UBM Electronics

EDN®

VOICE OF THE ENGINEER

FEB 16
Issue 4/2012
www.edn.com

SORTING OUT 4G ARE WE THERE YET?

Page 30

Protect POE systems from lightning surges and other electrical hazards

Page 23

Teardown: The power inverter—from sunlight to power grid

Page 37


The World's
Largest
Selection
OF ELECTRONIC COMPONENTS AVAILABLE FOR IMMEDIATE SHIPMENT!
SAME-DAY SHIPPING
on orders entered by
8:00 pm CENTRAL
NEXT-DAY DELIVERY
1.800.344.4539
DIGIKEY.COM
Digi-Key®
CORPORATION
2 MILLION PARTS ONLINE | 500+ INDUSTRY-LEADING SUPPLIERS | NEW PRODUCTS ADDED DAILY
Digi-Key is an authorized distributor for all supplier partners. New products added daily. © 2012 Digi-Key Corporation, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA
ecia
ecsn
member
CEDA

That’s what engineers are calling our new ultra-low DCR power inductors

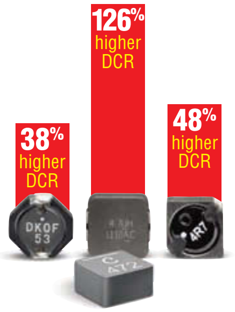
Super*con*ductors pass current with virtually no resistance.

Our new XAL/XFL inductors do much the same. Their DCR is incredibly low: often half that of similar size parts.

And their current handling is equally impressive. Coilcraft’s proprietary core material has a soft saturation characteristic that prevents drastic inductance drops during current spikes.

Unlike competitive parts, these inductors don’t suffer from thermal aging. And we give you far more footprint options to maximize PCB density.

To see what else makes our new XAL/XFL inductors so super, visit **coilcraft.com/xal.**



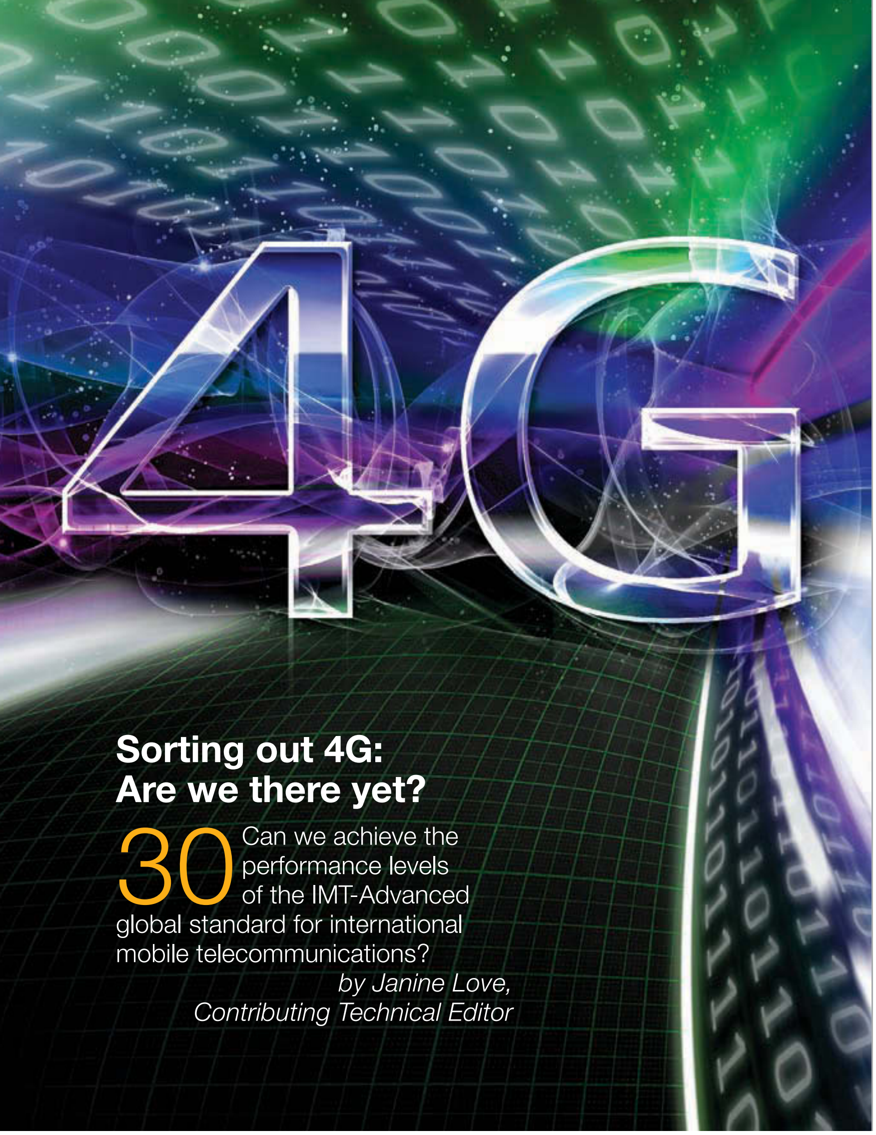
Competitors’ 4.7uH inductors have much higher DCR per mm³ than Coilcraft’s XAL5030.

Coilcraft®

WWW.COILCRAFT.COM

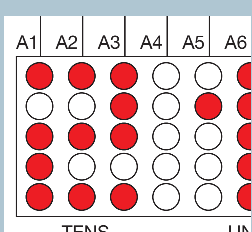
coilcraftdirect.com
No min order. Next day delivery.

EDN contents
2.16.12



COVER IMAGE: SHUTTERSTOCK/GIULIA FINI-GULOTTA

DESIGNIDEAS



▶ Find out how to submit your own Design Idea: http://bit.ly/DesignIdeasGuide.


AS9120A Certified Distributor
mouser.com
Semiconductors and electronic components for design engineers.
Authorized Distributor
Contribution To Sustainability
AWARDED #1
Stocking the Newest Products
Highest Industry Award for Sustainability.*
By identifying EOL, obsolete and NRND products, Mouser delivers the newest components to advance greater energy efficiency and longer product life. And that's good for the consumer and the environment.
Widest selection of newest products
Millions of products online
Localized global support
Fastest introduction of new products
2000+ microsites and resources
Accurate, same-day shipping
mouser.com | The Newest Products for Your Newest Designs®
MOUSER ELECTRONICS
a tti company
Mouser and Mouser Electronics are registered trademarks of Mouser Electronics, Inc. *2011 e-Legacy Award for Contribution to Sustainability.

contents 2.16.12

pulse

DEPARTMENTS & COLUMNS

51

54

EDN® (ISSN# 0012-7515) is published semimonthly by UBM Electronics, 600 Community Drive, Manhasset, NY 11030-3825. Periodicals postage paid at Manhasset, NY, and at additional mailing offices. SUBSCRIPTIONS—Free to qualified subscribers as defined on the subscription card. Rates for nonqualified subscriptions, including all issues: US, $150 one year; $250 two years; $300 three years. Except for special issues where price changes are indicated, single copies are available for $10 US and $15 foreign. For telephone inquiries regarding subscriptions, call 847-559-7597. E-mail: edn@omeda.com. CHANGE OF ADDRESS—Notices should be sent promptly to EDN, PO Box 3609, Northbrook, IL 60065-3257. Please provide old mailing label as well as new address. Allow two months for change. NOTICE—Every precaution is taken to ensure accuracy of content; however, the publishers cannot accept responsibility for the correctness of the information supplied or advertised or for any opinion expressed herein. POSTMASTER—Send address changes to EDN, PO Box 3609, Northbrook, IL 60065-3257. CANADA POST: Publications Mail Agreement 40612608. Return undeliverable Canadian addresses to APC, PO Box 503, RPO West BVR CRE, Rich Hill. ON L4B 4R6.

Volume 57, Number 4 (Printed in USA).

AS9120A **Certified Distributor**

mouser.com
Semiconductors and electronic components for design engineers.

Authorized Distributor

Highest Standard for Quality and Control.

Mouser has high-level traceability and anti-counterfeit controls to serve aerospace, industrial, and commercial products. Your one source for What's Next.

- Widest selection of newest products
- Millions of products online
- Localized global support
- Fastest introduction of new products
- 2000+ microsites and resources
- Accurate, same-day shipping

mouser.com | The Newest Products for Your Newest Designs®

MOUSER ELECTRONICS®
a tti company

EDN online

JOIN THE CONVERSATION

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

In response to "Noise wars: Projected capacitance strikes back against internal noise," an article by John Carey of Cypress Semiconductor, http://bit.ly/yyXkWK, Bill Bohan comments:

"I believe you have solved the issue. Right off the bat, you cited inferior power-supply designs as the source of noise. Just don't buy them! I've been designing dc/dc and universals for years. You can get good, clean power supplies or design your own! Those noise levels are so outrageous, why do you accept that [situation]? It is good that you cover the downstream effects as a result of inferior power management. Take the battle back upstream; put an American to work designing one."

In response to "The red-cable blues," a Tales from the Cube column by Larry Goga, http://bit.ly/A7qAhq, Sujit Liddle comments:

"LOL. This brings back memories. I once traced poor video quality in a video-capture system to the new batch of S-video cables that looked great but had been made using unshielded four-core wire instead of the expected dual coaxial cables."

DANIEL VASCONCELLOS

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

CONTENT

Can't-miss content on EDN.com

CALIFORNIA PASSES NEW REGULATIONS FOR BATTERY-CHARGING SYSTEMS

The California Energy Commission released a new standard for personal-electronics equipment sold in California that targets energy efficiency in battery-charging systems. Were these regulations necessary, and how do they play with Department of Energy regulations, which would pre-empt them?

http://bit.ly/xxAYvj

THRUN SAYS GOODBYE TO STANFORD, HELLO TO A WORLD UNIVERSITY

Higher education is way past due for a change. Sebastian Thrun, Google fellow and research professor at Stanford University, is taking steps to make that change. He has decided to quit Stanford, giving up his tenure, to start a new online university. Thrun wants to empower an entire world of people who understand technology and will tackle the big, hairy problems the world faces. And that's a big, hairy, audacious goal.

http://bit.ly/yiRrcH

ENGINEERING COMMUNITY

Opportunities to get involved and show your smarts

ACE AWARDS EE Times EDN

The Oscars celebrate Hollywood. The Super Bowl celebrates athletics. We celebrate engineering. New this year, *EE Times'* ACE (Annual Creativity in Electronics) Awards and *EDN*'s Innovation Awards are joining forces to honor the people and companies—the creators—behind the technologies and products that are changing the world of electronics and shaping the way we work, live, and play. Join us and network with your peers at the 2012 UBM Electronics ACE Awards taking place on March 27, 2012, during Design West, as we celebrate the industry's best of the best. Find out more at **http://ubm-ace.com**.

BY MARGERY CONNER, TECHNICAL EDITOR

Qualcomm offers $10 million for a real-life tricorder, not a moment too soon

During the past month, I have visited three hospitals for various family members, and, in each case, human error caused some severe mistakes: misread charts, incorrect drug prescriptions, and incorrect surgical procedures. Yet, these medical professionals are perfectly competent individuals. They are humans dealing with an extremely complicated system. When aspirin and morphine were among the only available drugs and patients were receiving treatment for one of the few diseases that medical "science" was able to treat, mere humans could track complex drug interactions, surgical procedures, and the like—nowadays, not so much.

You've probably heard of hospitals that remarkably improved their success rates by implementing checklists for procedures. Atul Gawande, MD, author of *The Checklist Manifesto* and a contributor to *The New Yorker*, initiated and champions the concept of checklists in hospitals. "Gawande begins by making a distinction between errors of ignorance (mistakes we make because we don't know enough) and errors of ineptitude (mistakes we made because we don't make proper use of what we know)," writes Malcolm Gladwell in a review of the book. "Failure in the modern world, he writes, is really about the second of these errors, and he walks us through a series of examples from medicine showing how the routine tasks of surgeons have now become so incredibly complicated that mistakes … are virtually inevitable. It's just too easy for an otherwise-competent doctor to miss a step, or forget to ask a key question, or, in the stress and pressure of the moment, fail to plan properly for every eventuality."

Computers competently keep track of what we know and follow checklists. Combine these characteristics with some clever sensor systems, and you just might come up with a tricorder—and not a moment too soon.

Qualcomm is offering a $10 million prize, the Tricorder X-Prize, for the first noninvasive health-diagnostic tool. For those of you who are rusty on your *Star Trek* plot lines, the tricorder is a piece of equipment that takes a quick scan of an injured or sick patient and instantly both diagnoses the problem and prescribes a treatment.

The winning team will be the one with the technology that most accurately diagnoses a set of diseases without using input from a doctor or a nurse and that provides the best user experience—thus most likely eliminating the use of invasive probes that play such prominent roles in alien-abduction stories. It will capture metrics for patient health. These metrics could include blood pressure, respiratory rate, and temperature. The device can, however, use sensors or electrodes that attach to the skin.

Looking toward the future, Qualcomm sees this tool collecting large volumes of data from ongoing measurement of health states through a combination of wireless sensors; imaging technologies; and portable, noninvasive laboratory replacements. "Noninvasive" means that the treatment would require neither biopsies nor blood tests. The only limitation is that the weight of both the tool and any components it requires must total 5 lbs or less.

The routine tasks of surgeons have now become so complicated that mistakes are virtually inevitable.

Qualcomm implies that the benefits of having a tricorder-like device are to bypass the personnel shortage and thus save time and money. I think there's another benefit that could be just as great: The diagnosis and ensuing care from a computer could be much better than that from a human. Paraphrasing from the Qualcomm site, a tricorder-like device will go a long way toward transforming health care by turning the "art" of medicine into a science.

Bones, we're ready. **EDN**

Contact me at margery.conner@ubm.com.

EDITED BY FRAN GRANVILLE

pulse

INNOVATIONS & INNOVATORS

Car-door-controller IC integrates window control

STMicroelectronics' new L99DZ80 car-door-controller IC removes the need for mechanical relays in car-window control, reducing component costs and eliminating the need for expensive EMC countermeasures. The door-zone driver supports adjustable window speeds related to the position of the window, soft start and shutdown, and reduced noise levels, thanks to the removal of the relay. The device embeds an SPI-programmable slew-rate-control capability that can drive four external MOSFETs in a half-bridge configuration dedicated to PWM-driven electric-window applications.

Other features include six bridges, including one full bridge for a 6A load with an on-resistance of 150 mΩ, two half-bridges for a 3A load with an on-resistance of 300 mΩ, two half-bridges for a 0.5A load with an on-resistance of 1600 mΩ, and one high-side driver for a 5A load. The device supports double door-lock control; mirror-folding and mirror-axis control; and a high-side driver for a mirror defroster, bulbs, and LEDs. The device also integrates a control block with an external MOS transistor for charging and discharging of electrochromic, dimmable mirror glasses. Standby current consumption is less than 6 μA, and junction temperature is 85°C or less. The device comes in a TQFP-64 package in tray and tape-and-reel options. Price is $2.50 (25,000).

—by Fran Granville

▷**STMicroelectronics**, www.st.com.

TALKBACK

"The lesson when it comes to proposals to introduce new tech that undermines existing product lines: 'It's better to shoot yourself in the foot than have a competitor shoot you in the head.'"

—*EDN* reader Dirk Bruere, in *EDN*'s Talkback section, at http://bit.ly/yvokLS. Add your comments.

STMicro's L99DZ80 car-door-controller IC has six bridges for mirror-fold and mirror-axis control and a high-side driver for a mirror defroster, bulbs, and LEDs.


Name
Dr. Laurel Watts
Job Title
Principal Software Engineer
Area of Expertise
Chemical Engineering
LabVIEW Helped Me
Control multiple instruments operating in harsh conditions
Latest Project
Engineer the ultimate storm chaser
NI LabVIEW
LabVIEW makes me better because the
INTEGRATION
with hardware is so seamless

Meter reference design enables secure purchase of energy credits

Smart meters promise to eliminate energy inefficiencies by allowing users to remotely monitor, control, and optimize their energy usage. Unfortunately, those benefits come at the expense of reduced security, leaving doors open for hackers to snoop, commit fraud, and criminally tamper with safety systems. To remedy these concerns, Freescale Semiconductor has partnered with Inside Secure on a prepaid smart-meter reference design that cures these security ills with proven NFC technology.

At the recent 28C3 (28th Chaos Communication Congress), which took place in December in Berlin, hackers demonstrated how smart meters allow unauthorized intrusions that can remotely control meters, the devices they control, and even the safety systems that households depend on to prevent burglaries. Fortunately, with proper designs—and a few extra security protocols—smart-meter designers can avoid these problems. "The smart-meter reference design enables secure mechanical meters that are virtually tamperproof," says Olivier Debelleix, Inside Secure's business-line manager for embedded security.

Freescale's secure-smart-meter design enlists banking-industry-proven NFC protocols, using a smartphone or a smartcard with NFC to load prepaid credits. Key to the secure smart meter is Inside Secure's VaultIC chip, which uses the company's MicroRead NFC technology. The technology allows users to purchase energy credits with their smartphones or smartcards and then securely load them into the smart meter using the same technology that allows users to make banking-card purchases using NFC.

The secure-smart-meter reference design uses the cryptographic hardware on Freescale's Kinetis MK30 microcontroller, employing the ARM Cortex-M4 core, which operates at speeds as high as 100 MHz with 1.25 DMIPS/MHz. The device uses mutual authentication, verification, security certificates, encryption/decryption, and on-chip management of secure cryptographic keys. The secure smart meter uses the MK30's built-in segment-LCD controller to drive the display of metering values at the push of a button and runs on Freescale's MQX real-time operating system. The system meets the requirements of Federal Information Processing Standard FIPS140-2 Level 3, a US-government computer-security standard to accredit cryptographic systems.

