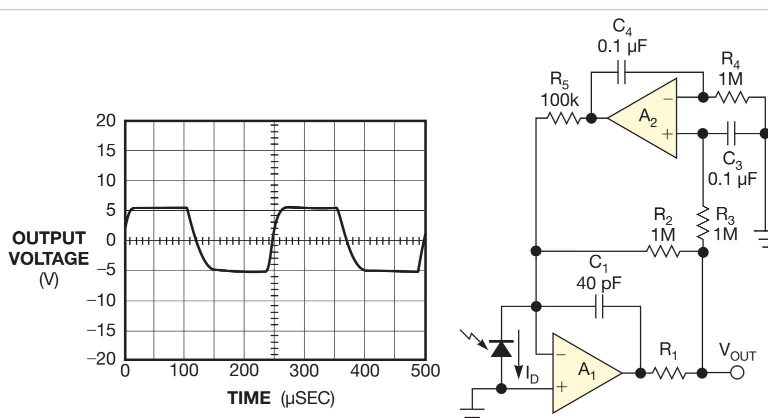
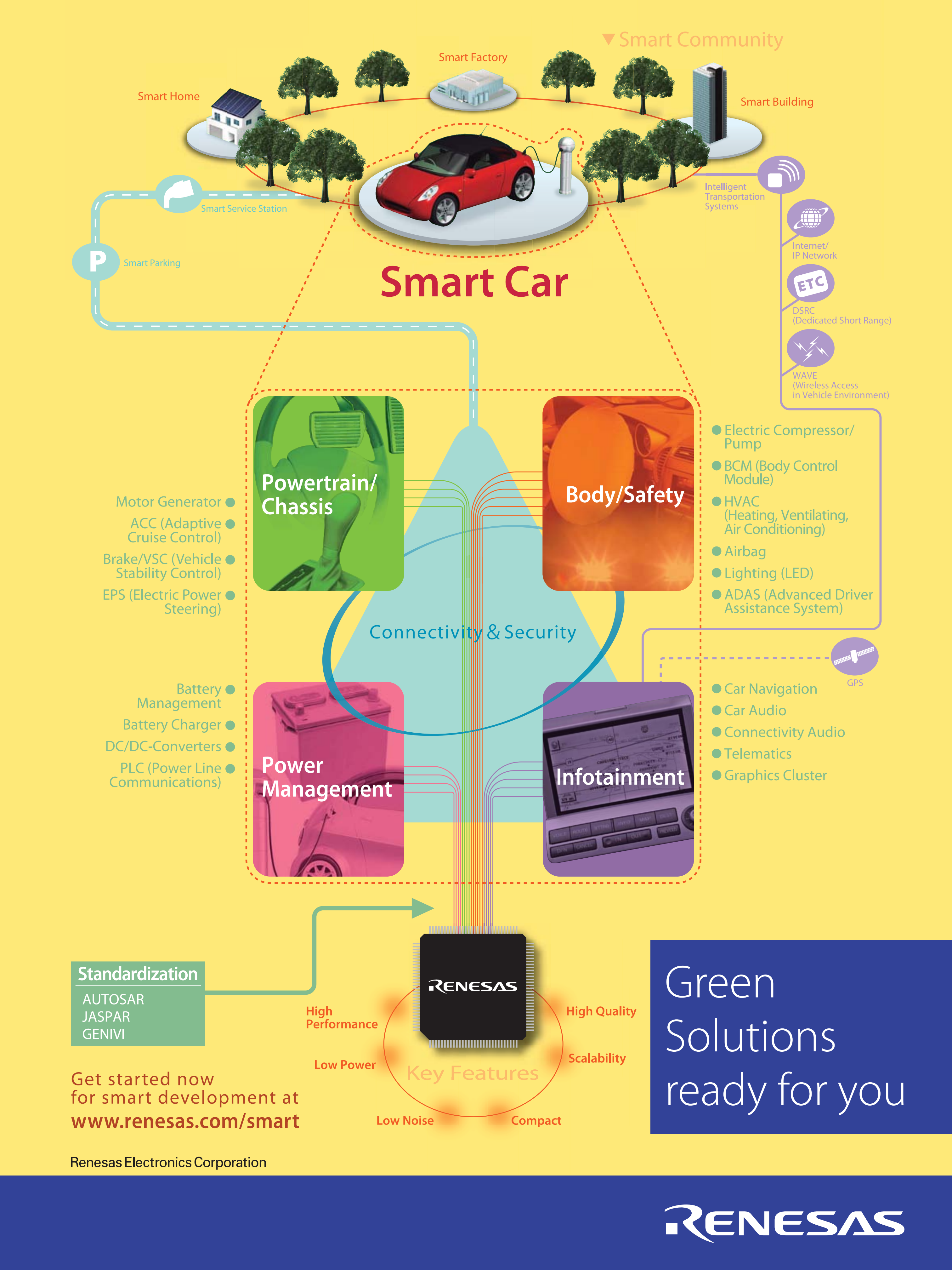


Figure 2 A dc-restoration circuit expands the output range of a transimpedance amplifier across both quadrants.

Bonnie Baker is a senior applications engineer at Texas Instruments.


Smart Community
Smart Home
Smart Factory
Smart Building
Smart Service Station
Smart Parking
Intelligent Transportation Systems
Internet/ IP Network
ETC
DSRC (Dedicated Short Range)
WAVE (Wireless Access in Vehicle Environment)
Smart Car
Powertrain/ Chassis
Motor Generator
ACC (Adaptive Cruise Control)
Brake/VSC (Vehicle Stability Control)
EPS (Electric Power Steering)
Body/Safety
Electric Compressor/ Pump
BCM (Body Control Module)
HVAC (Heating, Ventilating, Air Conditioning)
Airbag
Lighting (LED)
ADAS (Advanced Driver Assistance System)
Connectivity & Security
GPS
Power Management
Battery Management
Battery Charger
DC/DC-Converters
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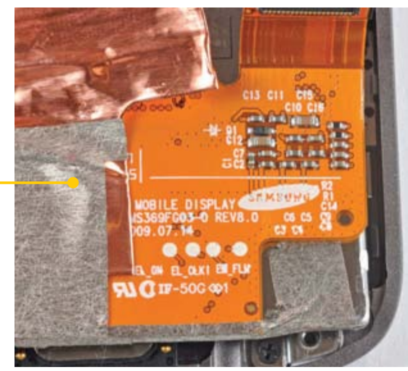
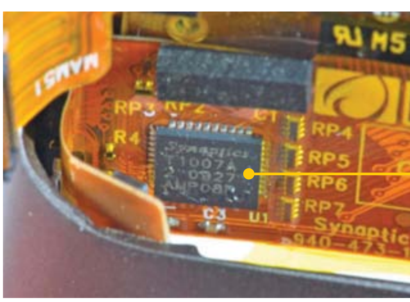
The Nexus One: Google hits a smartphone home run

About 17 months ago, *EDN* dissected Google's first Android-based and developer-intended handset, the HTC-designed T-Mobile G1, that Google had released roughly one year earlier (see "Google's Android OS emerges," *EDN*, Sept 17, 2009, pg 22, http://bit.ly/hlAa3R). About two months ago, Google unveiled its fourth-generation developer smartphone, the Samsung-developed Nexus S. Between these bookends, two other HTC-crafted devices, the Google Ion, or ADP2 (Android Developer Phone 2), and the Nexus One, emerged. Google last year sold the Nexus One directly to consumers in a six-month experiment. As a partnership project with iFixit shows, the Nexus One represents a substantial leap in capability beyond the G1 (see "Nexus One Teardown," http://bit.ly/8oFE7D). More than a year after its unveiling, it remains a leading-edge product, both in an absolute sense and relative to its Nexus S successor.

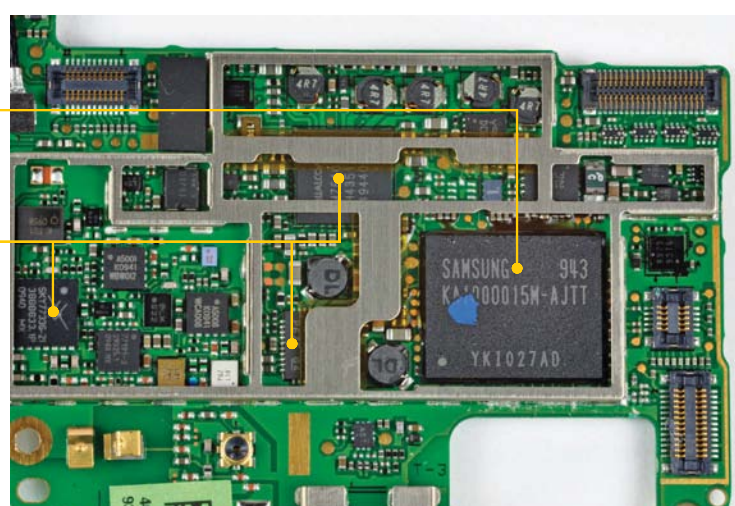
Like many of its HTC-developed contemporaries of the era, the Nexus One leverages a Samsung-manufactured OLED (organic-light-emitting-diode) display. Crisper and touting richer colors than a conventional LED-backlit LCD (liquid-crystal display), its comparative downsides include washed-out images in high-ambient-light environments, greater power consumption than LCDs in some situations, and limited availability. OLED-supply shortcomings prompted HTC to subsequently redesign several handsets for LCDs (see "Display-technology advancements: Change is the only constant," *EDN*, Dec 15, 2010, pg 24, http://bit.ly/gpZpSq).





Synaptics supplies the Nexus One with the same ClearPad 2000 touchscreen and controller technology as that in the Sony Ericsson Xperia X10 mini and many other touch-augmented mobile electronics devices (see "Sony Ericsson's Xperia X10 mini: the teardown skinny," *EDN*, Aug 26, 2010, pg 20, http://bit.ly/bBxoGd and "A magic touch: The concept's sound, but implementation options abound," *EDN*, Nov 4, 2010, pg 26, http://bit.ly/ia4bNM).

The primary system PCB's underside showcases a Samsung MCM (multichip module) encompassing 512 Mbytes of NAND-flash memory and 512 Mbytes of mobile SDRAM. Power-management ICs include Qualcomm's PM7540 and Texas Instruments' TPS65023, and Skyworks' SKY77336 tackles the GSM (global-system-for-mobile)-communications power-amplifier function. Google sold Nexus One versions that supported both AT&T and T-Mobile's 3G (third-generation) cellular-data frequencies in the United States. Google initially also planned a Verizon-cognizant CDMA (code-division-multiple-access) variant but decided a few months later to reference-sell the HTC Droid Incredible instead.



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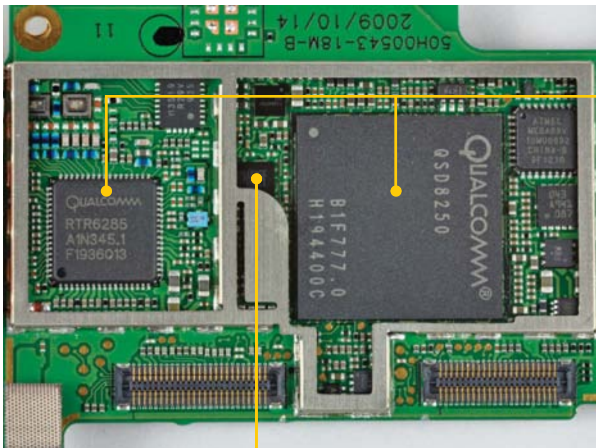
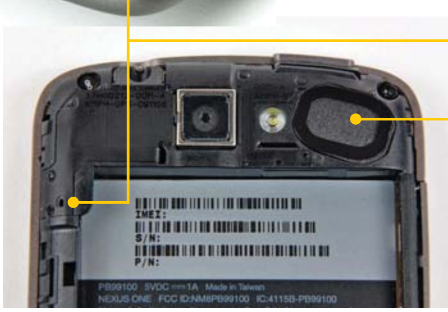
- Go to www.edn.com/pryingeyes for past Prying Eyes write-ups.
- For more on the Google Nexus One, see http://bit.ly/fCQVdl.