A smart-meter reference design combines Inside Secure's contactless-NFC-chip technology with Freescale's secure-microcontroller technology to enable virtually tamperproof secure mechanical meters (courtesy Freescale).

—by R Colin Johnson

▷**Freescale Semiconductor**, www.freescale.com.

▷**Inside Secure**, www.insidesecure.com.

MEMS-optical-IC platform allows the creation of custom structures

Si-Ware Systems Ltd, a fabless chip and design-service company, has announced its SiMOST (silicon-integrated-micro-optical-system) platform for the creation of single-chip optical systems. SiMOST allows the integration of optical-MEMS elements to create custom structures. Manufacturers can pattern and etch multiple optical-MEMS structures on SOI (silicon-on-insulator) wafers using DRIE (deep reactive ion etching). The manufacturer then packages the structures at the wafer level and dices them to create a one-chip optical system.

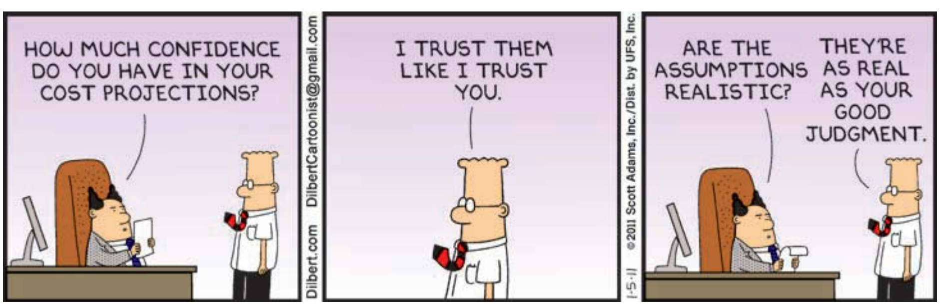
Si-Ware has created a library of building blocks for the platform. Optical components include flat, cylindrical, and spherical collimating mirrors; wide-bandwidth beam splitters; optical filters; and moving-corner cube reflectors. MEMS components include long-travel-range microactuators and micromotors. The components are lithographically aligned on the chip.

Si-Ware has already used the SiMOST system to create a monolithic infrared spectrometer and swept-laser source. Designers can complement such optical-MEMS monolithic-workbench ICs with electronic interface-and-control ICs from Si-Ware's ASIC division. These ASICs handle the MEMS control, current, voltage and capacitive sensing, data conversion using ADCs and DACs, and data processing. The systems can rival microelectronics in economies of scale in size and cost.

—by Peter Clarke

▷**Si-Ware Systems Ltd**, www.si-ware.com.

DILBERT By Scott Adams



RAQ's

Rarely Asked Questions

Strange stories from the call logs of Analog Devices

Considerations on High-Speed Converter PCB Design, Part 4: Plane Coupling

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.

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

A. Part 1 of this series discussed why splitting AGND and DGND is not necessary unless circumstances within the design force you to make that choice. Part 2 discussed the design of the power delivery system (PDS), and how squeezing the power and ground planes together provide added capacitance. Part 3 discussed how wise design of the E-Pad gets the best performance and most heat out of your signal chain design. Part 4 will make light of cross coupling between layers and planes within the PCB.

It is inevitable that some high-speed converter layouts will have a circuit plane overlapping another within the PCB design. In some cases, a sensitive analog plane (power, ground, or signal) might be directly above a noisy digital plane. Most designers wouldn't think that this would matter, as the planes are on different layers. So, here's a simple test:

Choose one of the adjacent layers and inject a signal on that plane. Next, connect the cross-coupled layer to a spectrum analyzer. Can you see how much signal is coupling through to the adjacent layer? Even though they might be separated by 40 mils, adjacent layers still form a capacitor in some sense, and will therefore still couple signal from one plane to another at some frequency.

Let's say a noisy digital plane on one layer has a 1-V signal that switches at a high speed. With 60-dB isolation between the layers, the non-driven layer will "see" 1 mV of coupling from the driven layer. To a 12-bit analog-to-digital converter (ADC) with a 2-V p-p full-scale swing, this is 2 LSBs (least significant bits) of coupling. This may be fine for your particular system, but keep in mind that as you increase the resolution from 12 bits to 14 bits, the sensitivity quadruples, so the error increases to 8 LSBs.

Ignoring cross-plane/cross-layer coupling will probably neither make the system fail nor cripple the design, but be aware, because more coupling exists between two planes than what might be imagined.

Keep this in mind when noise spurs are seen coupling in the frequency spectrum of interest. Sometimes layouts dictate that unintended signals or planes be cross-coupled to a different layer. Remember this when debugging your sensitive systems: the issue may lie one layer below.

To Learn More About High-Speed Layout
http://dn.hotims.com/40993-100

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

For Analog Devices' Technical Support, Call 800-AnalogD

Wideband I/Q demodulator improves receiver performance

Linear Technology's new ultrawide-bandwidth, direct-conversion LTC5585 I/Q demodulator features an IIP3 and an IIP2 of 25.7 dBm and 60 dBm, respectively, at 1.95 GHz. The demodulator provides baseband output-demodulation bandwidth of more than 530 MHz, which can support new-generation wideband LTE-multimode and digital-predistortion receivers. It operates over a frequency range of 700 MHz to 3 GHz, covering virtually all cellular-base-station frequency bands.

The device includes built-in calibration circuitry that enables designers to improve the receiver's IIP2 performance from a nominal 60 dBm to 30 dBm or higher. On-chip calibration circuitry nulls out the dc-offset voltages at the I and the Q offsets. Output power at 1-dB compression is 16 dBm. The LTC5585 offers typical amplitude mismatch of 0.05 dB and phase error of 0.7° at 1.95 GHz, producing a receiver-image-rejection capability of 43 dB.

The demodulator suits use in multimode LTE, WCDMA, and TDSCDMA base-station digital-predistortion receivers and main receivers. It also targets use in military receivers, broadband communications, point-to-point microwave data links, image-rejection receivers, and long-range RFID readers.

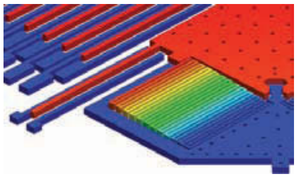
The LTC5585 has an on-chip RF transformer to reduce the need for external components; comes in a 24-lead, 4×4-mm QFN package; and operates over a temperature range of −40 to +105°C. It operates from one 5V supply, drawing a supply current of 200 mA. The device provides a digital input to enable or disable the chip. When disabled, the IC typically draws 11 μA of leakage current. The demodulator's turn-on time of 200 nsec and turn-off time of 800 nsec enable its use in burst-mode receivers. Prices start at $5.98 (1000). **—by Fran Granville**

Linear Technology's wideband LTC5585 I/Q demodulator features an IIP3 and an IIP2 of 25.7 dBm and 60 dBm, respectively, at 1.95 GHz.

▷**Linear Technology Corp**, www.linear.com/product/LTC5585.

Coventor automates MEMS design

With the market for MEMS chips growing at a 50% annual-growth rate, according to Goldman Sachs, EDA-tool vendor Coventor Inc aims to speed up MEMS-chip design by adding scripted automation and by dramatically expanding the size of the devices it can simulate. "Coventor users can now use the Python scripting language to automate the process of changing test parameters and then running simulations to make sure MEMS devices meet their design specifications under all operating conditions," says Stephen Breit, vice president of product development at Coventor.



Coventor claims its new hex-dominant meshes use 20 to 40% fewer elements, enabling the simulation of multiaxis MEMS sensors with hundreds of electrostatic comb fingers.

Coventor also expanded the resolution of its models from 32 to 64 bits, removing the 3-Gbyte limit on simulation sizes that had previously slowed the design process. "Now, our users can focus on solving even the most complex MEMS-design and -simulation problems without worrying about running out of memory space," says Breit. "It's just a matter of how much simulation memory you can afford, rather than how much our tools can access."

CoventorWare also sports a new hex-dominant extrude-meshing capability, which automatically generates meshes of uniform density and quality. Previously, inefficient tetrahedryl meshes were necessary for stacked layers of materials that are perforated with release etch holes. Coventor claims that its new meshes use 20 to 40% fewer elements, enabling the simulation of multiaxis MEMS sensors with hundreds of electrostatic comb fingers.

—by R Colin Johnson

▷**Coventor Inc**, www.coventor.com.

02.16.12

AUTOMOTIVE VARISTORS HAVE LOW LEAKAGE CURRENT

The AEC Q200-qualified automotive StaticGuard series varistors deliver capacitance of 40 to 200 pF at 0.5V and leakage current of 10 μA, providing ESD protection in CMOS, bipolar, and SiGe-based circuits. The varistors provide bidirectional transient-voltage protection in the on state and EMI/RFI attenuation in the off state, along with an ESD rating as high as 15 kV.

Typical ESD failure voltage for CMOS and bipolar parts is 200V or greater, and the devices comply with IEC 1000-4-2, Level 4, with 15-kV ESD pulse (air discharge) and generate less than 20 mJ of energy. The devices come in 0402, 0603, and 0805 case sizes for use in general-purpose drives and logic, transceiver chips, and sensor applications. Typical prices range from 4 to 9 cents (volume quantities).

—by Ismini Scouras

▶**AVX Corp**, www.avx.com.

AVX's StaticGuard varistors provide transient-voltage and signal suppression for automotive applications.

BY BONNIE BAKER

EMI problems? Just the facts, please

The proliferation of intentional and unintentional EMI radiators can wreak havoc on your circuits. The signals from these radiators are not out to contaminate your circuits, but you may want to keep your low-noise systems out of harm's way. Imagine a doctor using an ECG (electrocardiogram) diagnostic tool to get a good look at your heart. This high-precision measurement is also low-frequency, so the electronics don't extend past 1 MHz. However, if you are connected to an ECG tool with a poor EMI design and your physician answers his cell phone during the test, you may have cause for concern (**Figure 1**).

The heart's input signal to the system is approximately 0.25 mV p-p. This small signal requires an instrumentation amplifier's gain of approximately 6000V/V. The good news is that the results in **Figure 1** do not represent the performance of a doctor's office ECG-measurement tool. This measurement was actually taken in an engineer's lab from the board in **Figure 2**.

Don't fall into this EMI trap. Take care to create boards and use components that are EMI-resilient, regardless of your analog or digital circuit's bandwidth. When an EMI source is present in the vicinity of your application circuit, it may create a response to the radiating source.

How did the radiated noise from the phone get into the measurement with such a low-frequency board? In EMI terms, three elements are at work with this type of problem: a radiation source, a coupling path for the radiation signal to travel through, and a receptor. The radiation source in this example is the cell phone. The EMI signals may come through the air or be conducted across your PCB and originate from unexpected sources. EMI, or RFI, surrounds a receptor either by direct conduction or through fields. These fields couple directly into the circuit's connecting wires and PCB traces, where they are converted to conducted RFI.

The conditions that create physical forces between charges are electric, magnetic, and electromagnetic radiation. An electric field describes a force that an uneven charge distribution creates between two physical points. Force develops between charges in an effort to balance the charge distribution. Moving charges or current flow creates a magnetic field, exerting a force on all other charges around them. This field, or force, falls off rapidly with distance. Note that the electric and magnetic fields interrelate, and a change in one results in a simultaneous change in the other. The acceleration of an electron, or charge, creates an electromagnetic field. This electromagnetic field is most often responsible for the propagation of EMI.

To tackle this problem, read my next column, which will examine the characteristics of the radiating sources that can cause EMI problems, along with some tips on how to minimize their transmissions. EDN

ACKNOWLEDGMENT

Special thanks to John Brown for the ECG board and data.

Bonnie Baker is a senior applications engineer at Texas Instruments and author of A Baker's Dozen: Real Analog Solutions for Digital Designers.

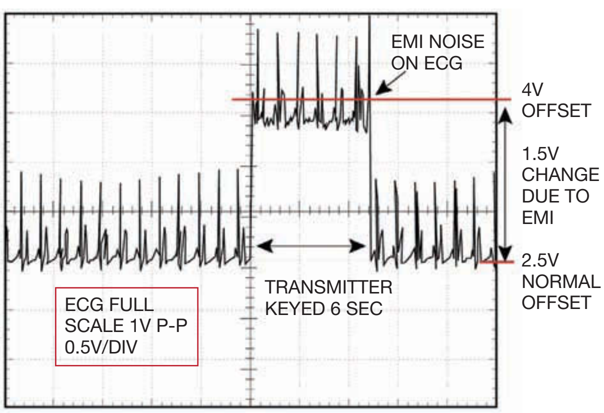


Figure 1 EMI from a cell phone can cause a 1.5V change from normal on an ECG. The ECG diagnostic tool senses a heart while a 0.5W, 470-MHz transmitter turns on and off just one and a half feet away.

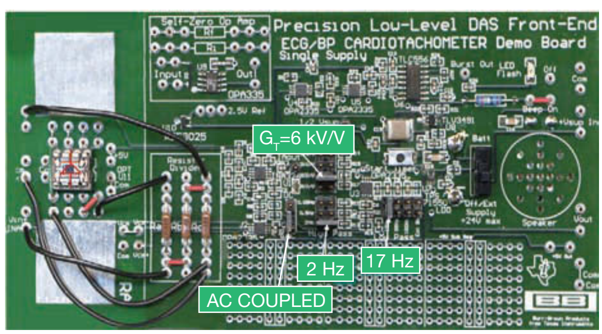
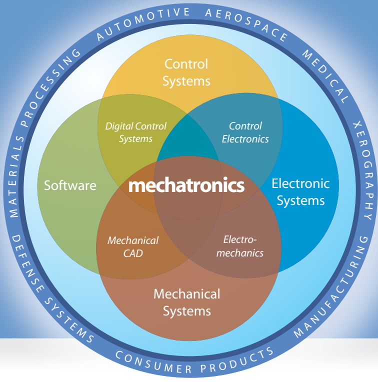


Figure 2 An engineer's precision, low-level ECG cardiotachometer board took the measurements for Figure 1.



Pulse-width modulation

All engineers need to know what PWM is and why it is so common.

As engineers, you use many components and devices every day that you treat as black boxes. You are concerned only about the inputs and outputs of the black box, and that approach is acceptable provided that you know the operating range and limitations of the device. The same can be said about certain concepts and techniques. You routinely use them, and they work, but you may not totally understand why they work. As fundamental performance limitations and safety come into question, a deeper understanding becomes necessary. In addition, innovation demands understanding. The widely used PWM technique may fall into this category. Most engineers use it every day to drive a variety of devices, but only a few know why they use it and how it works.

Some people refer to PWM as a poor man's DAC.

A pulse signal is defined by its amplitude and pulse width. A periodic pulse train has a frequency, or pulse-repetition rate, and a duty cycle—the ratio of pulse width to repetition period, varying between 0 and 100%. PWM modulates the duty cycle and keeps the period fixed. Microcontrollers, which operate in the digital domain, can generate a PWM signal. Although an analog signal is continuous in both time and amplitude, a digital signal is discrete in time—that is, it is sampled at a certain rate—and quantized in amplitude using a finite number of bits. The output of a microcontroller is typically either digital or PWM. The PWM signal typically ranges from 0 to 5V; thus, you can use it to turn an electronic power switch, a transistor, on and off and to control the amount of power a load receives.

Why would anybody be interested in this type of signal? PWM avoids losses normally incurred when a power source is limited by resistive means. In PWM, the average delivered power is proportional to the modulation duty cycle. Thus, the switched circuits to control the voltage across or current through a load have low power loss because the switching devices are either off—and no current yields no power loss—or on, with low power loss due to low voltage drop. You can augment the PWM signal, with a sufficiently high modulation frequency, using a lowpass filter to smooth the pulse train and recover an average analog waveform. Some people refer to PWM as a poor man's DAC.

What should the frequency of the PWM signal be? First, consider the case in which you are using the PWM signal as a DAC. Many microcontroller applications need analog output but do not require high-resolution DACs. In a typical PWM signal, the frequency is constant, but the pulse width, or duty cycle, is a variable, directly proportional to the amplitude of the original unmodulated signal. The bandwidth of the lowpass filter should equal the bandwidth of the unmodulated signal. Choose the PWM frequency to give an acceptable ripple magnitude in the analog signal. For example, if you use an RC lowpass filter, you derive the amplitude attenuation using the following **equation**:

$$\text{ATTENUATION (dB)} = 20\log_{10}\frac{1}{\sqrt{(F_{PWM}/F_{BW})^2+1}}.$$

To increase the attenuation, and thus reduce the ripple, you may need to use a higher-order filter or a higher PWM frequency.

Many devices inherently average an on/off signal to control their operation, based on the duty cycle. Examples include LEDs that humans and inductive loads view, such as motors and solenoids. For an inductive load, such as an LR circuit, you can derive the PWM voltage frequency so that the current waveform is within a certain percentage of the analog step response. A fundamental analysis of an LR circuit calculates the frequency according to the following **equation**:

$$\text{FREQUENCY (Hz)} = -\frac{R}{2L\ln\left(1-\frac{P}{100}\right)},$$

where P is percentage.

A shroud of mystery often envelops devices and concepts, which can often lead to avoidance or misuse. Focusing on the fundamentals removes that mystery. EDN

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

Extend Battery Life With IR's Benchmark MOSFETs

Small Power MOSFETs Designed for Handheld Devices

Gate Drive - 4.5V Optimized, 2.5V Capable, 12V Maximum

BV_{DSS}	Package	Max. $R_{DS(on)}$ @ 4.5V (mΩ)	Max. $R_{DS(on)}$ @ 2.5V (mΩ)	Part Numbers
-20V	PQFN 2x2	31	53	IRLHS2242
	SOT-23	54	95	IRLML2244
20V	PQFN 2x2	11.7	15.5	IRLHS6242
	SOT-23	21	27	IRLML6244
	Dual PQFN 2x2	45	62	IRLHS6276
30V	PQFN 2x2	16	20	IRLHS6342
	TSOP-6	17.5	22	IRLTS6342
	SOT-23	29	37	IRLML6344
	Dual PQFN 2x2	63	82	IRLHS6376

Gate Drive - 10V Optimized, 4.5V Capable, 20V maximum

BV_{DSS}	Package	Max. $R_{DS(on)}$ @ 10V (mΩ)	Max. $R_{DS(on)}$ @ 4.5V (mΩ)	Part Numbers
-30V	PQFN 2x2	37	60	IRFHS9301
	SOT-23	64	103	IRLML9301
	Dual PQFN 2x2	170	290	IRFHS9351
25V	PQFN 2x2	13	21	IRFHS8242
	SOT-23	24	41	IRFML8244
30V	PQFN 2x2	16	25	IRFHS8342
	TSOP-6	19	29	IRFTS8342
	SOT-23	27	40	IRLML0030

Features

- Available in both N & P Channel for simple design
- Latest silicon technology offering low $R_{DS(on)}$ for increased battery life
- 2.5V drive capable available for 1-cell Li-Ion Battery Applications
- PQFN package offers high power density reducing system size

Applications

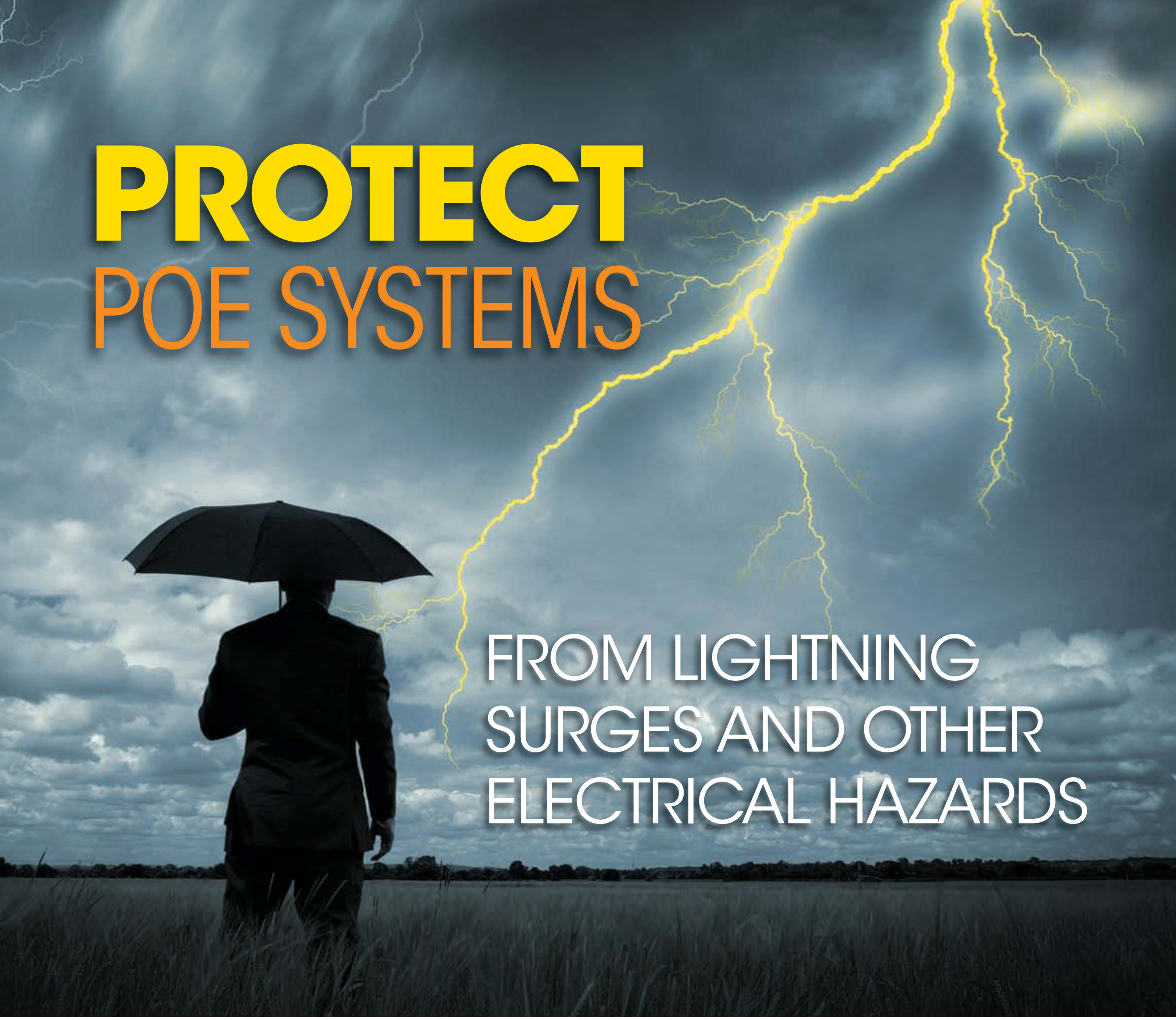
- DC Load Switch
- Battery Protection
- DC-DC Converter
- Screen Backlight Boost Converter

Your FIRST CHOICE for Performance

for more information call 1.800.981.8699 or visit us at www.irf.com

International IOR Rectifier
THE POWER MANAGEMENT LEADER


MPD
CR 2032
3V
+
Snap Dragon Only At MPD
www.batteryholders.com
Patent pending
sales@batteryholders.com 631-249-0001



PROTECT POE SYSTEMS

FROM LIGHTNING SURGES AND OTHER ELECTRICAL HAZARDS

IMAGE: JAMES THEW/SHUTTERSTOCK

THE INCREASED USE OF POE BROADENS THE RANGE OF LOCATIONS IN WHICH YOU CAN USE ETHERNET—FROM INDOORS TO CAMPUS LAYOUTS OR FIRST- AND LAST-MILE TELEPHONY APPLICATIONS. THESE USES INCREASE EXPOSURE TO LIGHTNING-INDUCED SURGES, ESD, AND ACCIDENTAL POWER FAULTS. PROPER DESIGN PROTECTS POE EQUIPMENT FROM THESE HAZARDS.

PHILLIP HAVENS AND CHAD MARAK • LITTELFUSE INC

POE (power over Ethernet) has been rapidly gaining popularity because it eliminates the requirements for separate power supplies and power cables for connected equipment and for locating equipment near an ac outlet. Recent increases have occurred in the amount of power that POE PSE (power-supply equipment) can deliver—from 15.4W for POE to 30W for POE+. These increases have in turn increased the number of potential applications. Ethernet now delivers sufficient power for VOIP telephony, to power extended-range wireless-access points, and to operate surveillance cameras, for which it can also power pan and tilt functions.

BASICS OF POE

In POE, PSE feeds power into the cable, either through a switch, also called an end span, or through a midspan, if it resides anywhere other than at the end of the cable. PDs (powered devices) on the cable consume power.

The IEEE 802.af POE standard limits PD power consumption to 12.95W, or 360 mA, which corresponds to a PSE output limit of 15.4W, or 400 mA, per port after accounting for cable losses. This standard takes into account line losses for maximum loops as long as 100m, thereby allowing as much as 57V dc from the PSE. The nominal level is 48V dc.

The POE+ standard, IEEE 802.at, allows the PSE to deliver as much as 30W and the PD to accept as much as 25.5W for Type 2 equipment; POE+ Type 1 is equivalent to POE. The PSE supplies a maximum of 600 mA. POE+ also requires the use of wiring, such as Category 5e or 6, with impedance that is less than or equal to 12.5Ω per loop pair, compared with 20Ω per loop pair for POE.

Companies are working to further increase this maximum power limit. PSEs that promise 60W per port are available, and one vendor sells midspan PSEs that the company claims provides 95W per port using a proprietary discovery process. This limit may be approaching the physical boundaries of Category 5 cable, however, which means that, for higher power, designers must find a way around this boundary. One simple approach is to increase separation between bundled cables to allow for improved heat dissipation. Power usage beyond the limit would require cable with heavier-gauge conductors. These higher voltages comply with neither IEEE 802.3af nor IEEE 802.3at.

It is important for the PSE to deliver the amount of power for the PDs it feeds without causing damage. To determine the required power level, the PSE and PD engage in a back-and-forth signaling-handshake routine at turn-on that involves voltage pulses from the PSE that determine the impedance signature of the connected PDs. This discovery process sets the system to one of five classes (**Table 1**). **Table 2** shows the POE-PD classifications for POE+.

AT A GLANCE

- Higher POE (power-over-Ethernet) power levels allow use of equipment outdoors, increasing exposure to lightning strikes and other electrical hazards.
- Include a series-current-limiting device in your equipment so that it can resume operation after a lightning-surge event.
- Bidirectional surge-protection devices, TVS (transient-voltage-suppression) diodes, fuses, and PTCs (positive-temperature-coefficient) devices can help ensure reliable operation despite hazards.

TABLE 1 POE-PD POWER SPECIFICATIONS

Class	Power range (W)
0 (default)	0.44 to 12.95
1	0.44 to 3.84
2	3.84 to 6.49
3	6.49 to 12.95
4	Reserved for future use

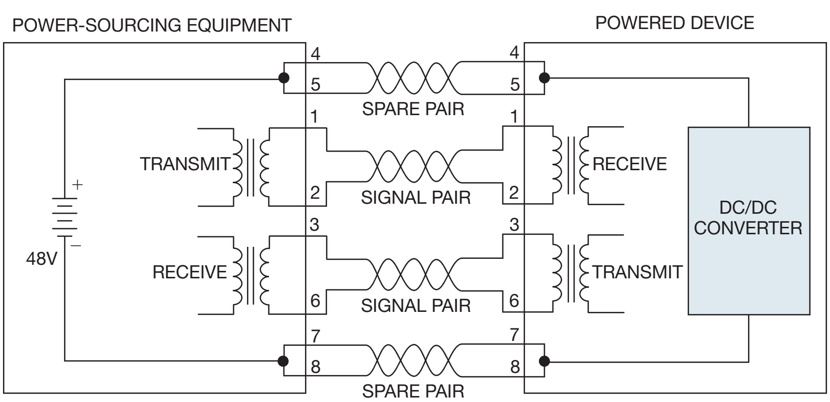


Figure 1 Apply POE Mode B power over the “spare” data pairs in 10 or 100BaseTX systems or over pairs 4 to 5 and 7 to 8 of a 1000BaseT system. POE uses the phantom powering technique so that a pair carries a 0V potential difference between its leads; power-supply voltage is the difference between two wire pairs.

POE MODES

PSE can provide power over the Ethernet cable in one of two ways. In Mode B, the PSE applies power over the “spare” data pairs 4, 5 and 7, 8 in 10BaseT or 100BaseTX systems because only RJ-45 pins 1 through 2 and 3 through 6 provide data delivery. Thus, RJ-45 pins 4 through 5 and 7 through 8 are available for power delivery (**Figure 1**). Notice that POE uses a “phantom” powering technique so that a single pair carries a 0V-dc potential difference between its leads. The power-supply voltage is the difference between the two center-tap connections of the wire pairs.

In a 1000BaseT application, there is no spare pair; therefore, two of the active data pairs, Mode A or Mode B, must supply power. Mode A combines the dc voltage with the signal over the data pairs 1, 2 and 3, 6, respectively (**Figure 2**). An isolation transformer connects across data pair 1, 2, and a separate isolation transformer connects across data pair 3, 6 with a center tap. These two center taps provide access to the dc power, and the voltage across any pair remains at 0V dc. This phantom-power technique for both Mode A and Mode B helps to prevent accidental shock hazards when users are handling single pairs.

You can use either Mode A or Mode B connections with any Ethernet application, including 10, 100, and 1000BaseT. The PSE cannot simultaneously provide power in both Mode

A and Mode B, but the PD must be simultaneously compatible with both Mode A and Mode B powering techniques because you cannot predetermine which PSE mode will connect to the PDs.

The details of the protective devices and how they connect depend on the power mode and data rate of the Ethernet system. Both the PSE and PD must be able to continue operation after a lightning surge and also safely handle power-fault events as defined in UL 60950-1 or EN 60950-1, although these standards do not require that the equipment operates after such a test.

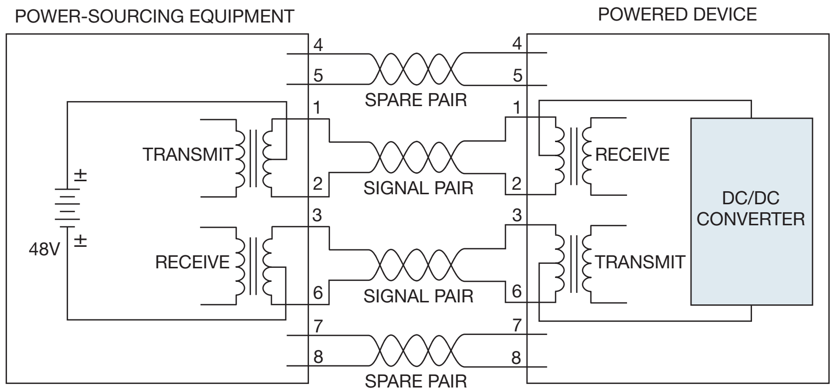


Figure 2 Mode A POE uses the data-signaling pairs 1, 2 and 3, 6, thereby combining the dc voltage with the signal over these data pairs.

TABLE 2 POE-PD POWER CLASSIFICATIONS

Class	**Conditions** (V)	**Classification current** (mA)	**Average PD power** (W)	**PD type**
0	–14.5 to –20.5	0 to 4	13	1
1	–14.5 to –20.5	9 to 12	3.84	1
2	–14.5 to –20.5	17 to 20	6.49	1
3	–14.5 to –20.5	26 to 30	13	1
4[1]	–14.5 to –20.5/–6.9 to –10.1	36 to 44	25.5	2

[1]POE+ Type 2 returns a Class 4 classification signature.

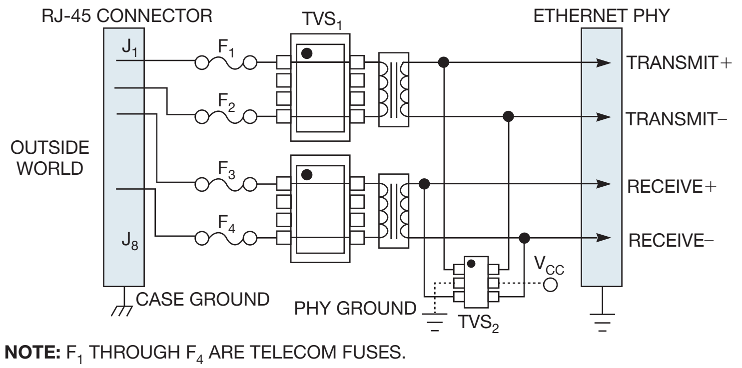


Figure 3 Lightning protection for 10 and 100BaseT applications uses a combination of clamping devices. A lightning-induced surge activates TVS_1 in the secondary position, providing a clamping function that routes the offending surge away from the sensitive Ethernet circuit. The tertiary device, TVS_2, then provides another level of protection on the line-driver side of the transformer. Power-fault events, characterized as long-term 50- to 60-Hz waveshapes, activate fuses F_1 through F_4. A 1000BaseT system uses the same schematic for the other two data-signaling pairs.

To meet this requirement, you must include a series-current-limiting device, such as a fuse, which does not open during lightning-surge testing but opens appropriately for long-term ac-power-fault conditions, or a PTC device, as long as it can operationally survive the lightning-surge testing. PTC devices can self-recover after a power fault but are incompatible with 100 and 1000BaseT Ethernet systems due to their off-state resistance and hysteresis-recovery characteristics. PTCs will not remain perfectly matched after multiple operations.