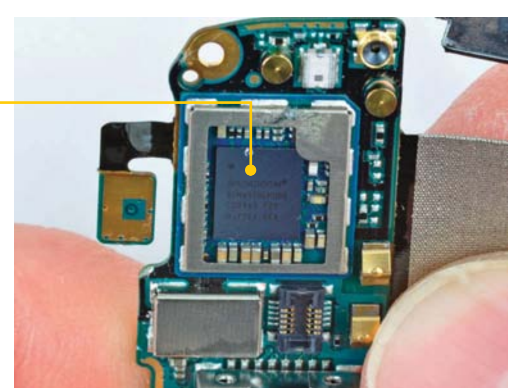


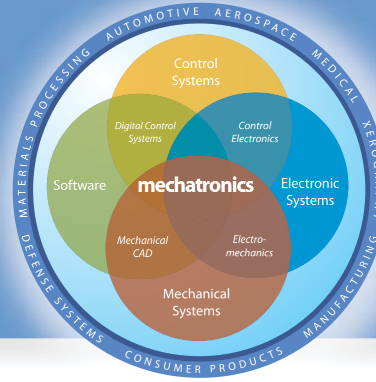
The primary PCB's topside includes Qualcomm's RTR6285 RF-transceiver IC and 1-GHz, first-generation QSD8250 Snapdragon application processor, which integrates cellular modem and GPS (global-positioning-system) functions. The QSD8250 also includes the proprietary Adreno graphics core that the company acquired from Advanced Micro Devices' ATI Graphics division. The QSD8250 is a variant of the ARM Cortex-A8 architecture, thereby supporting the ARM Version 7 instruction set, but Qualcomm's ARM architectural license gave Snapdragon's engineers additional design flexibility to—at least on paper—deliver multimedia performance higher than that of a conventional Cortex-A8 SIMD (single-instruction/multiple-data) multimedia product.



Between the two Qualcomm devices is the Audience A1026 audio processor. This IC works in conjunction with two Knowles Electronics MEMS (microelectromechanical-system) microphones; one resides on the handset's underside to capture the user's voice, while the other is located on the back—to the left of the 5M-pixel still camera lens and associated flash—and focuses on ambient environmental sounds. Whereas conventional beam-forming techniques simply subtract ambient noise from the voice input to enhance the perceived quality of the input on the other end of the cellular connection, Audience's more complex Computational Auditory Scene Analysis approach mimics how the human auditory system operates, thereby justifying a dedicated silicon engine in the Nexus One design. Other manufacturers, such as Motorola and Verizon, with the Droid, instead shoehorn the voice-processing algorithm onto the application processor. A speakerphone transducer resides in the handset backside's upper-right corner.

The Nexus One one-ups Apple's iPhone series and many other modern handsets by integrating Broadcom's BCM4329 wireless transceiver, which supports 802.11n-transfer-speed enhancements, albeit only in the 2.4-GHz band. The iPad, iPhone 4, and third-generation iPod touch also use the BCM4329, but Apple hasn't yet unlocked the chip's beyond-802.11g capabilities. The BCM4329 also handles the Nexus One's Bluetooth 2.1 and EDR (enhanced-data-rate) support, but Google hasn't yet harnessed the chip's FM-transmitting and -receiving features. Instead, hackers have migrated code from the similarly equipped HTC Desire to begin the unsanctioned and incomplete process of adding FM-radio capabilities to the handset.





From the real world to the digital world

Digitization, including sampling and quantization, is universal and essential in engineering.

In an April 2008 column for *Design News*, I focused on how the image sensor of a digital camera was replacing film (**Reference 1**). I never thought that, even if you had a roll of that film today, you could not get it developed anywhere in the world! Yet that scenario has occurred. On Dec 30, 2010, Dwayne's Photo in Parsons, KS, processed the last rolls of Kodachrome film. It dramatically shows how digital the world has become.

Figure 1 shows a computer-controlled system and the interface between the analog power domain and the digital information domain. Digitization (analog-to-digital conversion) is the act of converting an analog signal—continuous in both time and amplitude—to a digital signal—discrete in both time and amplitude. Discrete values in time are the result of sampling an analog signal; discrete values in amplitude are the result of representing those values using a finite number of bits (quantization).

Fourier showed that you can generate any waveform that exists in the real world by adding up sine waves of different amplitudes, frequencies, and phases, and that representation is unique. And Nyquist showed that you can convert a sampled signal back to its original analog signal (digital-to-analog conversion) without any error if the sampling rate is more than twice as large as the highest frequency of the signal.

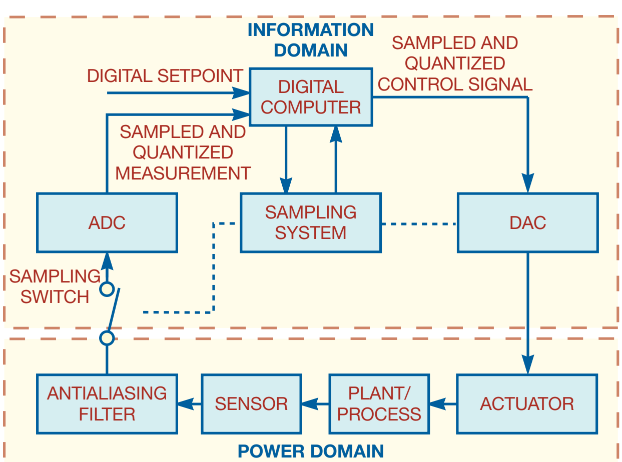


Figure 1 Digitization is the act of converting an analog signal to a digital signal.

If you violate this Nyquist Sampling Theorem, an inevitable, irreversible effect—aliasing—results. You cannot eliminate aliasing, but you can reduce it with an antialiasing analog filter before sampling takes place. Aliasing causes frequencies above the Nyquist frequency (one-half the sampling, or folding, frequency) to fold back into the useful frequency range and appear indistinguishable from the real signals. For example, a tone 1 kHz above the Nyquist frequency folds back to 1 kHz below, whereas a tone 1 kHz below the sampling frequency appears at 1 kHz. The control system responds to both signals—real and fictitious. The antialiasing filter limits performance because of time delay, but the effects of aliasing are much worse.

The accuracy of a digital memory device depends on the number of bits it uses to store each sample. Quantization is the process of changing the sample values to discrete levels and results in quantization-noise errors. The measure of the relative size of quantization noise is the SNR (signal-to-noise ratio), and you derive it from the simple **equation** $SNR=2^B$, where B is the number of bits used to store samples.

Yes, everything is going digital, but I hope that, like Kodachrome film, all these digital devices can "make you think all the world's a sunny day." We all need that! EDN

Kevin C Craig, PhD, is the Robert C Greenheck chair in engineering design and a professor of mechanical engineering, College of Engineering, Marquette University.
For more mechatronics news, visit mechatronicszone.com.

REFERENCE

1 Craig, Kevin C, PhD, "Mama Don't Take My Kodachrome Away," *Design News*, April 2008, pg 20, http://bit.ly/gxsDtn.

RENÉ JANSA/ISTOCKPHOTO.COM

ACCELEROMETERS AND TEMPERATURE SENSORS

FIGHT SIDS

BY MANISH SHAKYA, EMMANUEL TUAZON, MOHAMMED BHATTI, AND SUBRA GANESAN • OAKLAND UNIVERSITY

SIDS (sudden-infant-death syndrome), or crib death, is the sudden and unexplained death of infants from causes that forensic and death-scene investigation cannot explain (**Reference 1**). It is one of the leading causes of death during infancy, with an estimated 2500 SIDS-related deaths annually in the United States and thousands more worldwide. Although these rates, in the United States, are at an all-time low and have fallen by about 50% since 1983, the number of infants dying from SIDS remains a cause for concern. Globally, especially in developing nations, where access to quality medical care and accurate information is far lower than in the United States, SIDS-related deaths remain high.

Although there is no agreement on a single cause for SIDS, factors linked to the phenomenon include babies' sleeping on their stomach; overheating from excessive sleepwear and bedding; tobacco-smoke exposure following birth; maternal smoking, drinking, or drug use during pregnancy; poor prenatal care; prematurity or low birth weight; and maternal age of less than 20 years. Some of the suggested causes behind SIDS are related to choices that parents make—smoking, early pregnancies, and poor obstetrical care—and can be addressed through better education about the impact of lifestyle choices. Other suggested causes relate to the

environment in which an infant sleeps; the parents can address these causes by monitoring the infant and intervening when necessary. Current research suggests that a variety of preventive measures, such as ensuring that infants sleep on their backs rather than their stomachs and removing from the crib blankets, pillows, or other objects that might cause the infant to suffocate, are the best means of reducing the potential of a SIDS-related death.

With advances in computing technology and the plummeting prices of components, other available products can supplement physician-recommended preventive practices. A microprocessor-based baby-monitoring system fulfills demand from parents looking for peace of mind. Using this system allows parents to better monitor their infants and act more quickly to pre-empt some of the suggested causes of SIDS. The system can monitor both babies sleeping on their stomachs and those who are overheating.

MONITOR DESIGN

In its basic configuration, the monitor comprises a control unit and a baby-monitor unit (**Figure 1**). The baby monitor collects data from a variety of sensors and transmits it wirelessly or through a wired connection to the control module. The control module receives, analyzes, and displays this data and activates various alarm and warning modes.

AT A GLANCE

- A microprocessor-based monitor can give peace of mind to parents who want to prevent SIDS (sudden-infant-death syndrome).
- The baby monitor collects data from a variety of sensors and transmits it wirelessly or through a wired connection to the control module.
- The monitor comprises a temperature sensor, an accelerometer, and a wireless transmitter/receiver in a microcontroller.
- Lightweight, stackless “protothreads” implement a sequential flow of control without complex state machines or full multithreading and provide conditional blocking within a C function.

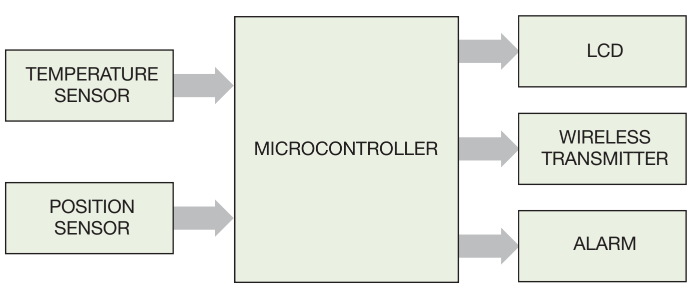


Figure 1 The baby monitor collects data from a variety of sensors and transmits it wirelessly or through a wired connection to the control module.

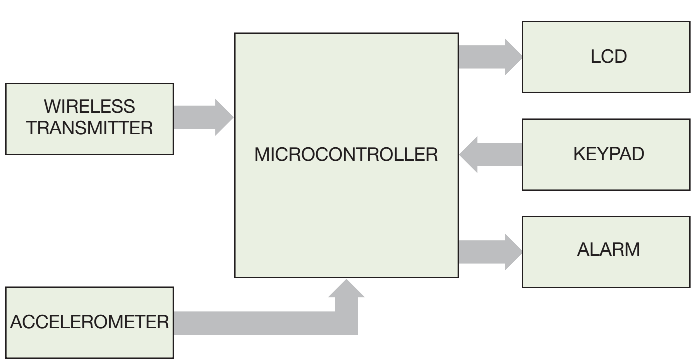


Figure 2 The control unit is responsible for menu functions, adjusting various settings, and updating and alerting the parent or guardian of the infant’s status.

The baby-monitor unit comprises a temperature sensor, an accelerometer, and a wireless transmitter/receiver in a microcontroller. An LCD allows users to monitor both the data the monitor receives from the sensors and the status of the system. Status includes whether communication with the control unit exists and whether an alarm is present. Using this system, the parent attaches the unit to the infant by bringing the sensors into contact with the baby.

The position sensor connects to the analog input on the microcontroller, and the temperature sensor is the built-in sensor available on the microcontroller. A serial interface transfers this data to the wireless HRTF (head-related-transfer-function) module. The HRTF module then transmits or receives data using FSK (frequency-shift-keying) technology to an identical HRTF module that attaches to the control unit.

The control unit is responsible for menu functions, adjusting various settings, and updating and alerting the parent or guardian of the infant’s status (**Figure 2**). The control unit includes another microcontroller, an LCD, a hexadecimal keypad, an accelerometer, and a multitone alarm. The wireless HRTF module that attaches to the microcontroller receives data from the infant-monitoring unit and routes it to the microcontroller through a serial interface.

Software displays various parameters on a menu on the LCD that attaches to the microcontroller. The parent uses the keypad to browse through the menu, access various options, and enter input. The alarm activates when the values of certain monitored parameters exit a predetermined safe zone. The accelerometer resets the LCD to the default view when the user shakes the device and so offers an easy way to exit the various menu options a user might be adjusting or viewing.

IMPLEMENTATION

The system uses two Hope Microelectronic HCS12 Mini-Dragon-plus2 development boards employing the Compact MC9S12DG256 board with a solderless breadboard, two RS-232 ports, one CAN (controller-area-network) port, two H bridges, and four servo connectors and headers (**Reference 2**). The board offers both an LCD interface and a keypad interface, which allow for easy integration of those peripherals. The MC9S12DG256 offers a 16-bit CPU; 256 kbytes of flash memory; 12 kbytes of RAM; 4 kbytes of EEPROM; and SCI (serial-communications-interface), SPI (serial-peripheral-interface), and CAN 2.0 ports.