LIGHTNING PROTECTION

The choice of lightning protection depends on the expected exposure for the application. For an indoor,

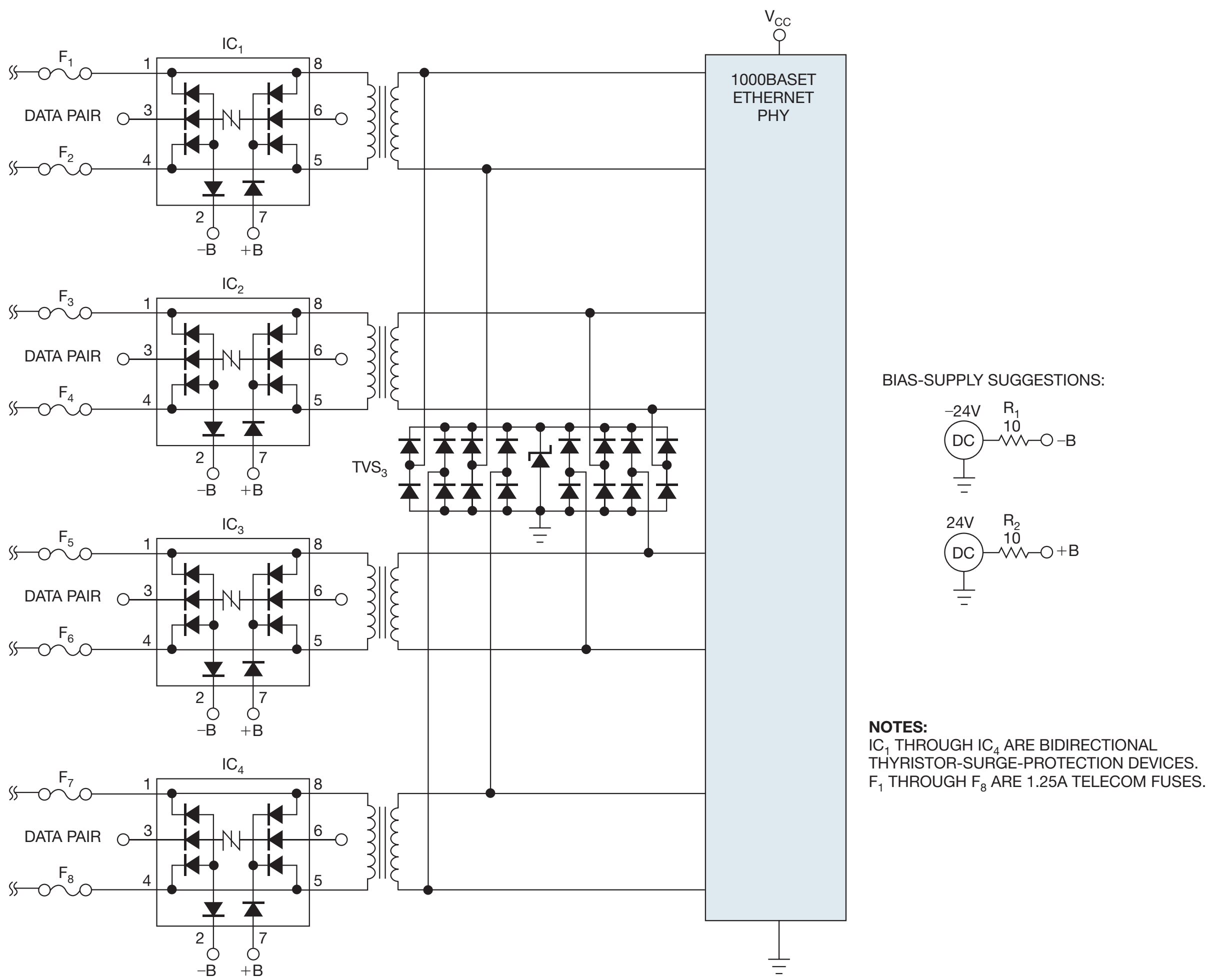


Figure 4 A GR-1089-compliant approach for overvoltage and overcurrent events for 10, 100, and 1000BaseT applications in an outdoor environment is subject to both lightning-surge and power-fault events. For 10 and 100BaseT, only the two data-wire pairs would require this protection.

less-severe application, you can use TVS-diode arrays between the RJ-45 connector and the Ethernet PHY chip set in both the secondary position and the tertiary position (**Figure 3**). A lightning-induced surge event activates TVS_1 within nanoseconds, providing a clamping function that routes the offending surge away from the sensitive Ethernet-line-driver circuit. TVS_2 clamps any residual surge that couples across the transformer. For a more robust approach, you can use a TVS-diode array for each wire pair; otherwise, one TVS array can protect two wire pairs, as TVS_2 does. Power-fault events, which involve long-term 50- and 60-Hz waveshapes, activate 1.25A fuses F_1 through F_4 after a TVS device provides a current path.

PD PROTECTION

Because you have no way of knowing whether a PSE will use Mode A or Mode B on an Ethernet installation, you must provide 57 to 90V protection for all wire pairs at the PD end, with everything hardened to more than 100V. The surge-protection device should have a trigger voltage greater than any steady-state voltage likely to appear on the cable. POE voltages can reach 57V, so the device must not trigger at or below this voltage.

This approach also prevents the surge protector from turning on during power-classification testing or during the resistive-power-discovery test. Further, some power systems supply 48V, whereas others supply –48V, so the protection device must not be polarity-sensitive. Designers typically use bidirectional thyristor-surge-protection devices in this case. The solid-state crowbar devices reset only when the available current falls below its holding-current parameter. This setup is not a problem because it draws excess current from the PSE, which temporarily shuts down during an overcurrent-load condition, and it allows the thyristor surge protector to reset.

Figure 4 shows a GR-1089-compliant approach for overvoltage and overcurrent events for 100 and 1000BaseT applications in an outdoor environment subject to both lightning-surge and power-fault events. The fuses in both data-pair leads provide the necessary overcurrent protection that is insensitive to lightning-induced overvoltage surges for first-level GR-1089 events. The bidirectional thyristor-surge-protection devices, IC_1 through IC_4, or SIDACtor (silicon-diode-alternating-current) devices, provide an overvoltage-crowbar-protection approach that complies with both first- and second-level lightning surges of GR-1089, Issue 6, port types 3 and 5.

The two bias leads for IC_1 through IC_4 connect to any available voltage rails that are less than the turn-on threshold voltage of the protective devices, which stabilizes their off-state capacitance and helps preserve signal integrity. The bidirectional thyristor-surge-protection devices IC_1 through IC_4 can have a 58V minimum threshold for a 48V POE. Noncompliant IEEE 802.3 systems that have a POE voltage higher than 57V would require a higher-minimum-threshold protection device.

The tertiary, or chip-side, approach is a TVS-diode rail-clamp array, TVS_3, which provides additional protection after the coupling transformer. You can use Bob Smith terminations, which Smith described in a US patent. Bob Smith termination is a method of reducing the longitudinal or common-mode current on multipair conductor systems in which the pairs interrelate in a uniform manner. If you use this method, you should capacitively isolate the terminations so that they do not load the POE power supply. This combined metallic/differential and longitudinal/common-mode-protection approach requires a fuse on both leads of the transmitting and receiving pair. An approach without the longitudinal mode may require only one fuse per pair for lower-data-rate Ethernet, such as 10BaseT. For 100 and 1000BaseT systems, it is prudent to place the identical fuse element in both legs of a pair to maintain loop balance (**Figure 4**).

The single-fuse approach is permissible if pins 3 and 6 of the protective thyristor device do not connect to ground but instead remain open for a 10BaseT Ethernet system. Because IEEE 802.3 does not strictly allow for common-mode protection on the primary side of the coupling transformer for cable-discharge-event-protection reasons, the thyristor-surge-protec-

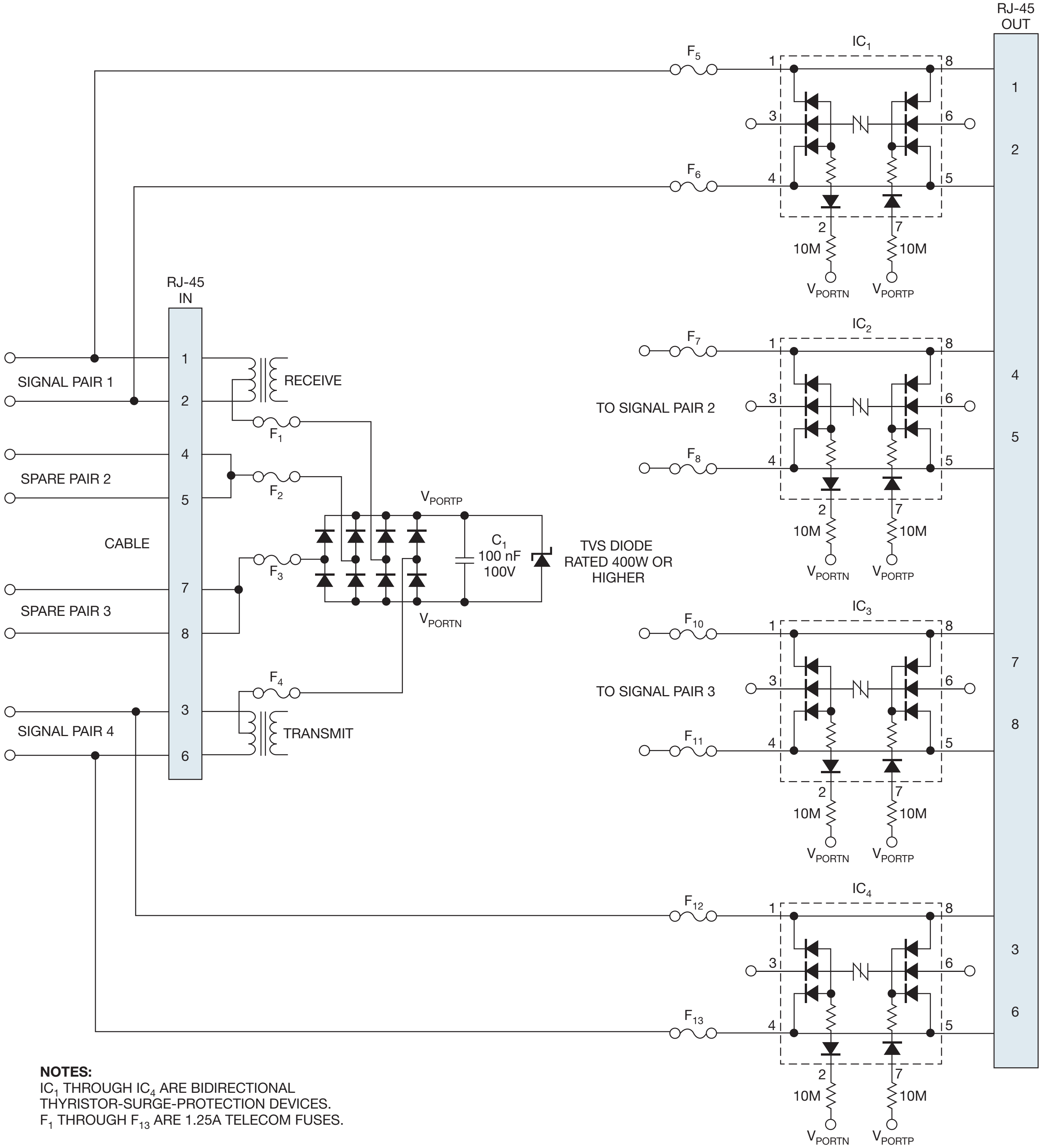


Figure 5 A POE-system-protection example includes both data-pair protection and PD power-connection protection. The TVS protection for the PD end's power-supply portion complies with both Mode A and Mode B POE power. Typical TVS devices for this type of circuit are available in 400, 600, 1500, and 3000W ratings. Fuses F_1 through F_4 provide overcurrent protection compliant with GR-1089, Issue 6, and UL 60950-1.

tion devices usually do not connect to ground. Therefore, most Ethernet approaches depend on the isolation rating of the coupling transformer for longitudinal/common-mode protection on the line side, whereas the tertiary position on the secondary side of the coupling transformer may connect to the Ethernet line driver's ground reference.

TVS_3, a 2.5V TVS-diode array, provides tertiary protection on the chip side of the coupling transformer. This approach complies with the surge and power-fault requirements of GR 1089-Core, Issue 6, for intrabuilding and interbuilding POE. You can substitute a 0.3A PTC device for the fuses for compliance with ITU K.20/21 enhanced and basic, which contain coordination clauses for 10BaseT Ethernet. However, for 100 and 1000BaseT, you would use a pair of appropriately sized, precision, 1% resistors to force coordination between the secondary and the primary protectors.

Figure 5 shows both data-pair protection and PD center-tap power-connection protection that comply with both Mode A and Mode B POE power for the PD end of the system. Both PD Mode A and Mode B POE are protected by a diode bridge and a 1000W TVS device. More robust, 1500 and 3000W, approaches are also available for harsher surge environments, such as those that regulatory standards ITU K.20 Enhanced or GR-1089 Port Type 5 describe.

As the power POE systems deliver has increased, developers are installing Ethernet equipment in areas that expose it to increased hazards from lightning-induced overvoltages and 50- to 60-Hz power-line faults. Judicious use of bidirectional surge-protection devices, TVS diodes, fuses, and PTC devices can help ensure reliable operation despite these hazards. **EDN**

AUTHORS' BIOGRAPHIES

Phillip Havens is the technical-marketing and application manager at Littelfuse and brings a wide range of electronics engineering expertise. He earned both bachelor's and master's degrees in electrical engineering from Louisiana Tech University (Ruston, LA), is a licensed professional engineer, and interfaces extensively with the technical teams of many leading electronics manufacturers to develop circuit protection for specialized applications. Havens represents Littelfuse at electronics-safety, circuit-protection, and telecom-related industry associations and helps define, direct, and support the company's silicon-based-protection-product lines. You can reach him at phavens@littelfuse.com.

Chad Marak is a product-marketing manager in the semiconductor-business unit of Littelfuse Inc. His responsibilities include providing strategic direction for the growth of the TVS-diode-array product line and managing the North America field-application-engineering team. Marak received a bachelor's degree in electrical engineering from Texas A&M University (College Station, TX) and a master's degree in electrical engineering from Santa Clara University (Santa Clara, CA). He has been in the semiconductor industry for 10 years and holds four US patents. You can reach him at cmarak@littelfuse.com.

SORTING OUT 4G ARE WE THERE YET?

CAN WE ACHIEVE THE PERFORMANCE LEVELS OF THE IMT-ADVANCED GLOBAL STANDARD FOR INTERNATIONAL MOBILE TELECOMMUNICATIONS?

BY JANINE LOVE • CONTRIBUTING TECHNICAL EDITOR

IMAGES: SHUTTERSTOCK

Thanks to clever marketing campaigns and branding, the general public believes that 4G has arrived. The performance of 4G/LTE mobile handsets has certainly improved, and designers are pushing the outer limits of performance in all parts of the handset to inch closer to the rates that the IMT (International Mobile Telecommunications)-Advanced standard dictates. In many cases, the limitation is available spectrum, so designers must develop creative approaches until governments act, preferably by making contiguous spectra available.

Riding the leading edge of what is possible, engineers are turning to new technologies, materials, and techniques, and they are taxing the upper limits of their simulation and test-and-measurement tools. On the bright side, all of the engineering communities seem to be working together to squeeze the most performance from low-power handsets and the most diverse wireless networks. With users downloading more than 1 billion apps a month and sending 8 trillion texts in 2011, the surge in mobile usage will need all the support it can get (**Reference 1**).

IMT-ADVANCED

The ITU-R (International Telecommunications Union-Radio Communication Sector) manages IMT-Advanced, whose features enable worldwide usability. The standard's targeted data rates of 100 Mbps for high mobility and 1 Gbps for stationary use get the most attention, however (**Reference 2**). For the physical-layer requirements, IMT-Advanced calls for a bandwidth exceeding 40 MHz, peak downlink spectral efficiency of better than 15 bps/Hz and uplink efficiency of 6.75 bps/Hz, and latency of less than 100 msec for users and 10 msec for control.

Although the latest commercial LTE, HSPA (high-speed-packet-access)+, and EVDO (evolution-data-optimized) Revision B services provide higher data throughputs than do traditional wireless services, they still do not provide a high enough data rate to meet IMT-Advanced requirements. "A wider bandwidth and as much as 4×4 [four antennas at the transmitter and four antennas at the receiver] MIMO [multiple input/multiple output] for the downlink are essential for achieving the IMT-Advanced requirement," says Jung-ik Suh, wireless-marketing-program lead at Agilent Technologies. Suh notes, however, that researchers are aiming for a 100-MHz bandwidth with as much as 8×8 MIMO for the downlink. Unfortunately, wireless-service providers will be unlikely to achieve this goal in real-world conditions.

One approach to the bandwidth problem is to use carrier aggregation, which requires the deployment of parallel receivers. "There are still many other technical hurdles to overcome to reach IMT-Advanced," says Suh. "It is hard to say if we are now at either true-4G performance or [at] LTE-Advanced, but lots of technical research and efforts will keep closing the gap to reach IMT-Advanced."

AT A GLANCE

- A surge in mobile traffic demands evolution to higher data rates.
- LTE-A (Advanced) is the next step toward IMT (International Mobile Telecommunications)-Advanced.
- Spectrum challenges are a limiting factor to closing the gap between LTE-A and IMT-Advanced.

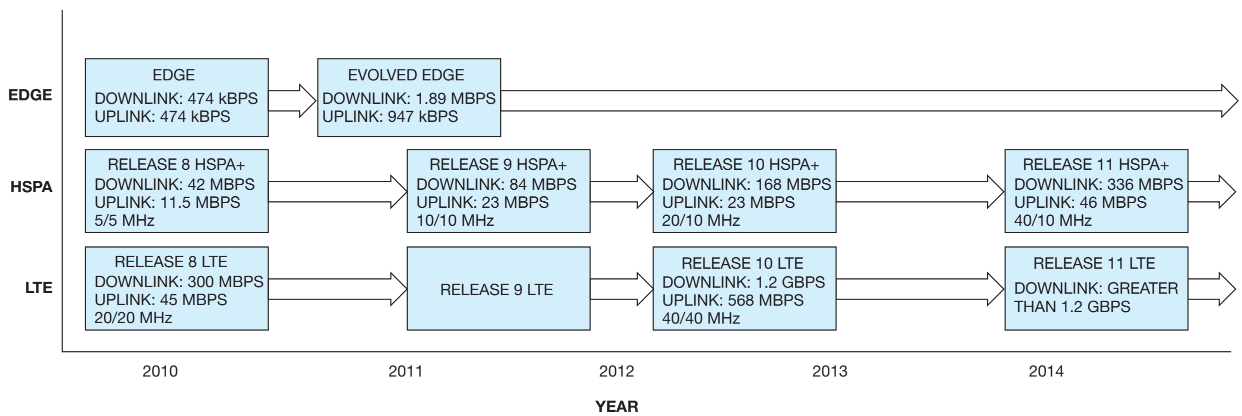
Developers of the 3GPP (third-generation partnership project) in 1998 created a global initiative to develop specifications to satisfy the latest mobile standards. To address the IMT-Advanced requirements, 3GPP has introduced LTE-A (LTE-Advanced). Initially part of Release 10 of the 3GPP specifications, LTE-A is the new target for mobile developers (**Reference 3**). "A main advantage of LTE-A over any other proposal is the backward compatibility with LTE Release 8," says Markus Willems, PhD, senior manager of product-marketing system-level solutions at Synopsys. "[LTE-A's] being an evolution rather than a revolution [should] result in [its] widespread adoption."