One wireless module attaches to the baby-monitor unit, and the other attaches to the control unit. Both units can both transmit and receive. The HRTF module functions on FSK technology in half-duplex mode in the ISM (industrial/scientific/medical) band. The user can select the transmitting-frequency deviation, the receiver bandwidth, and the data range. The HRTF module is compatible with either TTL (transistor-transistor-logic) or RS-232-logic levels. The compact and lightweight HRTF module is practical for use as a baby monitor. **Table 1** shows the pin definitions of the 24×43-mm wireless module.

The HRTF module has a working voltage of 5V. If the Config pin is high at power-on, the module enters the configure mode to allow a user to set up work parameters. This system uses the default parameters. If the Config pin is low at power-on, then the module enters normal mode for data transmission. The Enable pin serves primarily as a means of regulating power consumption. When you set the Enable pin, the wireless module immediately enters sleep mode. This circuit does not use the Enable pin.

The default configuration for the HRTF module is a baud rate of 9600, 8 data bits, no check or parity bit, and one stop bit. It caps the data-burst length at 32 bytes. The HRTF module works in half-duplex mode and immediately transmits data upon receipt of 32 bytes from the serial port. If the module receives less than 32 bytes of data, it

TABLE 1 WIRELESS-PIN FUNCTION

Pin name	Description
VDD	Power supply
DTX	Data transmission
DRX	Data reception
CONFIG	Configure mode
ENABLE	Working function

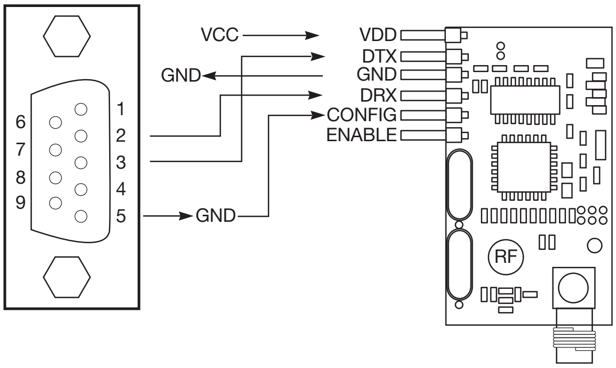


Figure 3 The HRTF module automatically switches to receiver mode, after transmission, in approximately 5 msec.

waits for 30 msec to ensure that the data package is complete and then transmits the data. The HRTF module automatically switches to receiver mode, after transmission, in approximately 5 msec (**Figure 3**).

The system uses two KXPS5 triaxis accelerometers with a full-scale output range of ±3g (**Figure 4** and **Reference 3**). The accelerometer measures 5×3×0.9 mm; the operating-voltage range is 1.8 to 5.25V dc, and the optimal operating voltage is 3.2V dc. The connection to the controller is straightforward (**Table 2**). Communication with the chip can be through either an I^2C (inter-integrated-circuit) interface or an SPI and can trigger analog-to-digital conversions, set threshold delays, or manage power consumption. The ASIC triggers acceleration thresholds when the device exceeds acceleration limits.

With the accelerometer, the monitor unit acts as a position sensor, which you attach to the infant to detect whether the infant rolls over from his back to his stomach. In this application, the data from the Y and Z axes are the most relevant. You determine the orientation of the baby depending on the values from the ADC.

LCD AND KEYBOARD

The system uses two LCDs for displaying system-status information, various infant parameters, and menu options. One LCD connects to the baby-monitor unit, and the other connects to the control unit. An advantage of having integrated LCDs in both modules is that it provides the ability to debug the system while you are programming it. **Table 3** shows the pin assignments of the LCD and the microcontroller.

The system uses one hexadecimal keypad for input and menu selection (**Reference 4**). The keypad is on the control unit

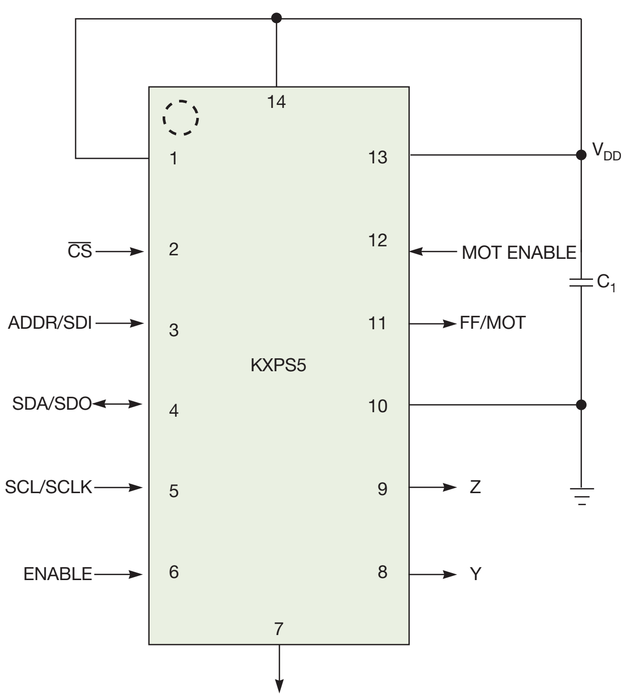


Figure 4 The system uses two KXPS5 triaxis accelerometers with a full-scale output range of ±3g.

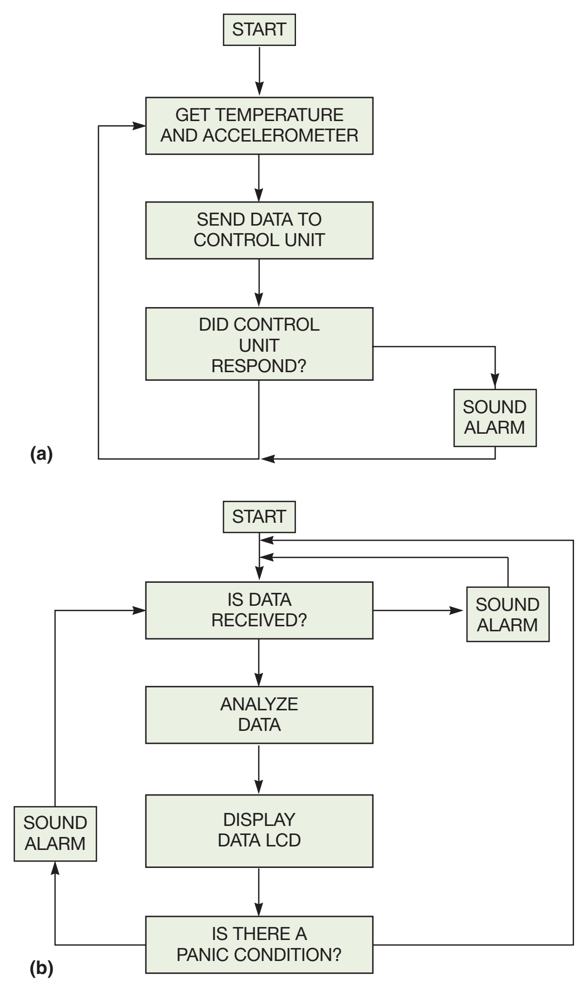


Figure 5 The firmware uses C and assembly language, using protothreads for the baby-monitor unit (a) and control unit (b).

and connects to Port A on the microcontroller. Ports 0 to 3 are input ports, and Ports 4 to 7 are output ports (**references 5** and **6**). The design uses internal pullup resistors from the microcontroller rather than external resistors.

The basic principle behind the operation of the keypad is as follows: A 16-character array stores the keypad codes. Firmware reads this array through a loop and assigns various codes to Port A. The microcontroller reads the codes after a few milliseconds and compares them with those in the previous values. If the comparison indicates identical values, then a key is pressed. If the comparison is not equal, the key is not pressed.

The keypad performs several functions in the system. It acts as the primary input peripheral for the user to set and reset the password, set the alarm to snooze mode, reset the alarm if it goes off, and select various tones for the alarm. It also resets the data-transmission counter on the LCD and can find use in debugging. Key A on the keyboard enables the keyboard to snooze for 10 seconds; Key B, 30 seconds; and Key C, 60 seconds. Key D stops the alarm.

SOFTWARE IMPLEMENTATION

The firmware uses C and assembly language, employing "protothreads" (**Figure 5** and **references 7** and **8**) in programming the control unit. The lightweight, stackless protothreads provide a blocking context on an event-driven system without the overhead of per-thread stacks. Protothreads implement a sequential flow of control without complex state machines or full multithreading and also provide condition-

TABLE 2 ACCELEROMETER AND MICROCONTROLLER CONNECTION

Microcontroller	Accelerometer module
PAD8 (Pin 68)	X-axis input
PAD9 (Pin 70)	Y-axis input
PAD10 (Pin 72)	Z-axis input

TABLE 3 LCD- AND MICROCONTROLLER-PIN CONNECTIONS

LCD pin	Microcontroller pin
Pin 1 (ground)	Ground
Pin 2 (power supply)	5V
Pin 3 (through a 220Ω resistor to ground)	
Pin 4 (RS)	PK0
Pin 5 (read/write)	PK7
Pin 6 (enable)	PK1
Pin 7 to 9 (not used)	
Pin 11 (DB4)	PK2
Pin 12 (DB5)	PK3
Pin 13 (DB6)	PK4
Pin 14 (DB7)	PK5

Figure 6 The prototype can monitor only one baby.

al blocking inside a C function.

In memory-constrained systems, such as deeply embedded systems, traditional multithreading may have too large of a memory overhead. In traditional multithreading, each thread requires its own stack, and each is typically overprovisioned. These stacks may use large parts of the available memory. In contrast, the main advantage of protothreads over ordinary threads is that protothreads are lightweight: A protothread does not require its own stack. Rather, all protothreads run on the same stack, and the system performs a context switch by stack rewinding.

This feature is advantageous in memory-constrained systems, in which a stack per thread might use a large part of the available memory. A protothread requires only 2 bytes of memory per protothread. Moreover, protothreads are implemented in pure C and require no machine-specific assembler code. For a description of the format for transmitting accelerometer data from the monitor unit, see **sidebar** "Transmission of data" in the Web version of this article at www.edn.com/110217df.

Interrupts can be external or internal. External interrupts occur when the external circuitry sends an interrupt signal to the CPU. Internal interrupts come from the hardware circuitry inside the chip or from software errors. The system uses various interrupts to coordinate I/O activities as well as for periodic data acquisition. Both the monitoring unit and the control unit use three interrupts each: interrupts 7, 13, and 20. Interrupt 7 is a real-time interrupt to deal with the timing issues of the system.

Upon every real-time interrupt, the system increments a Tick variable, from which all system-timing information is derived. Interrupt 13 uses enhanced capture timer Channel 5 for tone generation, generating various frequencies by appropriate reloading values. Interrupt 20 is the SCI at Port 0 for wireless communication.

The wireless modules in the baby-monitor system are relatively easy to configure, and data transmission between the two units is efficient. The two units can communicate with each other over approximately 100 feet, through walls, and in the presence of other electrical equipment. The prototype can monitor only one baby (**Figure 6**).

Adding a wireless sensor network allows you to monitor any number of babies. From a marketability standpoint, the prototype is too bulky (**Figure 7**). Size issues arise primarily from the size of the microcontroller-prototype boards (**references 9**, **10**, and **11**). EDN

ACKNOWLEDGMENT

The authors would like to thank Professor Richard Haskell of Oakland University

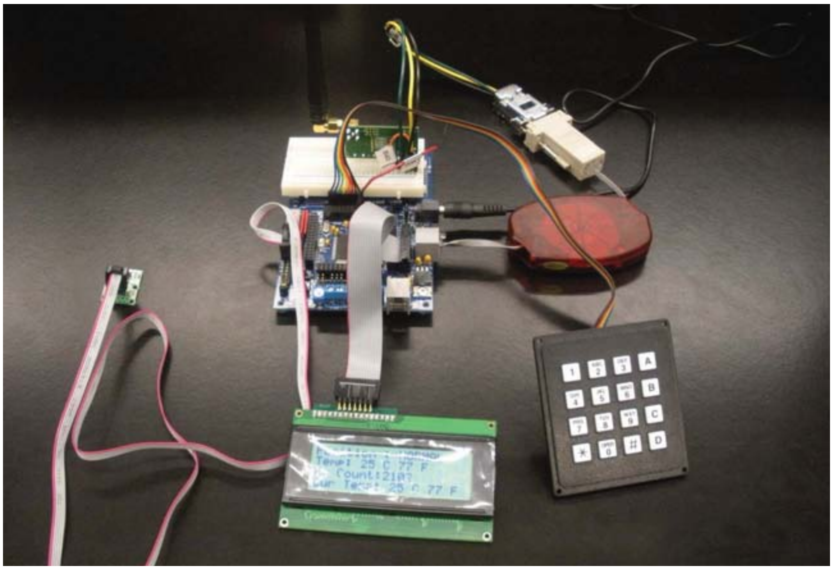


Figure 7 From a marketability standpoint, the prototype is too bulky.

for his support during this project.

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DESIGNING OFFLINE AC/DC SWITCHING POWER SUPPLIES, BRICK BY BRICK

BY PAUL RAKO • TECHNICAL EDITOR

IT'S A CHALLENGE TO CONVERT HIGH-VOLTAGE AC TO DC WHILE KEEPING EFFICIENCY HIGH AND COST LOW.

In an effort to meet worldwide efficiency requirements, engineers are designing offline power supplies integrating high-efficiency switching-regulator-control circuits. This approach uses less copper and is thus less expensive than that of conventional linear supplies with large transformers and no control IC. Designing these offline switching power supplies, however, brings a difficult set of problems, including EMI (electromagnetic interference), inrush current, input-capacitor discharge, and universal-input requirements. There are various approaches to dealing with these issues.

COMMON DESIGN PROBLEMS

Because these supplies radiate EMI into space and into the power cord feeding the supply, engineers often place differential and common-mode filters on the input circuit. The filter requires a Class X capacitor across the ac input. The failure of this type of capacitor cannot lead to electric shock but can cause safety problems if you disconnect the supply during high applied line voltage. You can discharge the capacitor with a parallel resistor, but this approach wastes power when the supply is working. Instead, you can use parts such as those in Power Integrations' two-terminal CapZero family of automatic-X-capacitor-discharge ICs, which eliminate power losses but still allow power supplies to comply with safety standards.

You may also need Y capacitors, whose failure can lead to electric shock, from the line to earth ground. These capacitors reduce conducted EMI into

the power cord, but large ones can trip ground-fault outlets and circuit breakers. You can solve radiated EMI into space with tight PCB (printed-circuit-board) layouts and by slowing any fast current transitions in the circuit (**Reference 1**). As a last resort, you can use shielding, which adds cost and may interfere with cooling.

Another problem that can occur when you are designing offline power supplies is their requirement for a large input capacitor, which in turn requires a large pulse of current that charges up the capacitor when you turn on or plug the supply into the wall. Using a large input capacitor reduces the input ripple to your switching stage but causes a greater inrush current, which can trip the ac circuit breaker feeding the supply, damage the rectifier diodes in the input section, or blow fuses in the input circuit. To mitigate these problems, you can add NTC (negative-temperature-coefficient) inrush limiters. When these inrush limiters are cold, they have a high resistance, limiting the inrush-current surge. In the hot state, the limiters have low impedance and allow the supply to deliver full power.

You must be careful when designing systems that have applied intermittent power because the input could lose power. The switching supply would then drain the input capacitor in 100 msec. Restoration of power while the NTC limiters are still hot could cause an unacceptable inrush. To overcome this problem, use control chips with undervoltage lockout. These chips prevent the switching supply from draining the input capacitor when the voltage reaches some threshold. You can design your

AT A GLANCE

- Offline switchers are high-voltage power supplies.
- Many design problems are unique to ac/dc supplies.
- Flyback and forward converters are the most common types of offline switchers.
- Quasiresonant flyback converters have 88% efficiency.
- LLC (inductor/inductor/capacitor) and asymmetrical half-bridge converters reach 93% efficiency.
- Phase-shifted full-bridge converters deliver power greater than 500W.

circuit so that the required energy to charge the input capacitor from this level to line operating levels does not damage the supply or blow the circuit breakers, even if the NTC limiter is hot.

Passive NTC limiters respond to ambient temperature. If your supply must work over large temperature ranges, you face the difficult task of balancing all the requirements and keeping the inrush current low (see **sidebar** "Testing your design"). Another way to solve the inrush-current problem is to put a series FET or another transistor in the input stage (**Figure 1** and **Reference 2**). If you properly size the FET, you can then slowly turn it on, operating it in its linear region and dissipating power. You must ensure that repeated turn-on or turn-off events do not overheat the part.

You must ensure that a failed input capacitor can safely blow a fuse or melt a trace without catching fire or causing a fire in another component. UL (Underwriters Laboratories) testing is primarily about fire prevention. In addition to examining failure modes, UL can short-circuit your supply output to observe whether it catches fire.

Although an undervoltage lockout keeps the input capacitors charged to reduce subsequent inrush events, you cannot allow these capacitors to stay charged up indefinitely. A constantly charged state would present a safety hazard to service personnel. To deal with this problem, wire a resistor across the capacitor; the resistor drains the capacitor's charge within a few minutes but is a constant power waste and drain on efficiency. To eliminate this efficiency loss, use a FET in series with the resistor to disconnect it when the supply is on.

After solving the inrush problem, you must decide whether your supply accepts universal inputs. If it does, it will work from worldwide line voltages and frequencies. These inputs can be as extreme as 85V at 60 cycles for Japan and 264V at 50 cycles for Europe. Wide input range causes problems relating to the minimum pulse width at which your supply operates. As the input voltage increases, a conventional PWM (pulse-width-modulated) switching power supply makes narrower pulses. At some point, the pulses become so narrow that the power transistors spend most of their time ramping high or low in their linear region. This linear region exposes the transistors to both significant voltage and significant current, overheating the parts.

To solve the universal-input problem, add transistors to the front end to change the input from a bridge-type rectifier to a push-pull type or use control ICs that support short rise and fall times. These fast transitions may solve the overheating problem but at the expense of greater EMI. Alternatively, you can address these wide input ranges using different topologies, such as PFM (pulse-frequency modulation).

You next must figure out how to power the control IC. The conventional way is to use a series-dropping resistor from the input dc bus to the control chip (**Figure 2**). Although simple, this scheme wastes a significant amount of power in the resistor. If the input bus is 264V ac, the rectified dc bus will be 373V. Control chips operate at 10 or

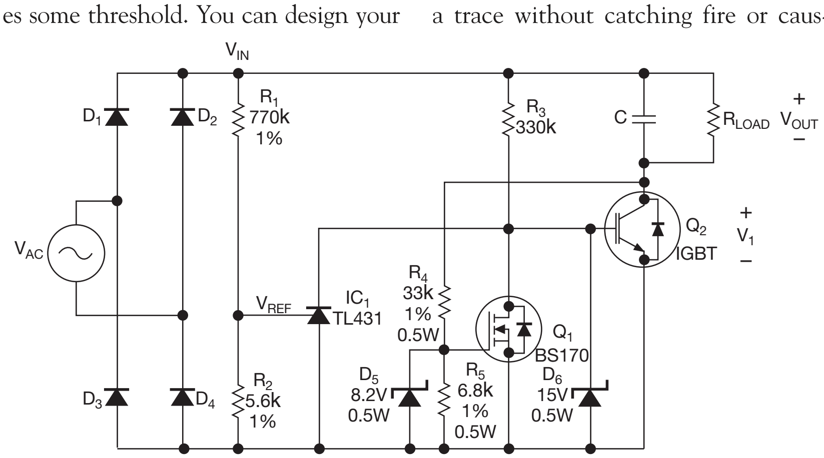

Figure 1 This circuit, a recent *EDN* Design Idea, eliminates the losses of NTC inrush limiters.

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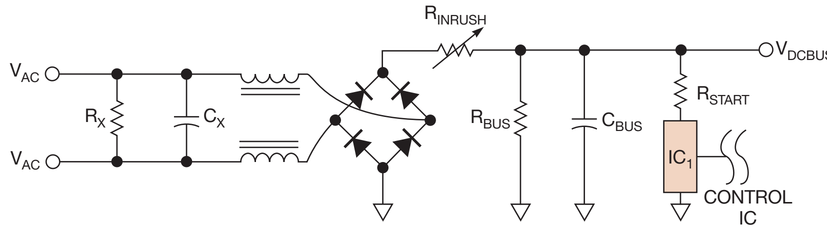

Figure 2 The resistors in this circuit create efficiency losses in the supply. You should switch them or use a chip that internally switches them out of the circuit.

20V and might consume 10 mA of current. The resistor wastes 353V times 10 mA, or 3.53W, of power. You can reduce this waste by using a small winding in the transformer to feed current to the chip once the supply starts up. This technique reduces but does not eliminate the current the supply draws from the dc bus. The wasted power violates the various "green" initiatives and regulations, such as Energy Star and other worldwide standards.

To eliminate the power loss in the start-up resistor, you have to either switch it out with an external FET or use a regulator chip that performs this task. Alternatively, you can use a chip from Power Integrations' SenZero family, which steers current to any manufacturer's chip. The chips require an external enable signal. Another option is to use a FET with a normally on depletion mode, such as the high-voltage PFETs from Supertex.

Once you have the control chip, you must select an output device. Regulator ICs have built-in power FETs, whereas controller ICs, which target use in tough ambient conditions, require that you add external FETs. Some designers use IGBTs (insulated-gate bipolar transistors) at powers greater than 1 kW. You can create cost-conscious, low-power designs using conventional bipolar transistors. The CamSemi C2471 chip, for example, controls inexpensive bipolar transistors. Power Integrations' TopSwitch family integrates the FET on die with a 700V process, whereas Fairchild uses two dice in one package in its FPS product line. Fairchild also makes a complete line of controllers, as do Texas Instruments and STMicroelectronics. Using a controller requires you to select primary-switch transistors, such as those from Vishay, On Semiconductor, International Rectifier, STMicro, Ixys, Texas Instruments, and Renesas. Fairchild recently introduced its SupreMOS FETs with smaller die and cost for a given breakdown voltage.

You might want circuitry to soft-start the supply. If so, you must ensure that the soft-start works properly when power is intermittent. Most control ICs provide a soft-start function, and many regulators and controllers also have built-in protection features for over-temperature and overcurrent. Once external, protection features are now parts of the IC.

OTHER CONSIDERATIONS

All of these design problems are just the start of the design process. You now must select a switching architecture. Part of this task might involve deciding to put the control chip on the secondary side to eliminate sending the feedback voltage over isolation boundaries and to enable synchronous rectification. Synchronous rectification allows you to replace the output diode with FETs that the control chip switches on and off at the proper times. Placing the control chip on the secondary side means, however, that you must send start-up power over the isolation boundary to get the chip working.

Another decision is whether to use current-mode or voltage-mode feedback. Current-mode feedback uses the current in the primary winding as the controlled parameter. This approach eliminates the reactive nature of the primary from the control loop and removes a pole associated with the primary inductance. Many engineers prefer current-mode control because, in this approach, the power supply has one dominant pole and exhibits better stability. Current-mode control also protects the switching transistor and measures current through the transistor at all times, preventing excessive currents that would damage the device.

Many semiconductor companies have begun to tout ICs that use digital power. Chips that use digital PWM loops are popular in PFC (power-factor-correction) circuits because the fundamental control is 60 Hz, slow enough that almost any digital loop can keep up with it. Digital power is inherently neither superior to nor inferior to analog power. Deciding the internal architecture of the chip is a problem for the semiconductor company (**Reference 3**). Companies such as iWatt have enjoyed high designer acceptance of their digital-power parts, but the parts' features are more important than their control methods.

Most ac/dc power supplies need output regulation because it compensates for changes in output load and input line voltage. To regulate the output voltage, you must feed the signal back to the control chip. Most ac/dc supplies use an optocoupler such as those from Fairchild and Avago. The supplies add phase shift and can cause control problems. The optocoupler reduces the bandwidth of the control loop, reducing transient response. Many control chips replace the optocoupler with a sense winding on the transformer. This scheme cannot hold as tight a regulation but does achieve 5% output accuracy. However, iWatt claims that its proprietary primary-sense algorithms can improve accuracy beyond that level. "Cell-phone chargers need tighter control than you can achieve with competing primary-sensing schemes," says Zahid Rahim, iWatt's vice president and general manager.