According to Chris Pearson, president of 4G Americas, a wireless-industry trade association representing the 3GPP family of technologies, some carriers will deploy LTE-A in 2013. In the meantime, he notes, HSPA+ and LTE now include tremendous technical advancements, providing subscribers with fast mobile. There are now 173 HSPA+ deployments in 86 countries, with peak speeds ranging from 21 to 42 Mbps; 39 operators in 25 countries commercially deploy LTE, which has more than 250 commitments for deployment in the coming years.

For Pearson, the major hurdles for LTE-A are not of a technical nature. He notes, however, that the mobile-broadband industry is growing at a fast rate and that customers are using large amounts of data (**figures 1** and **2**). "There is a major concern and opportunity for governments throughout the Americas to act soon to plan, reserve, allocate, and auction additional internationally harmonized spectra to the industry," he says. "The 3GPP standards will offer substantial gains in spectral efficiency as they evolve; however, the current rate of mobile-data growth demands additional spectrum resources globally."

DEFINING THE CHALLENGES

Despite Pearson's faith in the engineering community, real technical challenges remain for achieving the performance that the IMT-Advanced standard outlines. According to Madan Jagernauth,



NOTE: THROUGHPUTS ARE PEAK THEORETICAL NETWORK RATES. FUTURE DATES ARE EXPECTED INITIAL COMMERCIAL-NETWORK DEPLOYMENTS (COURTESY RYSAVY RESEARCH/4G AMERICAS).

Figure 1 As modern wireless standards evolve, data rates continue to climb (courtesy 4G Americas).

vice president of mobile broadband solutions for Huawei Technologies USA, those challenges include the use of multiple antennas in smartphones. Consumers' desire for larger screens is driving bigger form factors, which eases this challenge. However, when deploying MIMO in the device side of the link, form factor is not the only concern. According to Jagernauth, manufacturers will not deploy 4×4 transmission in smartphones because of its drain on battery life. He does, however, expect to see virtual MIMO, in which two subscribers can transmit simultaneously on the same time slot and in which the base station can decode it. This approach enables higher network usage. Huawei provides equipment on both the infrastructure and the terminal sides of the link, including a number of Android devices.

According to Synopsys' Willems, when it comes to chip design, the main hurdles are in the RF part. "Carrier aggregation as a key concept requires running multiple transceivers in parallel," he says. "Balancing area, power, and performance is a key challenge." Synopsys offers the LTE-A library with a simulation setup that allows users to run all the tests as specified in the 3GPP standard documents, thereby serving as an executable specification. The product is currently undergoing verification against equipment from Rohde & Schwarz.

BUILDING APPROACHES

Although manufacturers are on the verge of deploying LTE-based products, a lot of work still remains, according to Manfred Schlett, vice president of marketing at RMC (Renesas Mobile Corp), a division that Renesas formed after it acquired Nokia's wireless-modem business. Despite the availability of chip sets from multiple vendors, both power consumption and costs are high. Schlett sees the chip sets, definitions, and band allocations in the market as immature. Band fragmentation, which makes it challenging to define chip sets, further complicates these issues. RMC is now launching a dual-mode HSPA+/LTE platform, and it plans to launch LTE-focused parts this spring (**Figure 3**).

Power efficiency is crucial for the modem because of the need for more operations due to MIMO schemes. Selecting smart algorithms for the receiver part directly affects power efficiency, says Synopsys' Willems. "There is a dedicated need to explore algorithm alternatives that allow the system to stay close to the optimum maximum in throughput but that are less computationally intensive," he explains. According to Willems, using software-defined approaches with multiple DSP cores is becoming the norm because it allows the reuse of functional units across a variety of standards.

"One of the key [remaining technical hurdles] is achieving capacity gains to users that are farther from the cell tower," says YJ Kim, general manager of the infrastructure-processor group at Cavium Networks. "A heterogeneous network consisting of macrocells and small cells somewhat solves this [problem] at a higher level. Once you peel the onion, however, there is the issue of interference. The base stations need to be capable of achieving error-free high

Figure 2 Traffic growth has exploded as manufacturers develop new mobile terminals. In 2000 (a), traffic included 50-kbps GPRS (general-packet-radio service) and RTT (radio-transmission technology). By 2010, with approximately 500 million deployed smartphones, traffic had moved to 5- to 7-Mbps HSPA+ and EVDO (b). By 2020, traffic will move at 1 Gbps (c), with LTE-A, 4 billion new smartphones, 10 billion new smart devices, millions of new apps, and video- and cloud-based services (courtesy 4G Americas).

throughput to all users that demand it." Kim adds that sophisticated interference-cancellation algorithms, which demand high processing power, can achieve that throughput. Throughput is important in both macrocells and small cell base stations. Effectively built multicore-base-station SOCs enable these approaches without consuming much power, he says. Cavium is addressing the needs of 4G with its multicore Octeon processors, which target power management.

MEETING THE CHALLENGES

Systems implementing 4G involve a multitude of design challenges, including dealing with multiple channel bandwidths, transmission schemes for uplink and downlink, frequency- and time-domain transmission modes, battery-life management, and backward compatibility with 2 and 3G technologies. To address the limited-bandwidth issues, designers have developed carrier aggregation and MIMO techniques, but these technologies, in turn, bring their own challenges.

Figure 3 Renesas Mobile Corp has released the SP2531 integrated triple-mode LTE slim modem.

With the possibility of the emergence of 20 LTE bands worldwide, the issue of coexistence also arises. Coexistence gives rise to a number of issues, including board area, antenna design, sensitivity, configurability, and cost, according to RMC's Schlett. In response, RMC has designed its RF platform to support seven LTE, five HSPA, and four GSM bands. These products underscore the need for design-simulation tools and robust virtual prototyping for analyzing the real-time interaction between the protocol stack and the modem.

Carrier aggregation requires developers to pay more attention to control channels, cell edge, power management, spur management, and self-blocking, whereas MIMO design presents interference issues, especially on the terminal side, according to Agilent's Suh. On the user-equipment side of the link, designers are considering multistandard radios, which can help reduce the number of RF components by supporting multiple wireless technologies on one chip.

Unlike with previous generations, however, 4G designs have many complex considerations, so designers have more issues to address before moving to a prototype, says Suh. He points to tools such as Agilent's SystemVue, which can help to overcome the challenges during 4G user-equipment design before the specifications are defined. The tool also offers functional tests, such as a battery-drain test that can help designers solve battery issues using the terminal's status (sleep, standby, or call).

Power-consumption issues also lead to heat-dissipation problems, and the issue for 4G stems primarily from the need for multiple CPU cores in the RF section and the need to thermally manage the baseband chip. Some designers are addressing the power issue by using new process technologies. For instance, process technologies are now at 28 nm, with 20 nm on the horizon. As they design new architectures, developers are finding that traditional spreadsheet-based analysis is no longer enough because it lacks sufficient support for dynamic-use case scenarios, according to Willems. Designers need simulation-based analysis of what-if scenarios.

Willems says that hardware- and software-development engineers are moving to prototyping as early as possible, and virtual prototyping, which gained favor with 3G design, has become the mainstream approach as systems advance. High-performance simulation is also critical for algorithm design in modems, which allows designers to explore alternatives and maintain standards compliance. Synopsys offers simulation and prototyping tools from IP (intellectual property) and architecture to chip implementation (**Figure 4**).

WHAT'S NEXT?

Although much work remains, the path to true 4G performance seems achievable, and the popularity of smartphones and tablets is creating a huge market demand for improvements. In the mean-

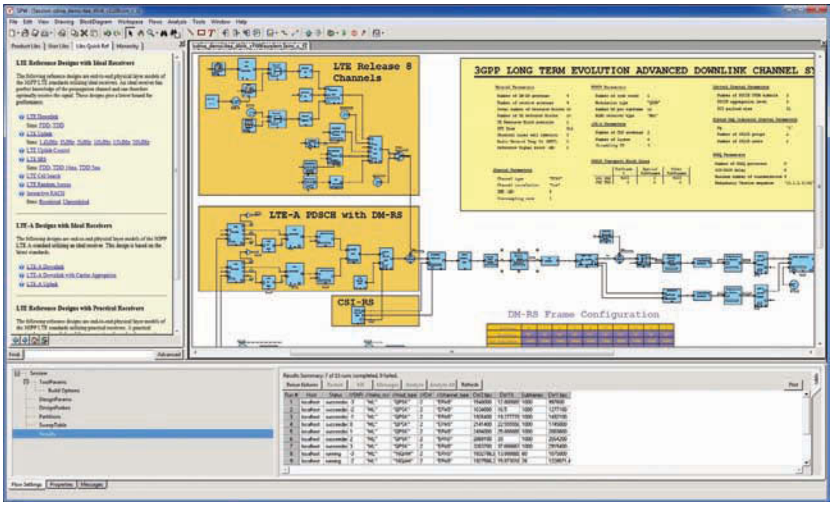


Figure 4 The Synopsys LTE-A physical-layer-simulation library allows users to run tests that the 3GPP standard documents specify.

time, the wireless industry continues to take defined steps toward the goals of IMT-Advanced, leaning on the improvements from HSPA+ and evolving LTE to LTE-A. Although a disconnection remains between the theoretical, such as 8×8 MIMO, and the achievable, today's wireless networks have significantly higher performance than their predecessors. Look for dramatic improvements over the next two years. To address the spectrum crunch, you are likely to continue to see interest in heterogeneous networks combining macrocell and microcell deployments. Until blocks of contiguous spectra become available, however, you can expect to see more creative design approaches to boosting data rates and maintaining battery life in next-generation mobile phones. EDN

REFERENCES

1 Love, Janine, "2011: the year mobile took over the world," *EE Times RF and Microwave Designline*, Dec 15, 2011, http://bit.ly/ymHvER.

2 "ITU global standard for international mobile telecommunications 'IMT-Advanced,'" http://bit.ly/f5FqtH.

3 Rumney, Moray, "Introducing LTE-Advanced," *EE Times RF and Microwave Designline*, Feb 5, 2011, http://bit.ly/i4Fx6k.

You can reach Janine Love, senior editor, *Test & Measurement World*, and managing editor, *Test & Measurement Designline*, at janine.love@ubm.com.

tear-
down

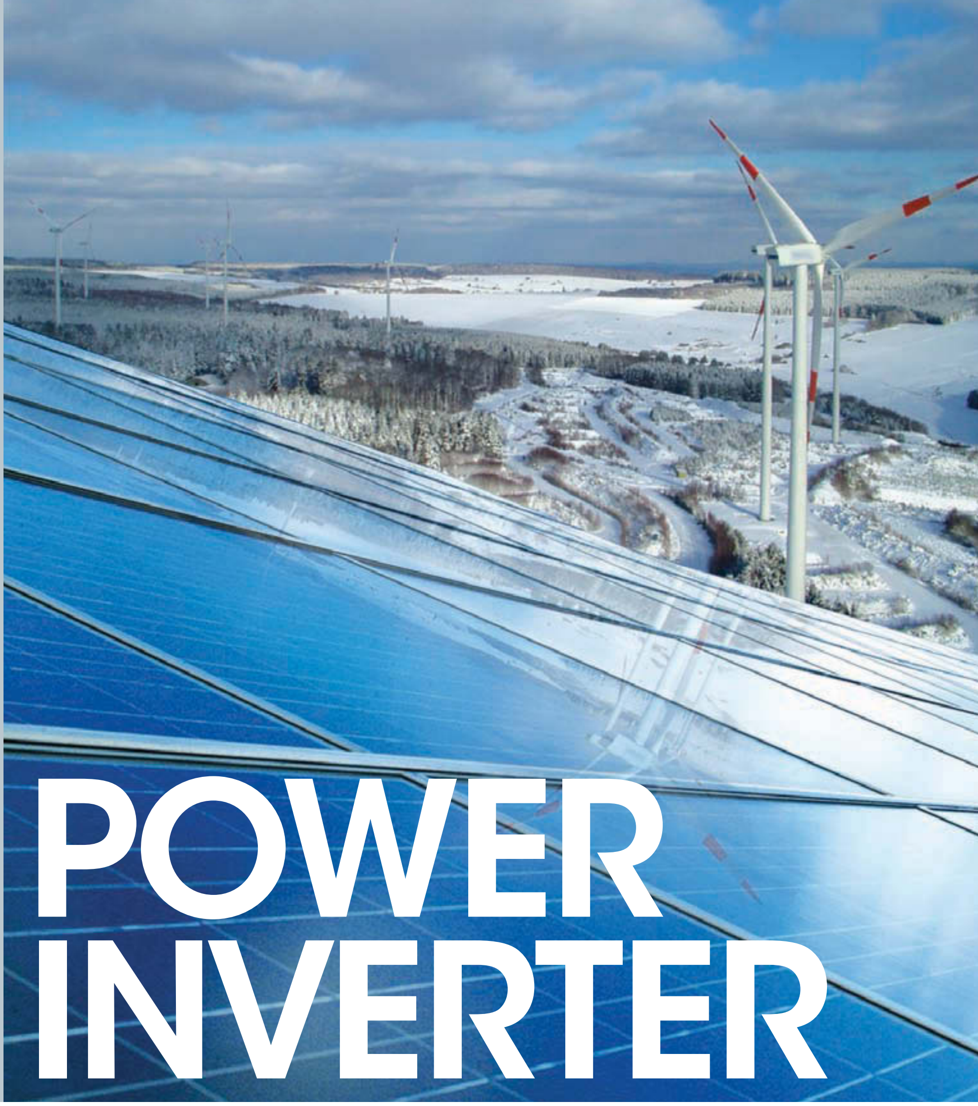


IMAGE: SMA AMERICA LLC

THE POWER INVERTER

FROM SUNLIGHT TO POWER GRID

The essence of solar-power harvesting is revealed.

BY STEVE TARANOVICH • CONTRIBUTING TECHNICAL EDITOR

The architectural design and components of a solar-inverter card range from the solar panel's dc inputs through dc/ac conversion to the ac output that is sent out to the power grid. The features you implement in such a design must meet various safety and other performance standards, as well as stringent power-company demands on the signal that is put onto the grid.

Photovoltaic power systems comprise multiple components, such as photovoltaic solar panels, which convert sunlight into electricity; mechanical and electrical connections and mountings; and solar-power inverters, which are essential for conveying solar-generated electricity to the grid (**Figure 1**). The inverter's main function is to convert variable dc voltage from sunlight on the photovoltaic panels or battery storage to ac voltage and frequency for use by appliances and feedback to the grid. The ac output varies by region, with the United States using 60 Hz, 115V ac and much of Europe using 50 Hz, 230V ac.

Enter SMA Solar Technology AG, which introduced the Sunny Boy series of transformerless solar inverters. The 3000TL, 4000TL, and 5000TL inverters operate at 3-, 4-, and 4.6-kW ac-output power, respectively, at 230V, 50 Hz (**Figure 2**). The inverter card has a multistring technology with two independent dc converters, easing the implementation of complex generator configurations. Each of the two dc inputs uses Vishay's 339MKP EMI-suppression capacitors as part of the filter, and the filter also includes dc-common-mode filter inductors on a common core and a 15-μF MKPC4AE boost-converter smoothing capacitor. Also on the dc-input side, two relays monitor the insulation resistance in accordance with IEC (International Electrotechnical Commission) 61557-8 in pure-ac systems.

The system measures insulation resistances between system lines and system earth. When falling below the adjustable threshold values, the output relays switch into the fault state. These relays use a superimposed dc signal for measurement. Using the superimposed dc-measuring voltage and its resultant current, the device measures the value of the insulation resistance of the system requiring measurement. The SMA inverter card uses high-quality active and passive components, enhancing the reliability and performance of this power-inverter design.

MAXIMUM-POWER POINT

The first dc function in the dc-signal chain, the MPP (maximum-power point), compensates for environmental conditions that affect power output. For example, photovoltaic-panel output voltage and current are susceptible to irradiance—the variations in temperature and light intensity per cell-unit area. The cell's output voltage is inversely proportional to cell temperature, and the cell's current is directly proportional to irradiance.

AT A GLANCE

- The inverter's main function is to convert variable-voltage dc from sunlight on the photovoltaic panels or battery storage to a specific ac voltage and frequency for use by appliances and feedback to the grid.
- The SMA inverter card uses high-quality active and passive components, enhancing the reliability and performance of this power-inverter design.
- Transformerless inverters have been available for several years in Europe; SMA received UL certification in August 2010 for distribution in the United States.
- As part of the H5-inverter technology, a fifth power semiconductor between the input capacitor and the H bridge inhibits a loss-inducing oscillation of electrical charge and lowers the power loss.