Alternatively, you can send the analog voltage across the isolation boundary with a delta-sigma modulator, such as those from Avago. As another alternative, you could represent the output voltage as a digital value and send it across the boundary with a digital iso-

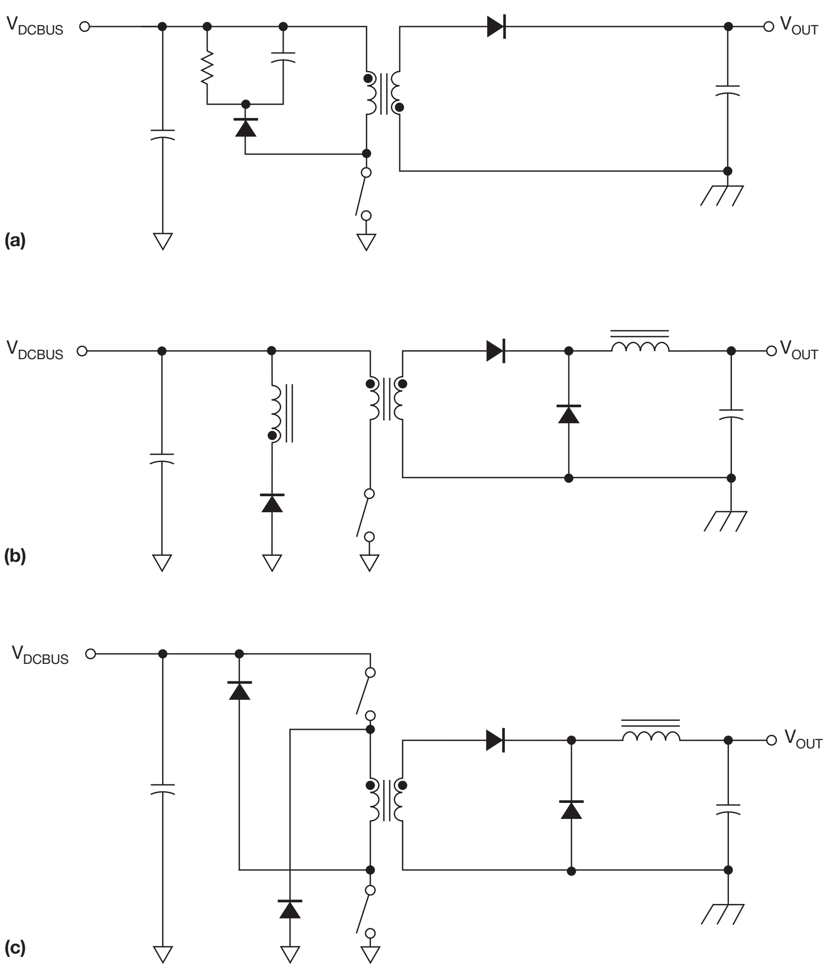

Figure 3 The flyback (a) and forward converter (b) are the workhorses of the industry. The two-switch forward converter (c) eliminates the reset winding.

lator (**Reference 4**). These alternatives are costly, however, and create phase lags that reduce the control-loop bandwidth. Another approach is to place the control chip on the secondary side and let it control the primary side across the isolation boundary. In that case, you must send isolated start-up power to the chip. You can achieve tighter voltage regulation if the control chip is on the secondary side, according to Richard Garvey, an application manager at Texas Instruments. You need not send the output-voltage feedback across an isolation boundary.

If your design has high power levels or low output voltages, you might want to replace the secondary-side diodes with synchronous FETs. You can control the power supply with the chip on the primary and send the secondary control over the isolation boundary. Texas Instruments' UCC28250 power-supply chip operates in this way. Alternatively, a secondary rectification circuit, such as International Rectifier's IR11672AS secondary-side-driver IC, can sense the power delivery and run independently of the primary control loop.

ARCHITECTURE ABUNDANCE

When designing a switching power supply, you'll find an abundance of available architectures for your design. The architectures include both fixed-frequency PWM and variable-frequency architectures. Among the fixed-frequency architectures is the flyback converter, a classic ac/dc switching power supply (**Figure 3**). A flyback converter transfers energy when the primary transistor switch is off. Closing a transistor switch allows current to build up in a transformer. When the current is flowing into the primary windings, the diodes on the secondary side block current, and the secondary windings deliver no current to the output. Turning off the input transistor causes the voltage at the drain node to fly to a value higher than the dc input bus. The voltage goes high enough to damage the transistor, so you must limit the excursion of the drain node with a snubber (**references 5** and **6**).

Flyback power supplies provide good tracking between multiple outputs. Thus, if you regulate a 5V rail with feedback to the control chip, the ±12V rails stay fairly close to their nominal values despite varying loads. On the other hand, flyback converters tend to emit more EMI and have worse transient response than do other topologies. The architecture must build current in the primary before it can respond to an output load change, so the switching frequency is a fundamental limit on the transient output response. Fairchild, Texas Instruments, STMicro, Power Integrations, and many other vendors make dozens of flyback control ICs.

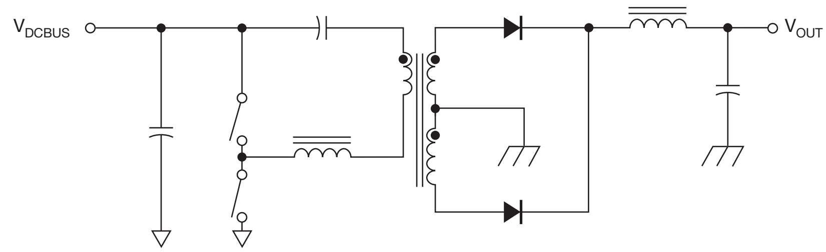

Figure 4 An asymmetrical half-bridge operates at a fixed frequency.

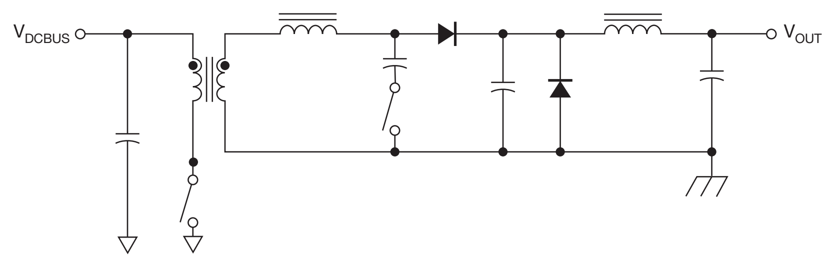

Figure 5 The series-resonant converter, which Vicor developed, shifts frequency as it operates.

When your design reaches power requirements of approximately 60W, you should consider using a forward converter, which transfers power to the output and switches the energy into the primary side. Forward converters, including push-pull devices, have lower secondary ripple current and better efficiency than flyback converters, and they respond more quickly to transient-load changes. They also can employ a smaller transformer for a given power because they need not store an entire cycle's energy in the core.

Flyback and forward converters have served the industry for decades, but recent eco-friendly initiatives have made them less attractive because they rarely provide more than 85% efficiency. As a result, control chips that support multiple architectures, such as Power Integrations' HyperPFS, have flourished. The chip incorporates PFC and a semiresonant, asymmetrical, two-switch forward topology.

You can achieve 93% efficiency at 200 to 500W power levels using an asymmetrical half-bridge topology (**Figure 4**). This architecture suits use in designs having output voltages lower than 24V (**Reference 7**). The fixed-frequency PWM circuit eases input- and

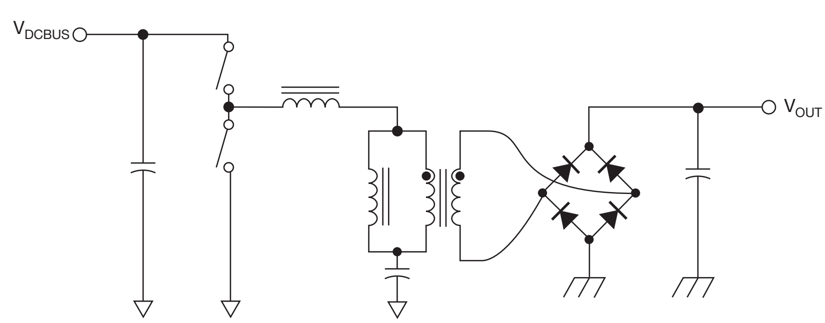

Figure 6 The LLC topology operates with variable frequency and delivers 93% efficiency.

output-filter design by combining series capacitors with the transformer and a series inductor. The inductor can be the transformer's leakage inductance or a discrete inductor, which adds cost and space but has a more predictable value. The asymmetrical half-bridge has a secondary-side output inductor that provides lower ripple current to the output capacitors, making it more attractive for low-voltage or high-current supplies.

For power levels greater than 500W, you should consider a full-bridge architecture using four MOSFETs. This approach fully uses the transformer's windings because it excites the primary with both polarities. The downside of this circuit is that it places stress on the FET switches. One approach to this problem is to use a phase-shifted full-bridge topology (**references 8**, **9**, and **10**). You accomplish this task by adding capacitors and fast-recovery diodes across the four FETs. Alternatively, you could use a FREDFET (fast-recovery epitaxial-diode field-effect transistor). You then use a control IC, such as the TI UCC2895 or UCC28950, which adds secondary-side rectification.

Another class of offline converters regulates the output by varying the pulse frequency. Vicor decades ago pioneered the series-resonant architecture, which, like other varying-frequency architectures, is more complex and more efficient than the fixed-frequency types (**Figure 5**). FETs usually switch in 0V or 0A modes, so these supplies emit less EMI and put less stress on the switches. A sine wave excites the transformer, requiring a tank circuit in the primary side. The sine wave has few harmonics, yielding fewer losses in the transformer. A downside of these devices' broad frequency range is that it is more difficult to design input- and output-filtering circuits for them.

Another variable-frequency architecture includes quasiresonant flyback supplies (**Reference 11**). You can improve these supplies' efficiency to 88%, and you can add a capacitor across their FETs to make the supplies resonant. This capacitor reacts with the transformer's leakage inductance to form a resonant tank. The circuit benefits from 0V or 0A FET switching. The control IC ensures that the transformer's primary current always returns to 0A. For this reason, the circuit's frequency changes with the load. By operating at the boundary or the transition mode, at which the primary current has reached 0A, the devices eliminate reverse-recovery loss in the output rectifier. A plethora of control ICs are available, including TI's UCC28610, Power Integrations' PLC810PG, and CamSemi's CC2163.

The LLC (inductor/inductor/capacitor) switching power supply is a true resonant architecture (**Figure 6** and **references 12**, **13**, and **14**). You operate the circuit at a frequency at which the tank is inductive. Lower frequencies see less impedance and deliver more power, and lower loads create an increase in frequency. LLC devices in-

TESTING YOUR DESIGN

Once you design the input, start-up, control, architecture, and power devices for a switching power supply, you can test your design. Experienced ac/dc-power-design engineers understand that safety is a constant concern. Keep one hand in your pocket while probing so that current does not conduct across your heart. Testing on wooden benches is safer than on metal ones because touching a high-voltage node on a wooden bench does not cause a short circuit to the parts of your body touching the bench.

Even small supplies store enough energy to blow up components. Your prototype most likely has a backward-polarized capacitor. Thus, you must wear safety glasses or a full-face shield when troubleshooting your design.

Test your design over all the ambient temperatures it will encounter. The applied ac does not necessarily start at 0V. A user can close a switch or plug in a supply at the moment the ac voltage is at its peak, causing a large inrush current.

Avoid applying full ac voltage to your design the first time you try it. Use a VARIAC (variable-ac) transformer to slowly increase the ac input voltage. Testing the input section requires a laboratory ac-power supply, such as those from California Instruments, Pacific Power Source, Elgar, or Kikusui. These instruments can vary input voltage over the universal range and supply 50- or 60-Hz frequencies. You can use an isolation transformer to make the negative rail of the dc bus into a chassis common for your oscilloscope. You can also use differential probes, but they rarely have adequate voltage capability for primary circuits.

To understand a switching power supply, it is essential for you to have at least one current probe with as great a bandwidth as possible. Most engineers comprehend resistive circuits, but reactive circuits with capacitors and inductors act in nonintuitive ways. Looking at the voltage of a node with an oscilloscope does not tell you what is going on. You must understand both the voltage at the node and the current passing through it.

Power supplies are servo systems. You feed back the output voltage to a control chip and add components to compensate that feedback loop. All the principles of control theory apply to power supplies. You must ensure that your design is stable over all line voltages, loads, and temperatures. You can apply a step load to the output and observe the ringing on the waveform as the supply recovers. The thorough way to test a supply's stability is with a network analyzer. Ridley Engineering and Venable Instruments make specialized network analyzers for power-supply applications. The source excitation in these instruments is isolated, so you can inject a signal into the feedback loop of your supply. Alternatively, you can combine a conventional network analyzer, such as the 200-MHz Agilent HP3577, with an isolation transformer. Omicron makes the B-WIT-100 and network analyzers for this purpose.

Once you have set up the network analyzer, get a bode diagram of the gain and phase plots of your power supply's control loop over frequency. Power-supply engineers leave 30 to 60° of phase margin. Measuring EMI (electromagnetic interference) requires instruments such as Kikusui's harmonic and flicker analyzer to evaluate conducted noise into the ac-power cord. Dozens of instruments will help you measure radiated noise. Using a control IC that dithers the PWM (pulse-width-modulated) frequency lowers the measured EMI but does not reduce EMI. It reduces only the measurement results from swept-receiver instruments.

clude Fairchild's FSFR2100 regulator and FAN7621 controller and International Rectifier's IRS27951S.

NO MAGIC

The many challenges inherent in designing offline switching power supplies are daunting. If you are new to switching-power-supply design, you should not start with offline switchers because they involve significant safety hazards. On the other hand, there is no magic to them. Look at other designs for inspiration (**Figure 7**). Prowl the electronics-salvage yards and find a supply that outputs 300W; you could use that supply's transformer to make your own 300W device. Try changing the architecture or increasing the switching frequency to see what happens. Playful experimentation will bring the intuition

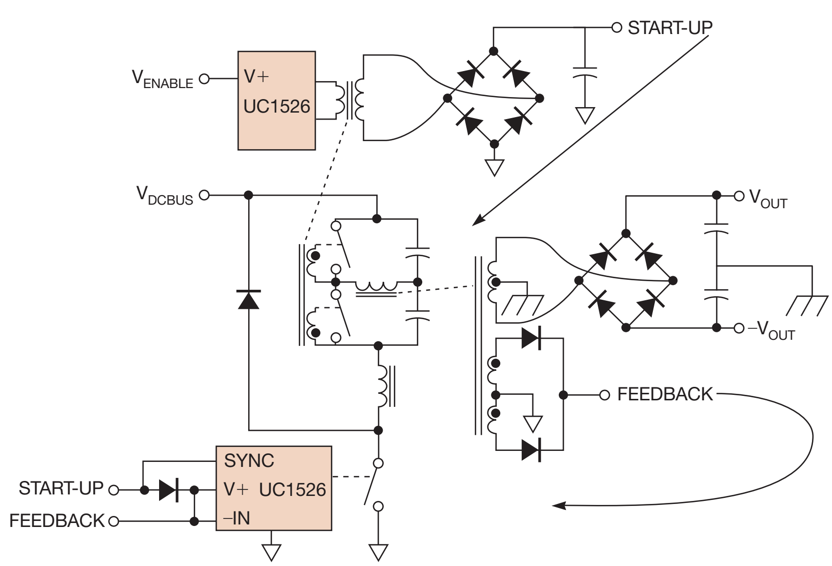

Figure 7 This compound power supply finds use in military systems. It has a buck converter that varies the voltage to a half-bridge converter that operates at a 50% duty cycle.

and experience you need to design off-line switchers.

Engineers who take on a design challenge often risk their safety to design high-voltage circuits. They enjoy the difficulties of understanding reactive circuits that behave in a nonintuitive manner. They read, study, and keep up with developments, and they often enjoy making the world a better place by squeezing every last percentage point of efficiency from a design. You are not alone. The vendors' application engineers will help you conceive, build, and test your ac/dc power supply. **EDN**

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READERS SOLVE DESIGN PROBLEMS

Reduce acoustic noise from capacitors

Damian Bonicatto, Landis+Gyr, Pequot Lakes, MN

Some surface-mount capacitors exhibit acoustic noise when operated at frequencies in the audio range. A recent design uses 10-μF, 35V X5R 1206 ceramic capacitors that produce noticeable acoustic noise. To quiet such a board, you can use acoustically quiet capacitors from manufacturers such as Murata (www.murata.com) and Kemet (www.kemet.com). Unfortunately, they tend to cost more than standard parts. Another option is to use capacitors with a higher voltage rating, which could reduce the noise. Those parts may also be more expensive than standard capacitors. A third path is to make a physical change to the PCB (printed-circuit board).

A ceramic capacitor expands when you apply a voltage and contracts when you reduce the voltage. The PCB flexes as the capacitor changes size because the ends of the capacitor mechanically couple to the PCB through solder (**Reference 1**).

Figure 1a shows a capacitor with no applied voltage, and **Figure 1b** shows an exaggerated condition of PCB flexing when you apply voltage to a capacitor. Applying the voltage makes the PCB operate as a speaker. Keeping that fact in mind, consider two methods for improving the situation. The first technique is relatively simple: If your circuit uses one capacitor, replace it with two in parallel, each with half the capacitance of the noisy capacitor. This approach lets you place a capacitor on top of the board and the other on the bottom of the board; the capacitors lie directly above each other, and their orientations are the same. As the upper capacitor tries to flex the board down, the lower capacitor tries to flex the board up. These two stresses tend to cancel each other, and the PCB generates little sound.

Adding a second capacitor increases cost but not as much as replacing the noisy capacitor with one that might not create noise. A ceramic capacitor from Digi-Key (www.digikey.com) sells for approximately 27 cents (1000). A quieter KPS-series part from Kemet costs approximately $1.50. The second method involves making a slot in the PCB near each end of the capacitor (**Figure 2**). When the capacitor expands and contracts, it flexes only a small portion of the PCB, which should reduce the noise.

A test with five 10-μF, 25V ceramic capacitors connected in parallel showed that putting three capacitors on top of the PCB and two on the bottom reduces the noise by 14 dBA (acoustic decibels). Routing a slot on both sides of the five capacitors reduces the noise by 15 dBA. Both are substantial noise reductions. A Murata JG8-series capacitor reduces the noise by 9.5 dBA. Combining these techniques should further reduce the noise.EDN

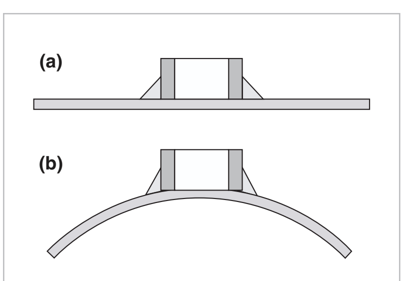

Figure 1 A ceramic capacitor expands when you apply a voltage (a) and contracts when you reduce the voltage (b).

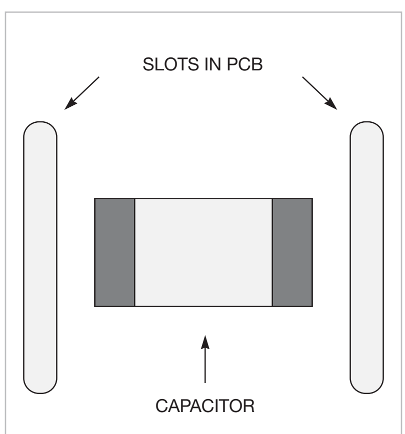

Figure 2 Adding a second capacitor increases cost but not as much as replacing the noisy capacitor with one that might not create noise.

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Function generator has variable frequency

Adolfo Mondragon, Electrolux Products, Juarez, Mexico

The Exar (www.exar.com) XR-2206 function-generator IC can generate square, triangular, and sinusoidal signals with low distortion. Its output frequency is inversely proportional to the components in an RC network, according to the formula F=1/RC.

Use a potentiometer as the resistor component to provide a frequency variation similar to a logarithmic scale. To change this behavior, the manufacturer's data sheet recommends connecting a resistor network to a variable external voltage source. The voltage should be stable and vary from 0 to almost 3V.

Instead of using an external voltage, the circuit described here uses an internal reference voltage of approximately 3V at Pin 7 of the XR-2206. With this internal reference, the circuit requires no voltage regulators—not even in the power supply. The circuit requires a power supply with only a 12V, 500-mA center-tapped transformer, a bridge rectifier, and two filter capacitors (**Figure 1**). You can define the frequency **equations** using **Figure 2** as a reference.

When V_X is 0V, you determine the frequency using F=1/RC. The current trough, I_R, equals 3/R, where 3 is the voltage reference in Pin 7. From this **equation** and resolving the recipro-

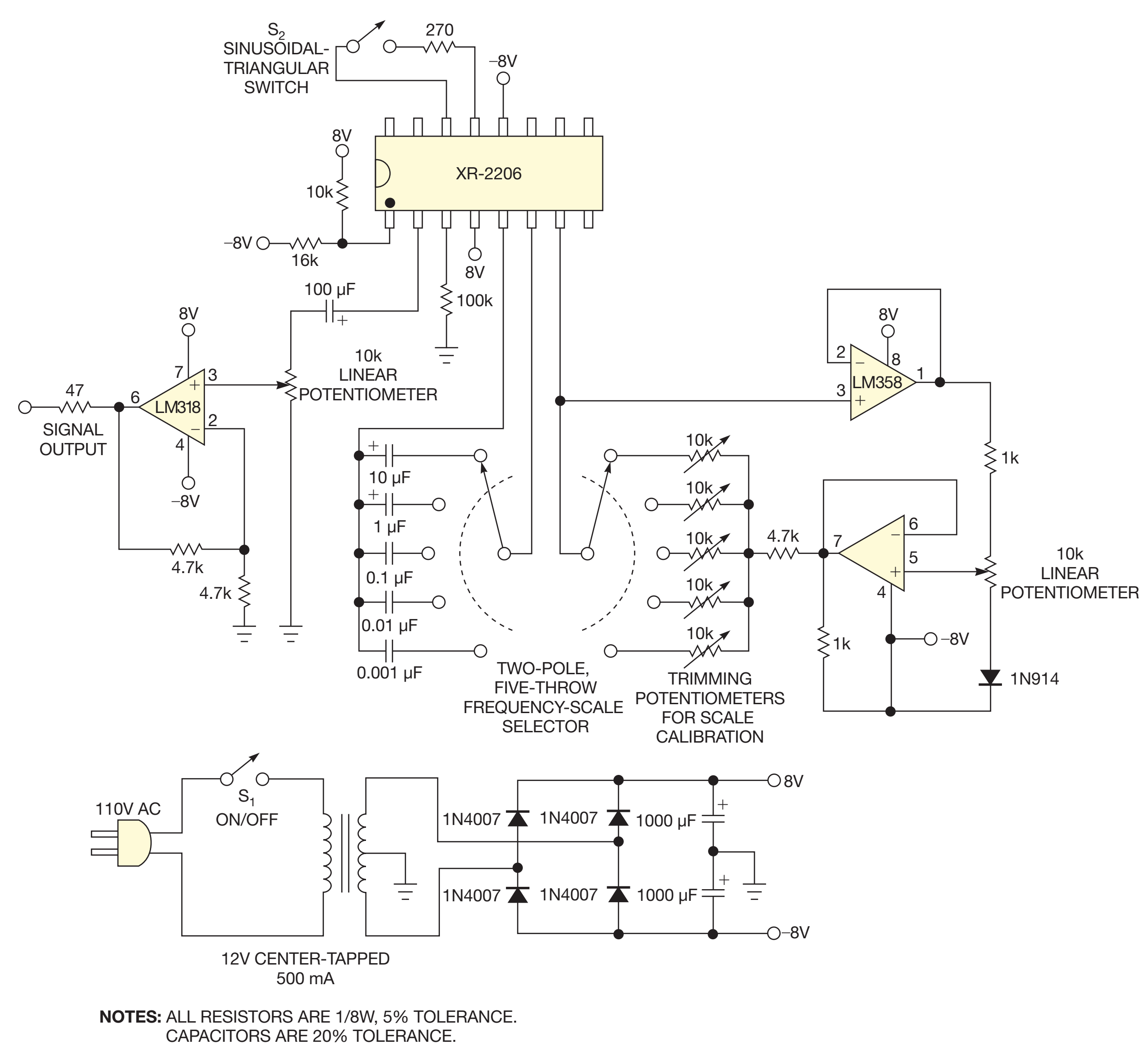

Figure 1 The waveform-generation circuit has a frequency of 1 Hz to 100 kHz in five scales.

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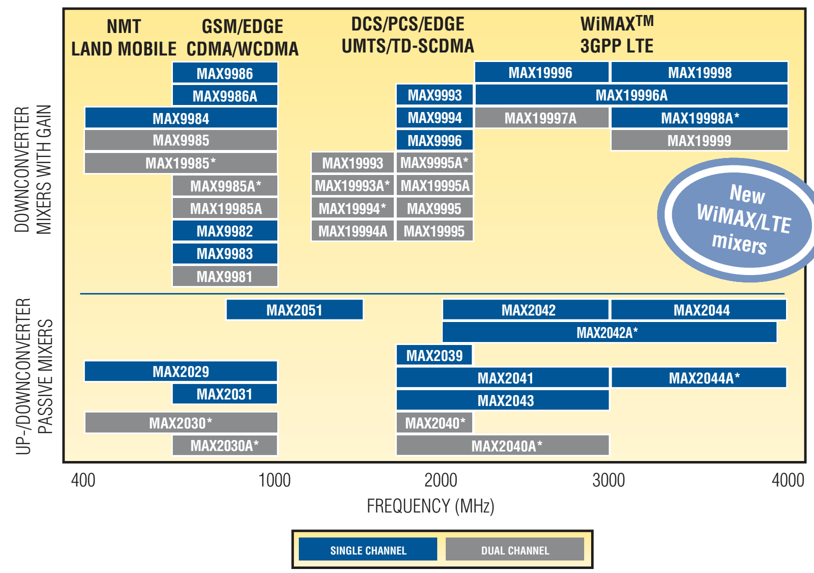

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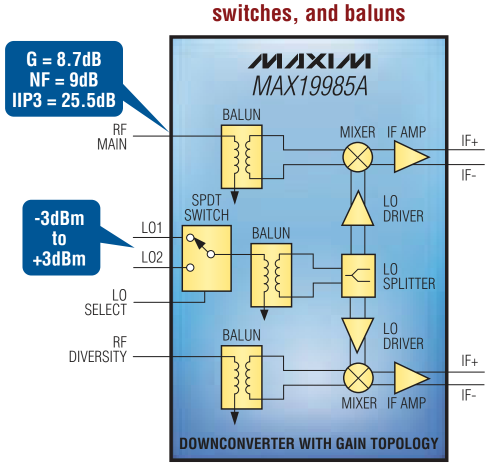

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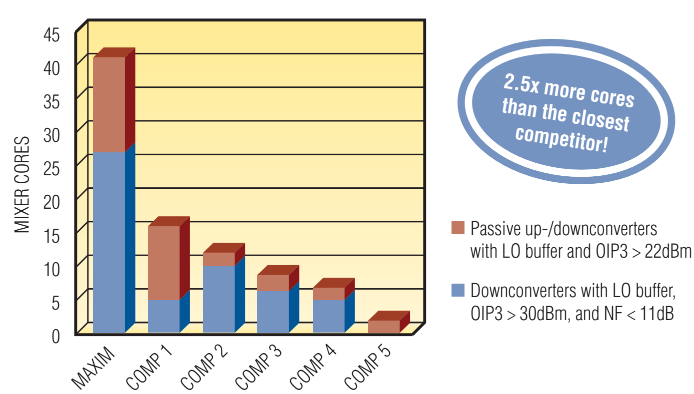

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cal of R, you define the frequency as $I_R/3R=1/R$, as a function of the current, $F=I_R/3C$.