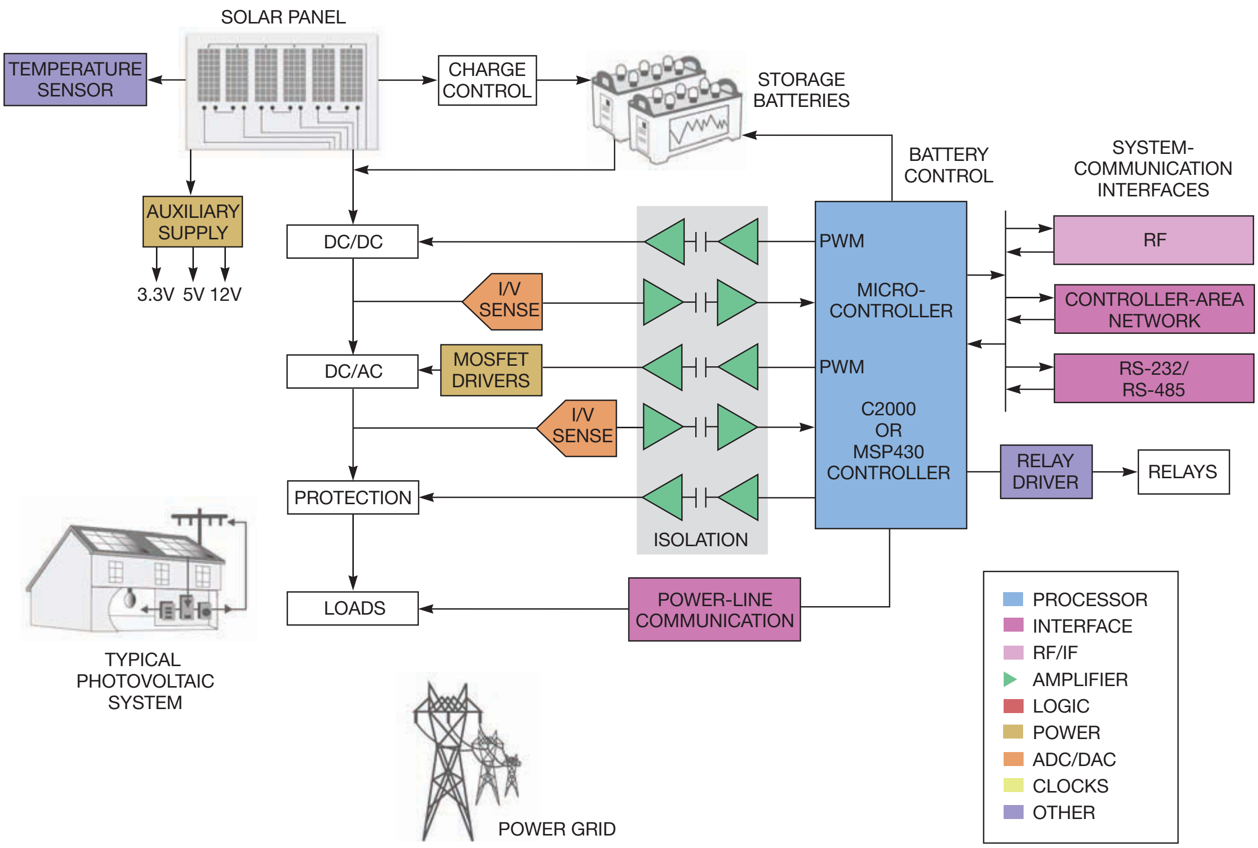


Figure 1 Photovoltaic power systems comprise multiple components, such as photovoltaic solar panels, which convert sunlight into electricity; mechanical and electrical connections and mountings; and solar-power inverters, which are essential for conveying solar-generated electricity to the grid (courtesy Texas Instruments).

The wide variation of these and other key parameters causes the inverter's optimum operating voltage and current to move about significantly. The inverter addresses this issue by using closed-loop control to maintain operation at the MPP, at which the product of voltage and current is at its highest value. SMA uses the OptiTrac Global Peak MPPT (maximum-power-point tracking) tracker. The proven operation-tracker-management system finds and uses the optimal operating point, which gives good yields despite partial shading in some photovoltaic plants. A Texas Instruments DSP controller contains the brains behind MPPT.

THE MAXIMUM-POWER POINT COMPENSATES FOR ENVIRONMENTAL CONDITIONS THAT AFFECT POWER OUTPUT.

The determination of MPP can vary with conditions (**Figure 3**). The most common approach for determining MPP is for the controller to perturb the panel's operating voltage and observe the output with every MPPT cycle. The algorithm continues oscillating around the MPP over a wide enough range to avoid movement in cloud cover or some other condition that can cause local but misleading peaks in the power curve. The perturbation-and-observation algorithm is inefficient because it oscillates away from the MPP in each cycle.

An alternative, the incremental-inductance algorithm, solves the derivative of the power curve for zero, which is by definition a peak, and then settles at the resolved voltage level. Although this approach overcomes the inefficiency that oscillation causes, it risks other inefficiencies because it may settle at a local peak instead of the MPP. A combined approach maintains the level that the incremental-inductance algorithm determines but scans at intervals over a wider range to avoid selecting local peaks. This approach, although efficient, also requires the highest-performing controller.

A capacitor, usually on the photo-

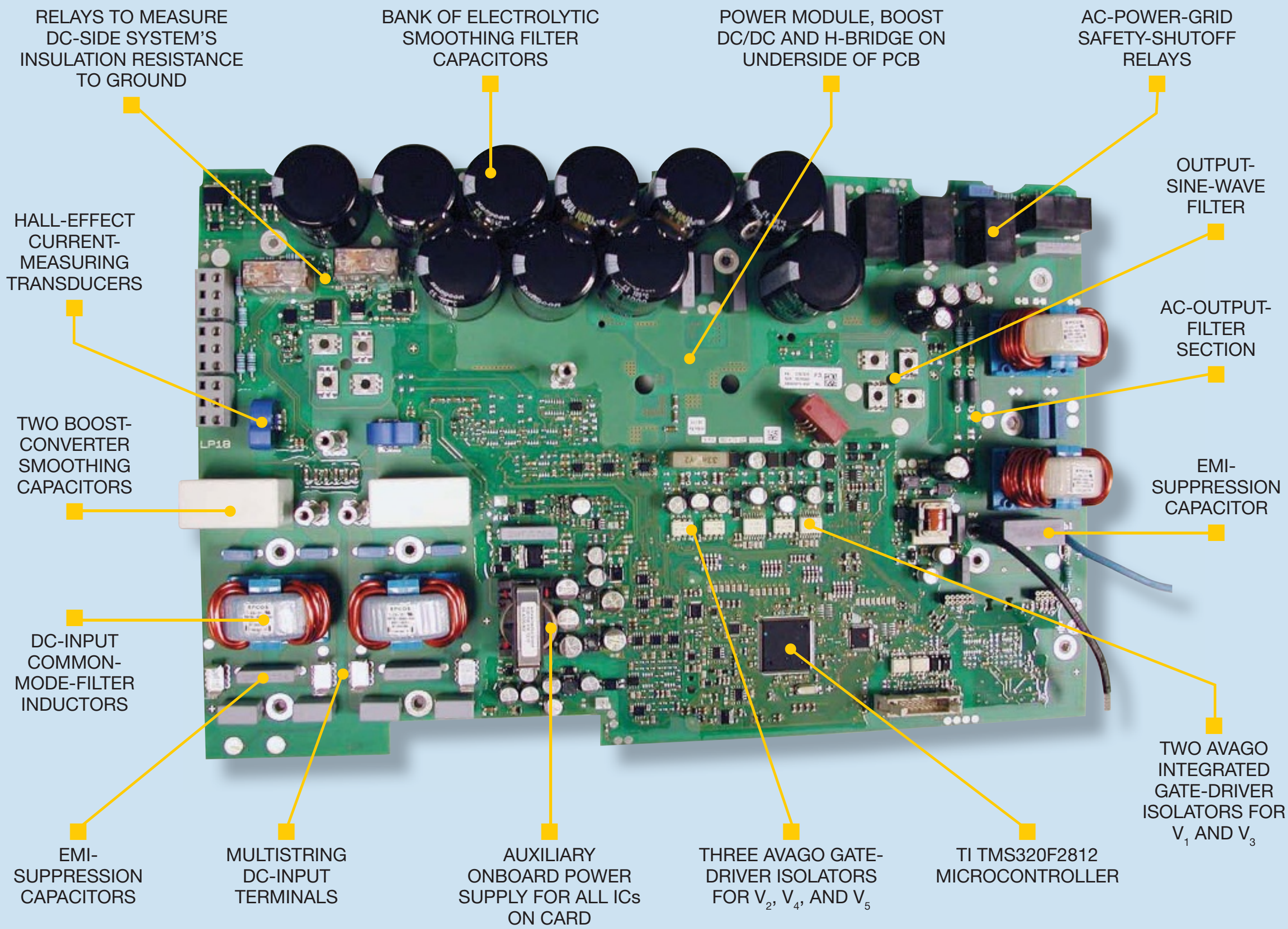


Figure 2 SMA Solar Technology's 3000TL, 4000TL, and 5000TL transformerless inverters operate at 3-, 4-, and 4.6-kW ac-output power, respectively, at 230V, 50 Hz.

voltaic bus, commonly stores the energy that the inverter must store and retrieve and must be large enough to control the voltage ripple across the bus. Otherwise, the ripple would be detrimental to the MPPT's accuracy. Electrolytic capacitors well suit the control of ripple because of their low ESR and high capacitance per volume.

DC/DC STEP-UP CONVERTER

Step-up dc/dc converters boost the dc input to the switching-MOSFET bridge so that the inverter can efficiently create a 230V, 50-Hz-ac sine wave to send to the grid. A separate heat-sink-inclusive module attaches to the back side of the inverter card and contains the dc/dc boost converter and the H5 switching bridge. **Figure 4** shows the essential basic dc/ac-conversion circuit or inverter in a typical transformerless configura-

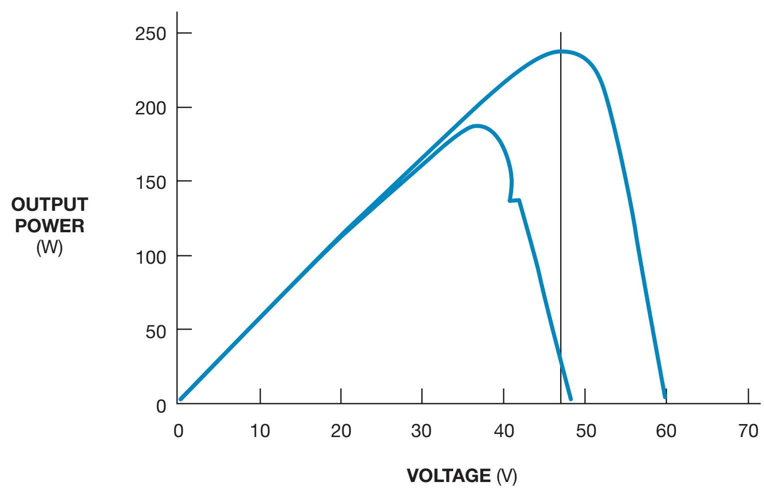


Figure 3 The determination of MPP can vary with conditions, such as weather, time of day, and heat of the panels (courtesy Texas Instruments).

tion, in which dc/dc conversion raises or lowers the incoming photovoltaic voltage, adjusting its output for greatest efficiency in the dc/ac-conversion stage; the capacitor provides further voltage buffering; the IGBTs or MOSFETs in the H4 bridge use a switching frequency of approximately 20 kHz to create an ac voltage; and the coils smooth the switched ac into a sinusoidal signal for generating a grid-frequency ac output.

The idea behind transformerless switching existed long before the emergence of the photovoltaic market. Device engineers know that a pair of FETs operates most efficiently in a completely on state or a completely off state, when no current flows through them and they dissipate no power. Thus, amplifying an ideal square wave would theoretically be 100%-efficient.

A square wave's modulation of a much-lower-frequency signal results in PWM, and the corresponding circuit is a Class D device. Thus, you can convert dc to dc or efficiently switch dc to ac. For solar inverters, the technology was previously unavailable because it used high-cost switching MOSFETs and IGBTs. These parts are becoming less expensive and speedier every year, however, so the technology has become more cost-effective than analog switching into large masses of copper and iron. The same technology is making electric cars feasible.

Transformerless inverters have been available for several years now in Europe, and SMA's units received UL certification in August 2010 for distribution in the United States. The certification applies to SMA's transformerless Sunny Boy 8000TL-US, 9000TL-US, and 10000TL-US inverters. UL granted the certification because the devices comply with UL Standard 1741 for photovoltaic and battery-powered inverters, which for the first time includes requirements for transformerless inverters. Transformerless inverters are significantly lighter than their galvanically isolated counterparts and can offer a wider range of operating voltages than traditional inverters because of their advanced switching circuitry.

The devices' lack of galvanic isolation can cause a ground fault, however, destroying the inverter and causing an electrical fire. With a transformer, if the secondary short-circuits, then all of the current flows through the primary. Theoretically, a thermal disconnection will stop this current once the transformer overheats. Without a thermal disconnection and either lacking the existence of protection or failure of the protection to detect the ground fault and trip, the large MOSFETs or IGBTs will immediately fail catastrophically. Fortunately, the likelihood of such an event is remote, and all such inverters must have ground-fault protection as per UL 1741 requirements. The burden, however, remains on the installer to take back-feed current in undetected

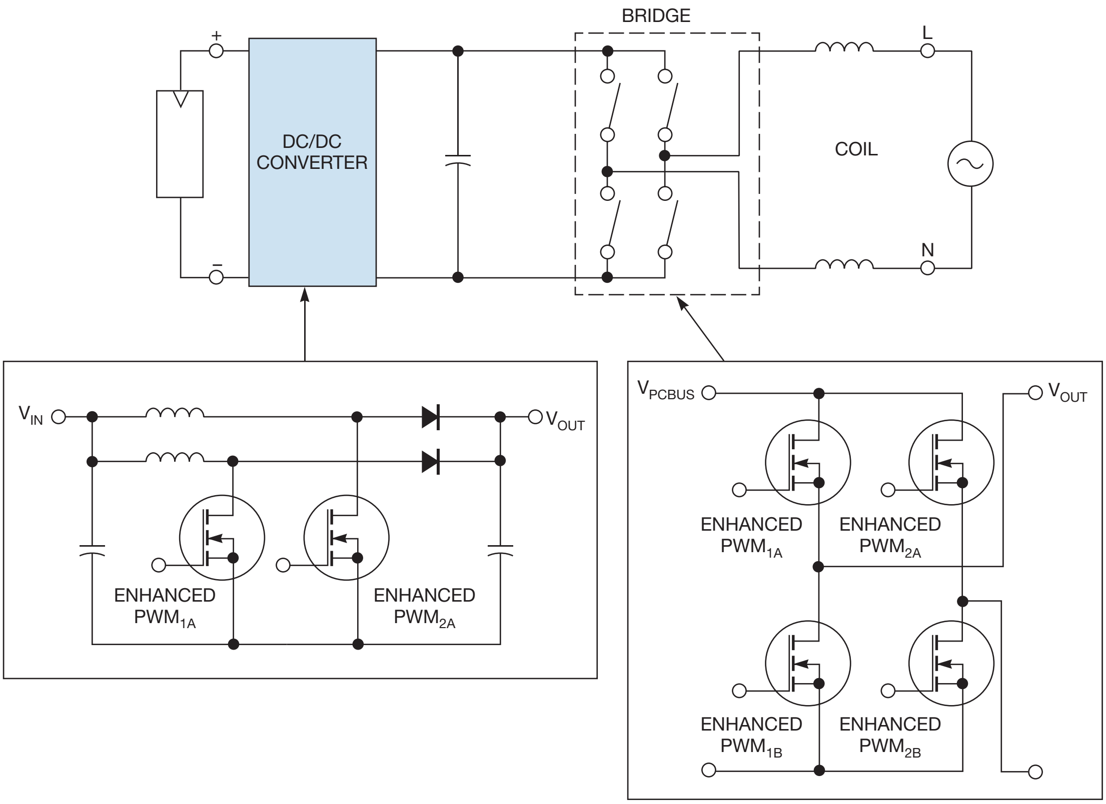


Figure 4 In a basic dc/ac-conversion circuit or an inverter in a typical transformerless configuration, dc/dc conversion raises or lowers the incoming photovoltaic voltage, adjusting its output for greater efficiency in the dc/ac-conversion stage. The capacitor provides further voltage buffering. The IGBTs or MOSFETs in the H4 bridge use a switching frequency of approximately 20 kHz to create an ac voltage, and the coils smooth the switched ac into a sinusoidal signal for generating a grid-frequency ac output (courtesy Texas Instruments).

ground faults into account when sizing combiner and disconnect fuses. Thus, provided that you correctly perform some simple calculations, transformerless inverters have few downsides and numerous benefits.

However, photovoltaic inverters provide still many other critical functions. For example, they offer a grid-disconnect capability to prevent the system from powering a disconnected utility. For example, an inverter remaining online during grid disconnection or delivering power through an unreliable connection can cause the photovoltaic system to back-feed local utility transformers, creating thousands of volts at the utility pole and endangering utility workers. Safety-standard specifications IEEE 1547 and UL 1741 state that all grid-tied inverters must disconnect when ac-line voltage or frequency is outside specified limits and that the inverters must shut down if the grid is no longer present. Upon reconnection, the inverter cannot deliver power until the inverter detects rated utility voltage and frequency over a five-minute period.