When $V_X>0V$, you define the current as $I_R=(3-V_X)/R$. Replacing I_R from the previous **equation**, you can define the frequency as a direct function of the voltage: $F=(1/3RC)(3-V_X)$.

Figure 1 shows the final circuit to generate the waveforms. The circuit's frequency ranges from 1 Hz to 100 kHz in five scales. The rotary switch lets you select the scale by switching in a set of capacitors.EDN

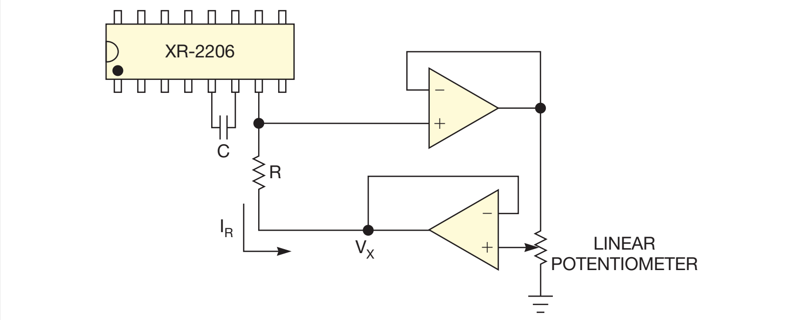


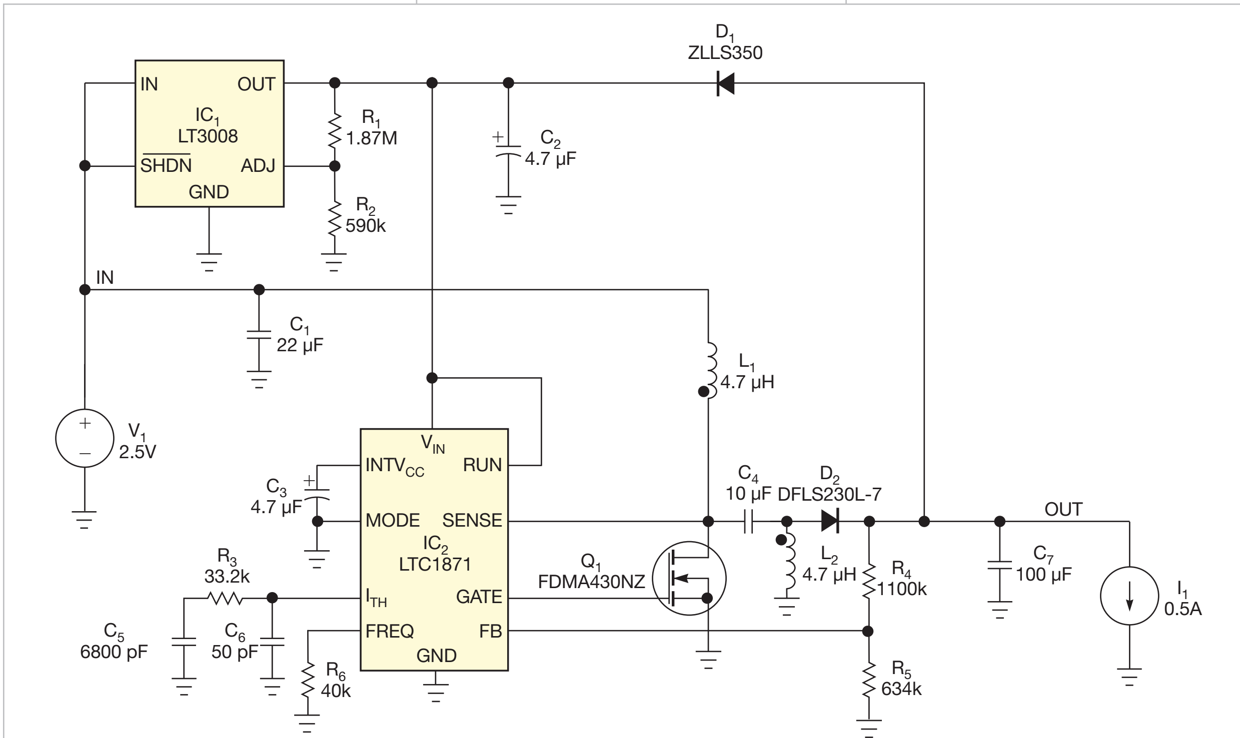
Figure 2 With an internal reference, this circuit requires no voltage regulators—not even in the power supply.

Power supply accepts wide input-voltage range

Jim Windgassen, Northrop Grumman Undersea Systems, Annapolis, MD

The switching power supply in **Figure 1** produces 3.3V dc from an input voltage of 2.5 to 20V dc with high efficiency. The circuit operates at an input voltage as low as 1.5V once it starts from a minimum of 2.5V dc, allowing the switcher to fully discharge a pair of alkaline cell batteries nearing end of life. The power supply can also run efficiently off higher input voltages, such as 12V automotive power. The heart of the circuit is a SEPIC (single-ended-primary-inductance-converter)-based switching power supply, which provides an output voltage greater than or less than the input voltage (**Reference 1**).

This power supply includes bootstrap circuitry comprising IC_1, an LT3008



NOTES: INDUCTOR MODEL IS BASED ON 4.7-µH WÜRTH 744878004 DUAL INDUCTOR FOR 600 kHz. L_1 AND L_2 ARE WOUND ON A COMMON CORE.

Figure 1 The power supply can provide a 3.3V output from 2.5 to 20V input voltages. It needs 2.5V to start.

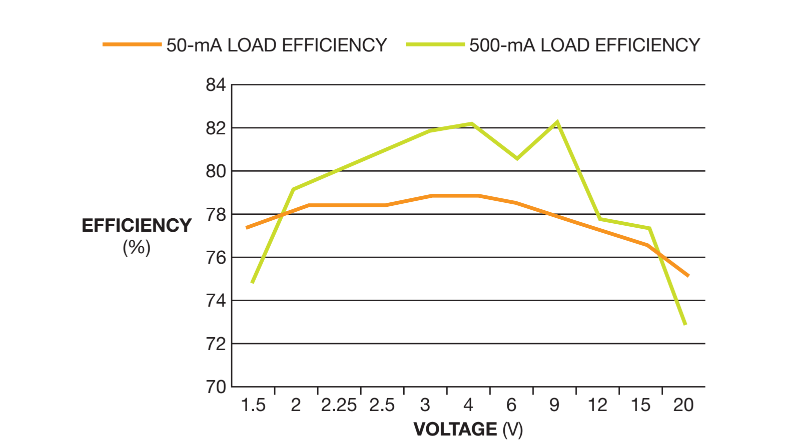


Figure 2 The power supply's efficiency is consistent over 50- and 500-mA loads.

voltage regulator; Schottky diode D_1; and capacitor C_2. It needs a minimum of 2.5V to start. Voltage regulator IC_1 provides 2.5V to start SEPIC controller IC_2. Once the output voltage of the SEPIC power supply reaches its normal output voltage of 3.3V, D_1 lets the output power of the switcher flow back to power IC_2. Once this action occurs, IC_1 drops out of the circuit because the voltage at its output is above its setpoint voltage. The converter's own output now powers IC_2, and the regulator's internal circuitry prevents backflow of power through IC_1. MOSFET Q_1 has low threshold voltage, appropriate on-resistance to provide current feedback to IC_2, and a maximum drain-to-source voltage of 30V to allow for operation up to a 20V input.

The bootstrap circuit allows the converter to run from very low input voltages by maintaining the input voltage to IC_2, and it increases efficiency at high input voltages by eliminating the use of IC_2's internal linear voltage regulator. **Figure 2** shows the efficiency of the prototype power supply at both 50- and 500-mA loads. The power supply's efficiency is consistent over a range of operating voltages because of the bootstrapping circuit.

Because the circuit uses a low-threshold-voltage MOSFET, the switch, keeping the gate drive voltage low, reduces the total charge that must go into and out of the MOSFET gate, further improving efficiency. SEPIC controller IC_2 normally uses its internal low-dropout capability to generate an operating voltage of 5V from the input. Running IC_2 from the bootstrapped output reduces IC_2's operating voltage to approximately 3V, which also limits the drive voltage to Q_1's gate.

Table 1 lists the key components for the power supply, including an appropriate commercially available coupled inductor. The PCB (printed-circuit-board) design and the choice of coupled inductors for this power supply are critical for good performance. For the power supply to achieve high efficiency at low input voltages and high output current, the coupled inductor must have low-resistance windings, and the high current tracks should use wide copper pours to minimize resistance

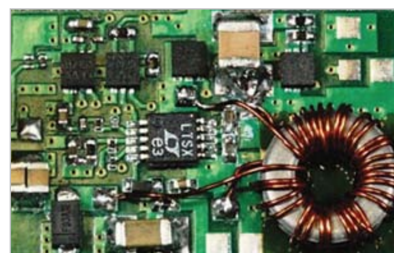


Figure 3 The complete power supply fits onto a 23×15×3.5-mm PCB.

TABLE 1 KEY PARTS FOR POWER SUPPLY

Component	Description	Manufacturer	Part
Input capacitor	22-µF, 25V, 10%-tolerance, 1210-size X5R ceramic capacitor	AVX	12063D106KAT2A
Output capacitor	100-µF, 6.3V, 1206-size X5R ceramic capacitor	Kemet	C1206C107M9PACTU
Coupled inductor	4.7-µH coupled-inductor Cuk SEPIC	Würth	744878004
Bootstrap low-dropout regulator	Regulated-low-dropout-adjustment, 20-mA, 6-DFN-packaged IC	Linear Technology	LT3008EDC#TRMPBF
SEPIC controller	10-MSOP-packaged current-mode-IC controller	Linear Technology	LTC1871EMS#PBF
MOSFET	30V, 5A, N-channel microMOSFET	Fairchild Semiconductor	FDMA430NZ
Bootstrap diode	SOD-523-packaged, 40V Schottky diode	Diodes Inc	ZLLS350TA
SEPIC diode	2A, 30V Schottky power diode	Diodes Inc	DFLS230L-7

losses and unwanted inductance.

A prototype of the power supply measures 23×15×3.5 mm (**Figure 3**). It uses a custom coupled inductor, but you can choose from many off-the-shelf coupled inductors available from BH Electronics (www.bhelectronics.com), Coilcraft (www.coilcraft.com), and Würth Elektronik (www.we-online.com). You can download the Linear Technology LTSpice code for this circuit from the online version of this Design Idea at www.edn.com/110217dia.EDN

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Circuit lets you test capacitors

Raju R Baddi,
Tata Institute of Fundamental Research, Maharashtra, India

Electrolytic capacitors tend to leak with time. The circuit in **Figure 1** lets you test capacitors and decide whether they're worth using. You can set the constraint on the leakiness through the values of C_{REF}/R_{REF}. The values in the **figure** are typical for general testing of all capacitors, from 1-nF ceramic versions to 1000-µF electrolytic types. The value of C_{REF} in the circuit is near the value of the test capacitor, C_X. You can also choose R_{REF}, by a rotary-switching arrangement, to be greater than or less than 22 MΩ.

When the pushbutton switch closes, capacitors C_{REF} and C_X charge through their respective PNP transistors. When the switch opens, the capacitors begin to discharge. C_{REF}, assuming that it is in good condition, has an additional discharge external resistance, R_{REF}. The capacitor under test, C_X, discharges through its internal resistance. If the leakage in C_X is greater than that of C_{REF} through R_{REF}, then its voltage will fall faster. Thus, the voltage at the op amp's noninverting input will be lower than at its inverting input, forcing the op amp's output low and lighting the red LED. This LED indicates that the test capacitor leaks. Testing of the circuit reveals that even a 1-nF ceramic capacitor holds against the reference. Check the voltage rating on the test capacitor to make sure that it is higher than the voltage to which it will be charged—in this case, V_{SUPPLY} is –1.8V.

The LF357 has a minimum supply voltage of 10V, but the testing took place at only 6V to allow a low upper-limit voltage for the test capacitor. Make sure the capacitor has a FET or a MOSFET input stage.EDN

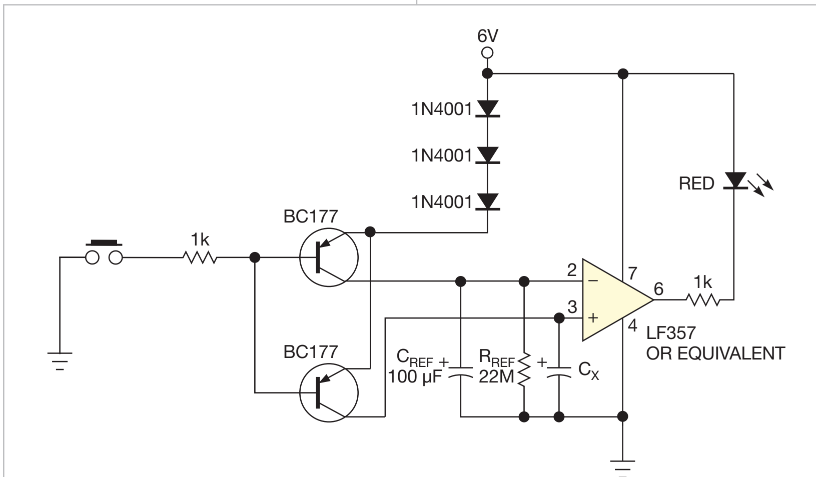
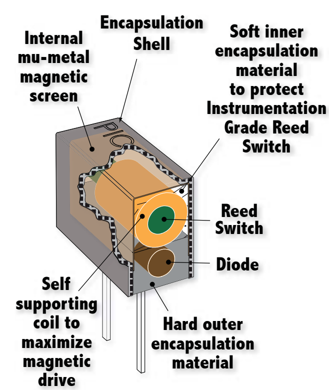
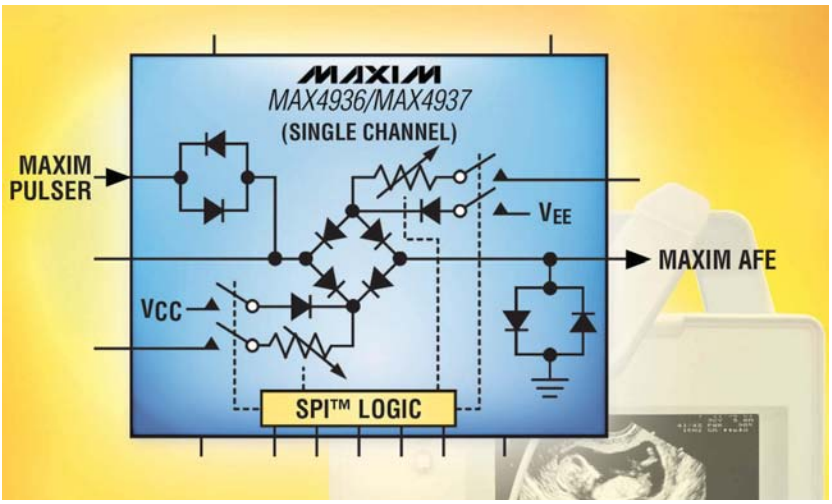


Figure 1 Electrolytic capacitors tend to leak over time, but this circuit lets you test them and decide whether they're worth using.



productroundup

SWITCHES AND RELAYS



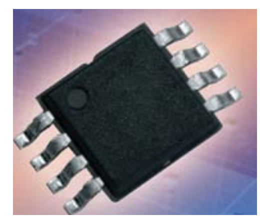
Transmit/receive switches integrate clamping diodes

The MAX4936/MAX4937 fully integrated octal high-voltage transmit/receive switches integrate clamping diodes to isolate the low-voltage receiver path from the high-voltage transmitting path. This feature protects the receiver input from voltage spikes due to leakage currents flowing through the switches. The devices feature eight individually programmable switches controlled through an SPI with a 12-bit shift register and transparent latch. The devices operate over the 0 to 70°C commercial-temperature range and come in 5×11-mm, 56-pin TQFN packages. Prices start at $12 (1000).

Maxim Integrated Products, www.maxim-ic.com

Dual SPST analog switch operates from a 1.8 to 5.5V power supply

The monolithic DG723 analog switch switches both analog and digital signals. It contains two independent SPST switches; Switch 1 is normally open, and Switch 2 is normally closed. Working from a 1.8 to 5.5V power supply, the DG723 delivers low switching noise for signal integrity and system accuracy. It combines a compact surface-mount package with low power consumption and the ability to work with the low voltages in new-generation portable designs. It features a typical on-resistance of 2.5Ω, typical leakage current of 1 pA, off-capacitance of 8 pF, on-capacitance of 19 pF, and charge injection of 1.8 pC. On-resistance flatness is 0.9Ω at 5V, and typical bandwidth is 366 MHz at –3 dB. The switch sells for 70 cents (1000).



Vishay Siliconix, www.vishay.com

Miniature pushbutton switches feature built-in RGB-LED illumination

The KP series of miniature RGB-LED-illuminated pushbutton switches have square caps with a clear lens and a white diffuser. They come in flat, sculptured, or home-key styles in 17.4-, 15-, and 12-mm sizes. They provide a choice of two-stroke-travel or actuation-force combinations and measure 23 mm high from the PCB to the top

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of the cap. The switches feature a maximum current of 100 mA at 12V dc. Prices start at $17 (sample quantities).
NKK Switches, www.nkkswitches.com

Power-off-protection switches prevent damage to data and systems

The ADG4612 and ADG4613 power-off-protection switches operate either open or closed and guarantee an off state in the absence of a power supply, preventing potentially damaging current from flowing to PCBs. The devices suit use in applications in which analog signals may be present at the switch inputs before the power-supply voltage is on or in which a user has no control over the power-supply sequence. The switches also feature overvoltage protection, which can block signal levels as high as 16V in the off state. The switches have a maximum on-resistance of 6.1Ω and contain four independent SPST switches. Each switch in the ADG4612 turns on with logic one on the appropriate control input, and two switches in the ADG4613 turn on with logic zero. The switches sell for $1.87 each (1000).
Analog Devices Inc, www.analog.com

Crosspoint switches support multiple data rates

The family of six crosspoint switches includes the industry's first 290×290 crosspoint switch. The GX3290, with 84,100 unique paths at 3.5 Gbps, consumes 34W with all channels active and operates at 1W in standby mode. The devices support the development of routers with an assymmetrical number of inputs and outputs and feature an on-chip pattern generator and checker. Packaged in a 50×50-mm BGA (ball-grid array), the GX3290 is priced at $2400 (1000).
Gennum, www.gennum.com

EDN productmart

This advertising is for new and current products.

A wrench in the works

In the summer of 1965, I went to work in the family airline business as a radio technician. As a new hire, I got the jobs that were in line with my experience and that nobody else liked to do, such as sweeping the floors and cleaning the shop. One interesting assignment was to repair and overhaul the large backlog of MG-149G and H-model rotary inverters. Our DC-3 and C-46 airplanes used the inverters, dc motors with ac generators that ran off the airplanes' main 28V-dc bus and supplied 115V ac and 400 Hz for certain radio-navigation equipment and instruments.

Overhaul involved completely disassembling and cleaning the unit. Once I cleaned up the components, I thoroughly examined them to check for anything out of the ordinary. The inverter rotor had a bearing in each of the end bells. The rotor had some sealed bearings and some open bearings. I had to thoroughly clean and regrease the open bearings. All bearings required hand operation to make sure they were smooth. Upon reassembly, the inverter end bells, bearings, and rotor had to be in perfect alignment, which I accomplished by starting up the inverter on the bench, listening, and then lightly tapping the end bells with a nonmetallic hammer to align the bearings.

It took me a week or two to work through the stack of inverters, but I finished them. Our spares rack was now full of shiny, clean MG-149 inverters. By now, though, everyone considered me the inverter expert. I received instructions to remove the No. 2 inverter from the DC-6 over in the hangar and take it to a local shop for overhaul.

The DC-6 used a much larger inverter than the MG-149 due to the larger ac load. Our test bench was not set up for the larger inverters. Off I went, but not before asking where the inverters in the DC-6 resided. It turns out that they were directly behind the radio rack in a closed compartment, with No. 1 at the top and No. 2 at the bottom.

When I climbed into the DC-6, I popped the fasteners that held the compartment covers and exposed the two inverters. I scoped out their mountings and electrical connections. There were two large, approximately #4/0 AWG wires for the 28V-dc input and several smaller ones for the three-phase ac output and on/off control. The ac system in the DC-6 used a delta configuration with one corner grounded.

I decided to disconnect the large dc wires first and grabbed an open-ended wrench from my toolbox; the company forbade the use of adjustable wrenches. I started to unscrew the nut on the positive dc input stud. When my wrench hit the enclosure structure, all hell broke loose.

There was a big flash, and the wrench instantly turned red. I had shorted the live dc bus to ground. Nobody told me to have one of the air-frame mechanics disconnect the batteries in the airplane before working on the inverters because the dc bus was hot all the time. The DC-6 had big batteries with lots of short-circuit current capability because they had to start four huge Pratt & Whitney R2800 engines.

I flinched but quickly again grabbed the wrench. It had welded itself to the aluminum structure. Worse, red-hot, molten aluminum and steel had splattered onto the carbon dust that coated everything in the inverter compartment and set it on fire. I was somehow able to pull the wrench away without burning myself. Miraculously, the carbon fires fizzled out, and no significant damage occurred to anything except my new wrench.

I climbed out of the airplane and, still shaking, told the mechanic foreman what had happened. He had a good laugh and said he'd have a mechanic disconnect the battery. I then vacuumed the inverter compartment and removed the inverter without further trouble and took it to the overhaul shop. I realized how close I had come to burning up a perfectly good DC-6 and probably the hangar with it.EDN

Whitham D Reeve is an engineer at Reeve Engineers (Anchorage, AK).

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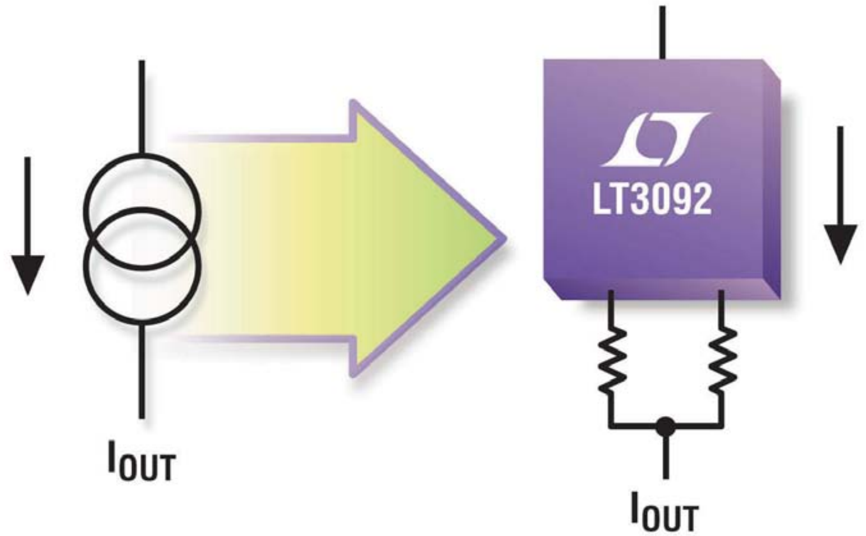

A Simple, Precise 2-Terminal Current Source

The simplest functions are often the most difficult to design. The current source—a basic circuit element—has not been available as an IC. Discrete implementations suffer from poor accuracy, high TC or complexity. Our new current source, the LT®3092, provides all the performance without the compromises: programmable up to 200mA, high AC and DC impedance, low TC and no capacitors required. Its two floating terminals make it easy to use in precision or remote current limiting, bias circuits, intrinsic safety circuits, temperature sensing, active load and signaling applications.

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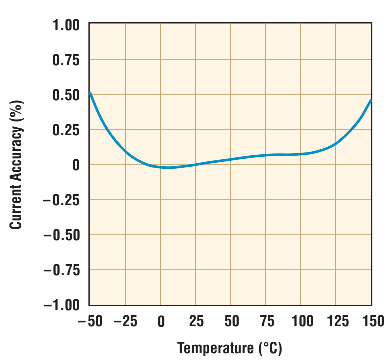
- Thermal Protection
- 1% SET Pin Current Accuracy
- 3mm x 3mm DFN-8, 8-Lead ThinSOT™ and 3-Lead SOT-223 Packages

Current Accuracy vs Temperature



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