In addition to these tasks, inverters also support manual and automatic input/output disconnection for service operations, EMI/RFI conducted and radiated suppression, ground-fault interruption, PC-compatible communication interfaces, and more. Encased in a ruggedized package, the inverter should remain in full-power outdoor operation for more than 25 years.

A typical single-phase photovoltaic inverter, such as the one on the SMA board, uses a DPC, a DSP, and a pair of high-side/low-side gate drivers to drive a PWM full-bridge converter. This application and many other inverter applications use a full H-bridge topology because it can carry more power than any other switch-mode topology. SMA uses the H5 technology, in which a fifth power semiconductor between the input capacitor and the H bridge inhibits a loss-inducing oscillation of electrical charge and lowers the power loss. H5, with maximum efficiency of 98%, represents a marked improvement over the classic H4-inverter-bridge circuit. To prevent a fluctuating potential of the photovoltaic generator, the architecture disconnects the dc side from the ac side during the inverter's freewheeling periods.

The H5 topology **(Figure 5)** needs only one more switch than the full H4 bridge. Switches T_1, T_2, and T_4 operate at a frequency of approximately 20 kHz, and T_1 and T_3 operate at grid frequency—in this case, 50 Hz. During freewheeling, T_5 is open, disconnecting both the dc and the ac sides. T_1 and the inverse diode of T_3 close the freewheeling path for positive currents, and T_3 and the diode of T_1 close the freewheeling path for negative current.

The PWM's voltage-switching action synthesizes a discrete but noisy 50-Hz current waveform at the full-bridge output. The circuit inductively filters the high-frequency-noise components and produces a moderately low-amplitude, 50-Hz sine wave. The H bridge works by asymmetric unipolar modulation. A 50-Hz half-wave should drive the high side of the asymmetric H bridge, depending on the polarity of the mains. The PWM modulates the opposite low side to form the mains' sinusoidal shape.

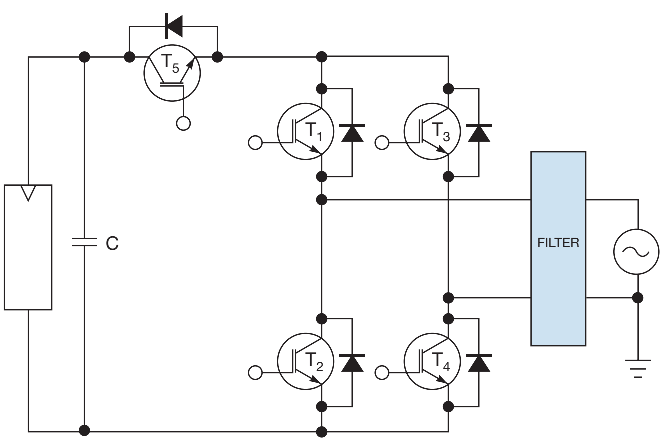


Figure 5 The H5 topology needs only one more switch than the full H4 bridge.

Photovoltaic-inverter design requires many design compromises that can cause designers grief if they make the wrong trade-offs. For example, photovoltaic systems should operate reliably and at full rated output for a minimum of 25 years, yet they must be competitively priced, forcing designers to make tough cost-versus-reliability trade-offs. Photovoltaic systems need highly efficient inverters because higher-efficiency inverters run cooler and last longer than their less efficient counterparts, and they generate cash savings for both photovoltaic-system manufacturers and the users.

CONTROL ARCHITECTURE

The brains behind the inverter are its controller—usually, a DPC or a DSP. DSP-based controllers, such as the Texas Instruments TMS320F2812, provide the high level of computational performance and programming flexibility needed for the real-time signal processing in solar-power inverters. Highly integrated DSCs help inverter manufacturers create more efficient, more cost-effective products that can support the growing demand for solar energy in the upcoming years.

A control processor for an inverter must meet a number of real-time-processing challenges to effectively execute the precise algorithms for efficient dc/ac conversion and circuit protection. MPPT and battery-charge control need only near-real-time response, but they do involve algorithms with a high level of processing. DSCs, combining high-performance DSPs and integrated control peripherals, offer an excellent approach for real-time control of the dc/ac-converter bridge, MPPT, and protection circuitry in solar-power inverters. DSP controllers inherently support high-speed mathematical calculations for real-time control.

Integrated peripherals, such as ADCs and PWM outputs, make it possible to directly sense inputs and control power IGBTs or MOSFETs, saving system space and expense. On-chip flash memories aid in programming and data collection, and communication ports simplify design for network-

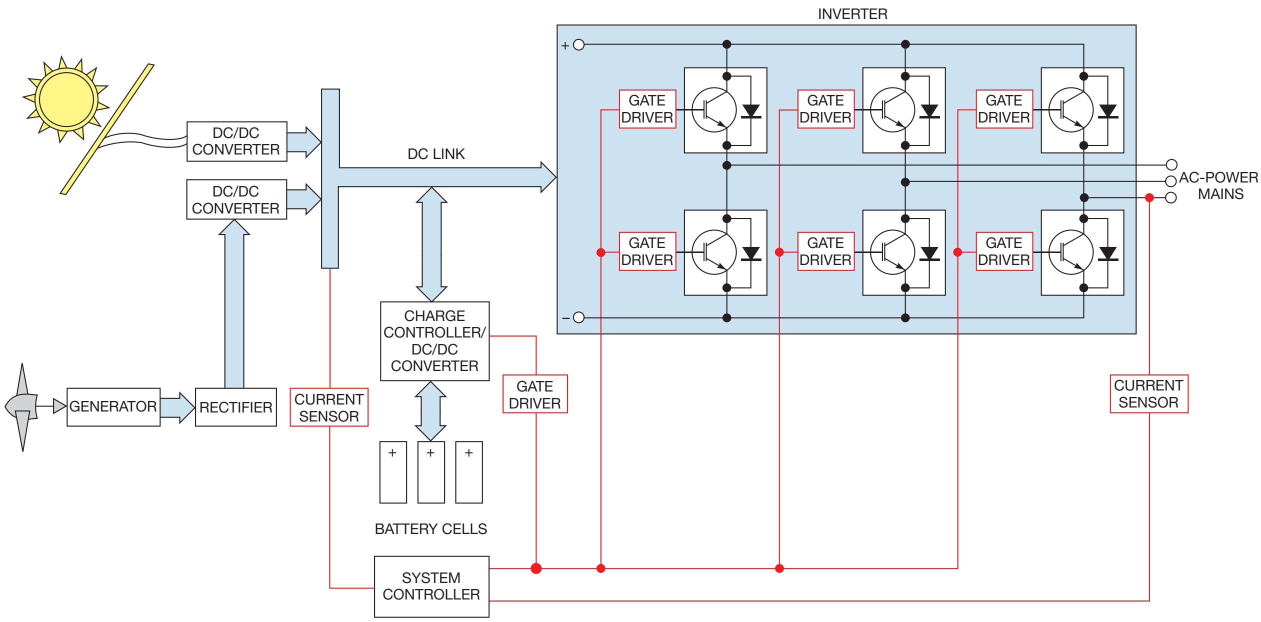


Figure 6 Alternative-energy systems need isolated connections (red) between the high-voltage power circuits and the controller managing power flow (courtesy Avago).

ing with units such as meters and other inverters. Solar-power inverters using DSP controllers have demonstrated 50% decreases in efficiency losses, as well as significant cost reductions.

Designers typically implement a controller's firmware in a state-machine format for efficient execution using nonblocking, or fall-through, code, which prevents execution from inadvertently entering an endless loop. Firmware execution is hierarchical, typically serving the highest-priority functions more frequently than lower-order functions. In photovoltaic inverters, isolated feedback-loop compensation and power-switch modulation are usually the highest priorities. Critical protection functions to support safety standards and efficiency control or MPP are second and third priorities, respectively. The remaining firmware tasks pertain mostly to optimizing operation at the current operating point, monitoring system operation, and supporting system communication.

TI's TMS320F2812 controller demonstrates the use of cost-efficient integrated functions. It features ultrafast 12-bit ADCs that provide as many as 16 input channels for performing the current and voltage sensing to achieve a regular sinusoidal waveform. For safety, the ADCs also can provide current sensing in the residual current-protection device. The device also features 12 individually controlled enhanced-PWM channels that provide variable duty cycles for high-speed switching in the converter bridge and battery-charging circuits. Each enhanced PWM has its own timer and phase register, allowing developers to program in phase delay, and you can synchronize all of the enhanced PWMs to drive multiple stages at the same frequency. Multiple timers give access to multiple frequencies, and fast interrupt management is available to support additional control tasks. Multiple standard communication ports, including the CAN bus, provide simple interfaces to other components and systems.

SMA's inverter card includes five Avago isolated-gate drivers (**Figure 6**). Two of the isolated MOSFET drivers control T_1 and T_3 switching at the grid frequency of 50 Hz. These 2.5A Avago HCPL-316J gate-drive optocouplers integrate desaturation detection and fault-status feedback. The isolated HCPL-J312 MOSFET drivers control T_2, T_4, and T_5. See **Figure 5** for the H5 configuration. An in-depth video interview with Jamshed Khan, Avago factory applications engineer for optical isolation products, available at http://bit.ly/z5jXx8, provides more analysis on the often-overlooked topic of isolation in solar inverters.

The Sunny Boy 3000TL, 4000TL, and 5000TL inverters are available with reactive power control. The online version of this article, available at http://bit.ly/zcYFwX, includes additional information on reactive power—how it develops, why it is important in a photovoltaic inverter, and its effects on the grid.

Photovoltaic systems are relatively new to energy production. Like other emerging technologies, they will be subject to rapid changes as the technology matures, and will undoubtedly continue to evolve to meet market demands for higher capacity, lower cost, and higher reliability. As this scenario plays out, photovoltaic inverters will expand in performance, and designers will demand more integrated, application-specific, component-level devices. Photovoltaic power systems will become more widespread and ultimately represent a viable segment of the utility mainstream that significantly reduces our dependence on fossil fuels. EDN

You can reach Contributing Technical Editor Steve Taranovich at staranovich@yahoo.com.


WHERE'S
BRIAN
HEADED
?
ENGINEERING UNIVERSITY 240 MI
GURU INTERVIEW 210 MI
AUTOMOTIVE LAB 125 MI
IC INNOVATOR 30 MI
Join Brian on the Avnet Express Technology Road Trip Adventure as he:
Meets with today's top innovators
Uncovers the hottest technologies
Tears down an electric vehicle
Follow along on
DRIVEFORINNOVATION.com
to read Brian's latest road trip blog and a chance to participate in weekly contests, vote on upcoming destinations and more!
BRIAN
DRIVEFORINNOVATION.COM
AVNET®
Express

designideas

READERS SOLVE DESIGN PROBLEMS

RC-timed shutoff function uses op amp and momentary switch

Glen Chenier, Teeter Totter Tree Stuff, Allen, TX

A handheld, battery-operated "fiber finder" measures the light escaping from an optical fiber when clamped in a V-shaped block under slight pressure. A pair of photodiodes on each side of the resulting bend compares analog levels to indicate the presence and direction of light travel, and PLL tone decoders indicate the presence of as many as three optical-modulation tones. The idea is to "tag" a fiber with a central-office signal so that an operator in a pole tent or a manhole can search for and positively identify the correct fiber before cutting and splicing, thus avoiding accidental outages.

With no room on the front panel for a power switch, the design requires a sliding clamp mechanism to turn the unit on at its extreme travel position when an operator inserts a fiber. The unit must remain on each time the operator inserts another fiber and then automatically turn off when the operator finishes and no longer activates the clamp slider. This design has no room for a bulky, multipole switch; the feature works with just one pole. The design uses a PCB-mounted phosphor-bronze-plated wire against a gold post, an almost no-cost and no-real-estate switch. Without a processor or a digital clock, the function uses a spare op amp and a handful of components (**Figure 1**).

S_1's contacts are normally open. With the power off, any residual charge on C_1 drains through R_5 and D_1, a low-leakage switching diode, such as the MMBD2836, in a common-anode package with D_2 to prevent input current through IC_1 to the power rail. PNP transistor Q_1, sized for the current draw to the unit, is held in cutoff; the voltage drop across R_1 due to current in R_4 is too low to bias Q_1 on. Q_2 is biased off due to zero output at the nonpowered IC_1.

Closing S_1 biases Q_1 into conduction, providing power to the voltage regulators for the remainder of the unit's circuitry. S_1's closure also ensures the complete discharge of C_1 through R_5 and D_2. IC_1 is now functional; its positive input is biased at 60% of the battery voltage through R_6 and R_7—the voltage after approximately one RC time constant. IC_1 is a single-supply CMOS device, such as an LMC6482 rail-to-rail op amp, with low-leakage inputs. You can also use a CMOS comparator with low-leakage inputs; if it uses an open-collector out-

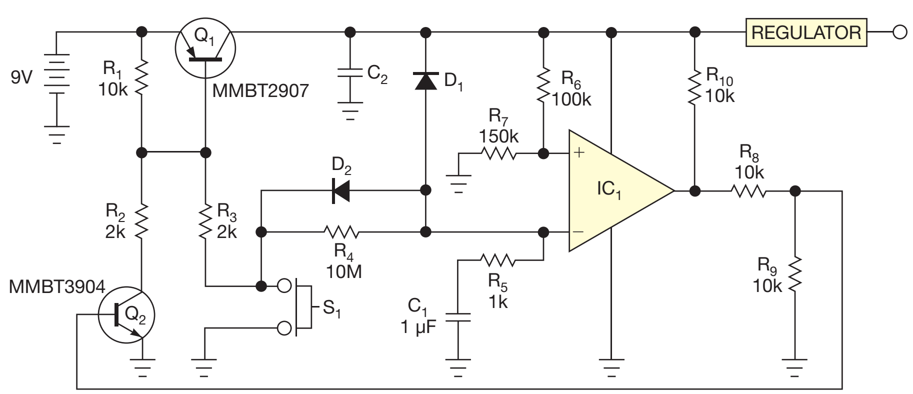


Figure 1 Employing an RC timer, this circuit holds power on for a preset time after each momentary-switch-contact closure.

put, you must add the R_{10} pullup resistor.

With C_1 remaining discharged, IC_1's output is near the upper rail and turns on Q_2, which can be any low-leakage, general-purpose NPN transistor, such as the MMBT3904, or N-channel enhancement-logic-level FET. Q_2 maintains base current through Q_1 after S_1 is open to hold the power on.

With S_1 open, C_1 begins to charge through R_3, R_4, and R_5 toward the base voltage of Q_1, a base-to-emitter-voltage-junction drop below the battery. Subsequent closures of S_1 discharge C_1 to restart the timer. When S_1 remains open for longer than the RC time constant of C_1R_4—approximately 10 sec with the values in the **figure** (the values of R_3 and R_5 are negligible)—the voltage at IC_1's input rises above the positive input, and IC_1's output drops nearly to ground. This action turns off Q_2, which turns off Q_1 and powers off the unit. As the rail voltage falls, C_1 discharges through D_1 and R_5 to avoid clamping-diode damage to the negative input of IC_1 but remains close to the power rail. The positive IC_1 input is always 60% of the power rail, which ensures that IC_1's output will remain low all the way down to the power rail. Adjusting R_8 and R_9 to limit Q_2's base voltage below its turn-on threshold prevents any slight, dying output glitches that might exist with op amps or comparators. EDN

THE POSITIVE IC_1 INPUT IS 60% OF THE POWER RAIL, SO IC_1'S OUTPUT REMAINS LOW DOWN TO THE POWER RAIL.

Simple diode serves as a sensor for a thermal probe

Raju Baddi, Tata Institute of Fundamental Research, Pune, India

This Design Idea describes a two-transistor thermal probe for diagnosing circuit problems, such as hot components and thermal runaway. Although the probe does not provide an accurate temperature measurement, it acts as a quick check for potential thermal problems by simply probing a suspicious component with the sensing diode. The circuit, including the indicating meter, can fit into a small housing, such as an empty 20g glue-stick tube. An ordinary 1N4148 silicon signal diode serves as the temperature sensor, exhibiting approximately a –2-mV/C° forward-voltage-drop temperature coefficient. The volume-unit meter has a full-scale deflection of approximately 300 µA. You can power the circuit with a 3.6V rechargeable NiCd battery for portability and easy recharging.

The circuit uses transistors Q_1 and Q_2 with diode biasing of the base-emitter junctions. You adjust the multiturn trimming potentiometer to match the currents through the two collectors when the sensing diode is at room temperature, resulting in a zero meter reading. When the sensing diode becomes hotter than room temperature, the forward-voltage drop across the diode decreases, increasing collector current through Q_2 and decreasing collector current through Q_1. The collector current imbalance between Q_1 and Q_2 causes current to flow through the meter, indicating the increased temperature. The trimming potentiometer in series with the meter lets you adjust the sensitivity of the meter to temperature changes (**Figure 1**). You can download circuit-layout and construction details at www.edn.com/120216dia. EDN

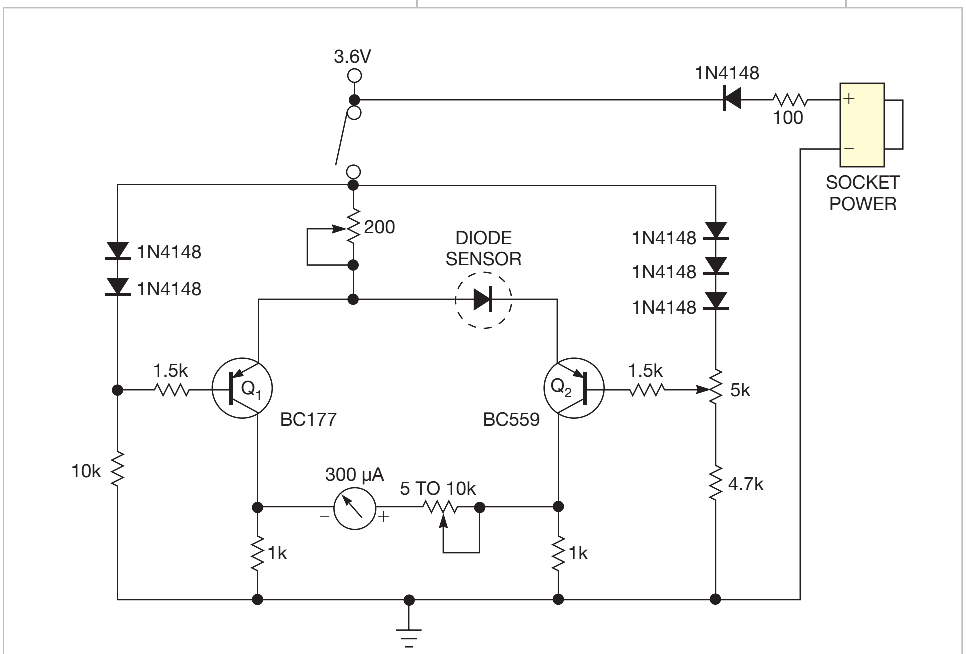


Figure 1 In this two-transistor thermal probe for diagnosing circuit problems, such as hot components and thermal runaway, the trimming potentiometer in series with the meter lets you adjust the sensitivity of the meter to temperature changes.

Use an LED matrix horizontally

Noureddine Benabadji,
University of Sciences and Technology, Oran, Algeria

LEDs provide a convenient way to electronically display information. Although the seven-segment LED display, arranged in the form of the digit 8, is common, it does not allow the display of some alphanumeric characters. A 5×7 LED matrix allows the display of all ASCII characters, as well as graphics shapes. The circuit in this Design Idea shows an unconventional way to use a 5×7 LED matrix.

You can use a design containing a set of 5×7 LED units without changing anything in the circuitry, except for the arrangement of the LED units. Using one 5×7 LED matrix, or N units, horizontally instead of vertically allows the display of two characters, or 2×N characters. The minimum pattern for lowercase and uppercase letters requires only a 3×5 LED configuration, except for the letters M and m, which require at least a 5×5 LED configuration and

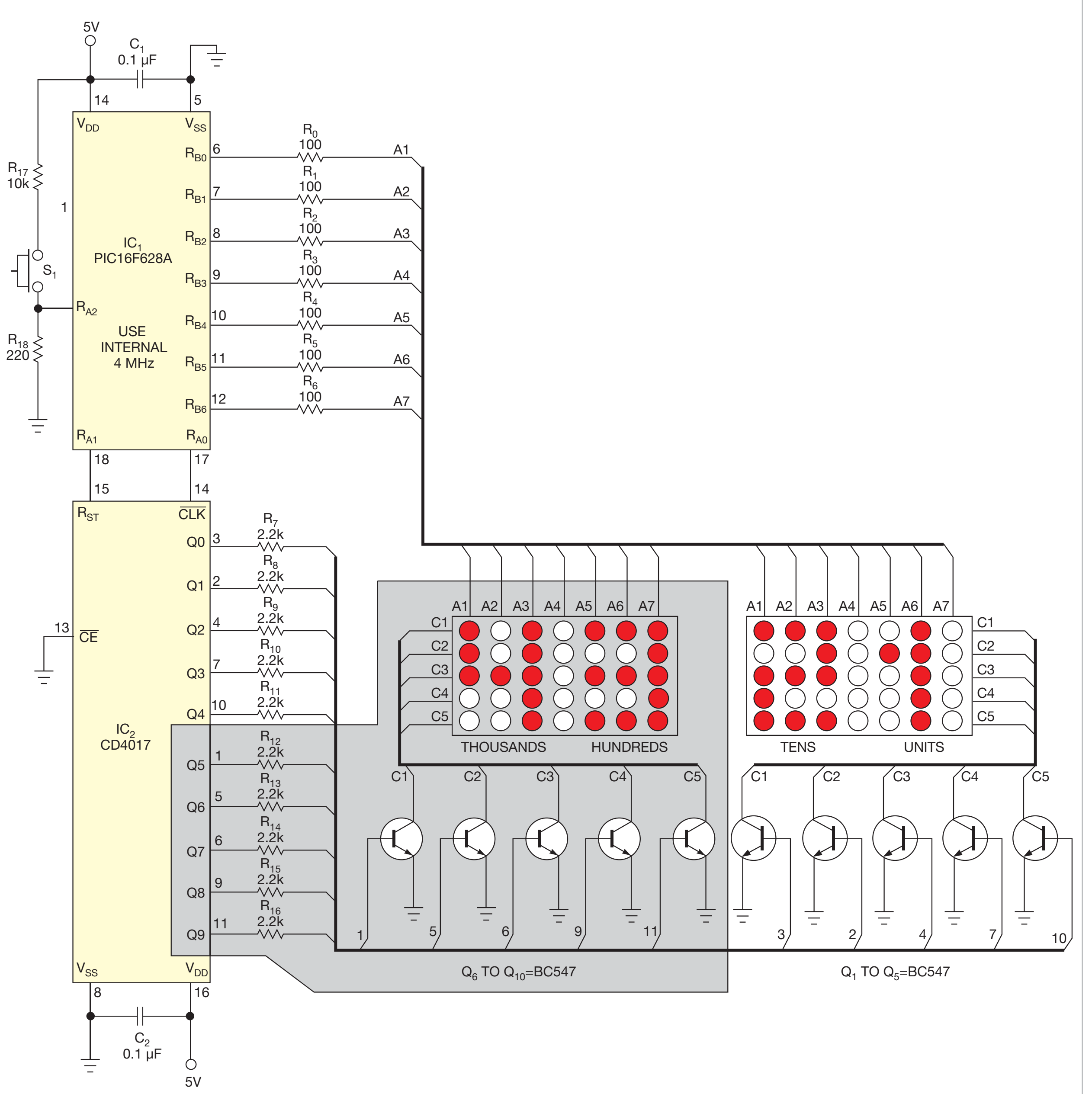


Figure 1 Use one 5×7 LED matrix horizontally to make a two-digit display.

need a dedicated subroutine. The circuit in **Figure 1** uses an 8-bit, 18-pin PIC microcontroller and a decade counter to drive one or two 5×7 LED units to provide a display module of two or four digits. The circuit uses a small pushbutton switch to increment the counter. By default, the circuit works in high-brightness mode. If you press the pushbutton during power-on, the circuit works in low-power mode.

You can download two assembly source codes that take up fewer than 256 words at www.edn.com/120216dib. Each uses a top-down scan-line multiplexing technique in a high-brightness mode, in which you can turn all LEDs in a scan line on or off, and a low-power mode, in which you can turn only one LED at a time in a scan line on or off. EDN

Use an integrator instead of coupling capacitors

Vladimir Rentyuk, Modul-98 Ltd, Zaporozhye, Ukraine

An ultrasonic sensor circuit requiring self-adjustment to the level of an ac-input signal also must accommodate the signal's unknown and variable dc-bias voltage. The circuit cannot use an ac coupling capacitor, and the resulting output must be level-shifted to a known dc offset. The design uses a dc-offset compensator (**Figure 1**).

For proper circuit operation, use a single-supply, high-input-impedance, rail-to-rail-input/output dual operational amplifier similar to the AD822 (**Reference 1**). You can adjust the reference voltage, V_R, using potentiometer R_1 to set the output offset level, which is equal to the reference voltage and usually half the supply voltage, V_{CC}, for full dynamic range. IC_{1B} amplifies and inverts the high-frequency ac-input signal with a gain of R_4/R_3.

Subtracting integrator IC_{1A} provides compensation of any unsuitable offset voltage within the negative-feedback loop. The ac-signal component attenuates based on R_2C_1 values, leaving only the averaged dc-offset component to hold the IC_{1B} output's average voltage equal to the reference voltage. **Figure 2** shows the compensation action for a bias step of 4V, which completes in approximately 100 msec.

This device has two additional useful features. It is a first-order highpass filter in which the frequency-response fall-off is 6 dB/octave, with a −3-dB cutoff frequency of $1/(2\pi R_2C_1)\times R_4/R_3$. The cutoff frequency is 47 Hz for the circuit values in **Figure 1**. This circuit also works as a differentiator to step changes in the dc input with constant-output offset voltage. EDN

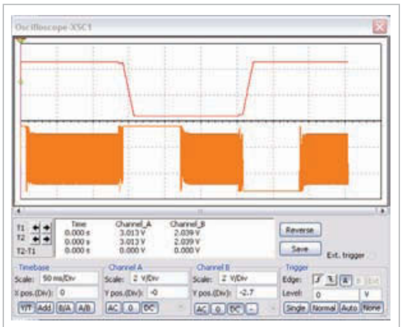


Figure 2 The compensation action for a bias step of 4V completes in approximately 100 msec.

REFERENCE

1 "AD822 Single-Supply, Rail-to-Rail Low Power FET-Input Op Amp," Analog Devices Inc, 2003, http://bit.ly/yckb04.

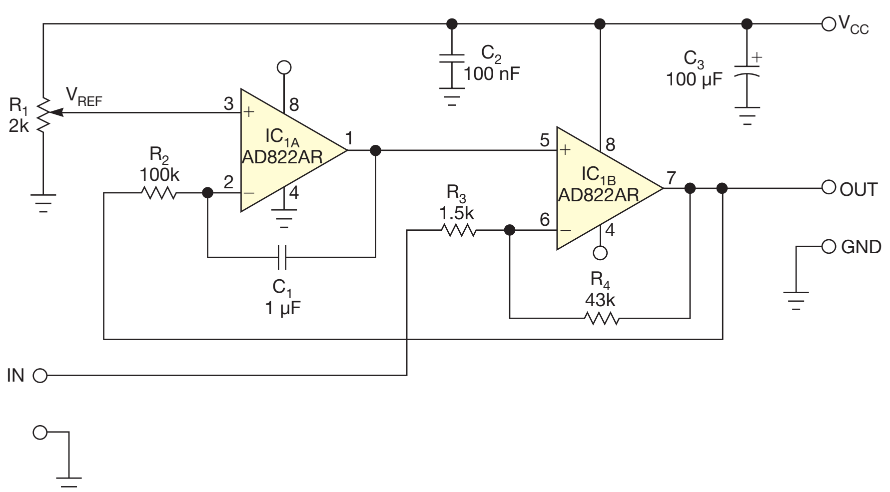


Figure 1 An ultrasonic sensor circuit uses a dc-offset compensator.

Originally published in the January 18, 2001, issue of *EDN*

PC hardware monitor reports the weather

Sean Gilmour, Analog Devices, Limerick, Ireland

You usually use PC hardware monitors to keep a close eye on power-supply voltage levels, the speed of system cooling fans, and even the temperature of the CPU. Until fairly recently, this level of system monitoring was reserved for high-end servers running mission-critical applications. However, now that low-cost hardware monitoring ASICs are available, advanced hardware monitoring has become a standard feature in most new PCs. And hardware monitors are now finding their way into diverse applications, such as weather stations (**Figure 1**).

IC_1 has two external temperature-measurement channels. One channel connects to a resistive humidity sensor, and a second channel uses a 2N3906 transistor to sense the outdoor temperature. The internal temperature sensor measures the indoor temperature. One of the tachometer inputs connects to the output of a wind-speed meter. For each of the measurement inputs, you can set limits that warn the user of changing weather conditions. IC_1 uses a switching-current-measurement scheme, so you can mount the sensors hundreds of feet from the IC and still maintain a high SNR.

IC_1 connects to a parallel printer port using a 74HC07 open-drain noninverting buffer. Pin 2 of the parallel port is the serial clock. Pin 3 writes configuration data into IC_1, and Pin 13 reads data from IC_1.

The necessary software is simple, and the parallel-printer port is easily accessible using freeware drives and DLLs that you can find on the Internet. You can bit-bang the SCL and SDATA lines using a programming language such as Visual Basic or Visual C++.

The temperature-measurement channels use a thermal diode, such as that on Intel's Pentium processors (PII+), or a discrete NPN or PNP transistor. These channels use a two-wire scheme that supplies switching current levels to the transistor. IC_1 measures the difference in V_{BE} between these two currents and calculates the temperature according to the following well-known relationship:

$$\Delta V_{BE}=KT/q\times\ln(N),$$

where K is Boltzmann's constant, q is the charge of an electron, T is the absolute temperature in Kelvin, and N is the ratio of the two currents.

You can also use the CPU temperature-monitoring channels to measure changes in resistance, making them useful for most resistive sensors, including photo diodes, photo resistors, gas sensors, and resistive-humidity sensors. EDN

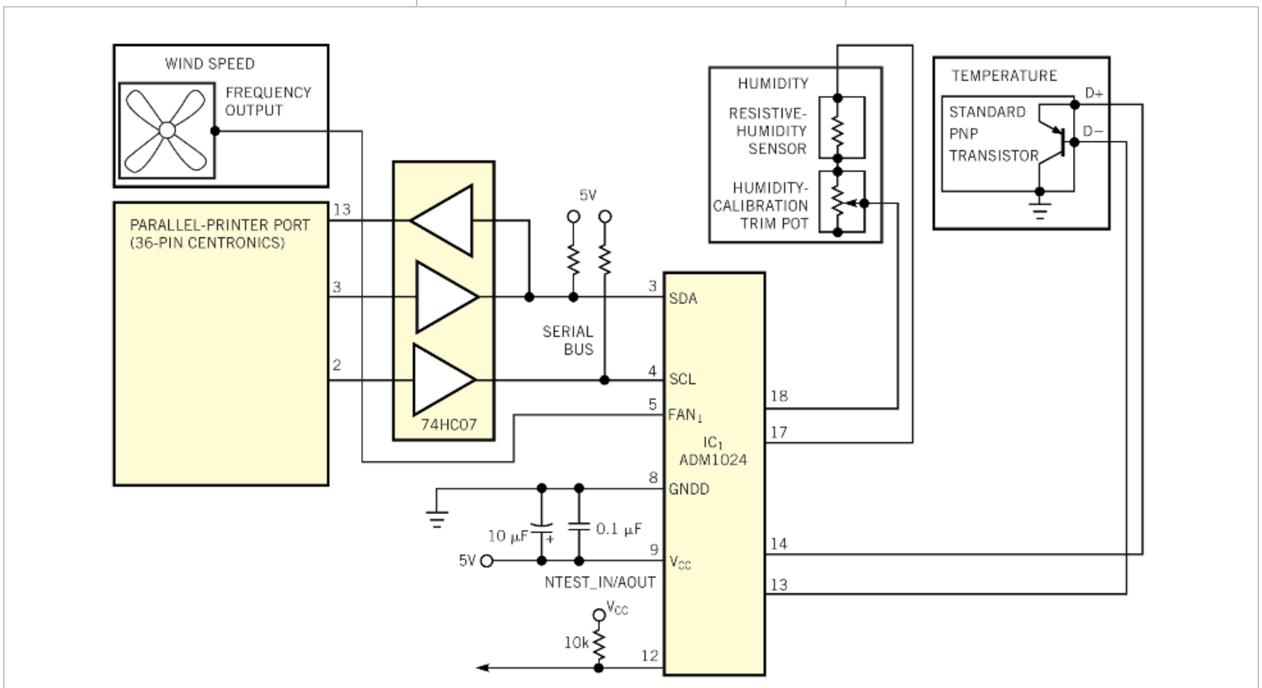
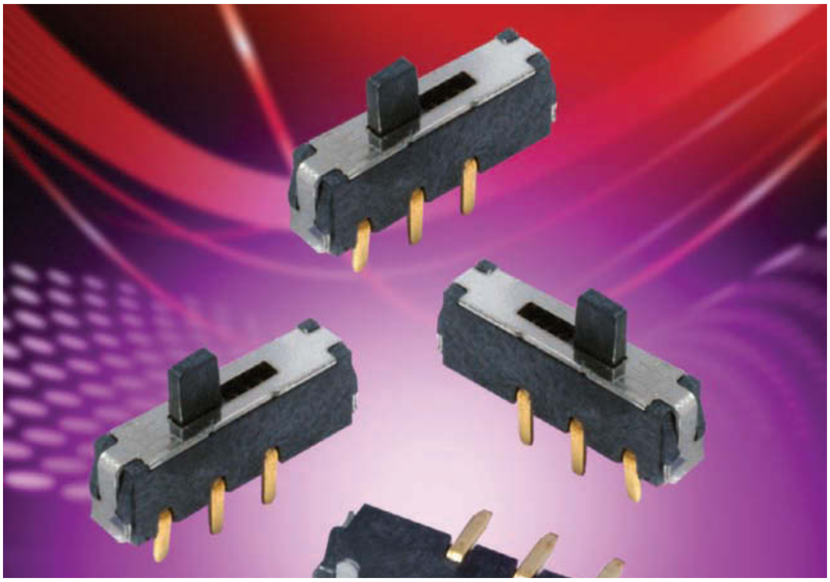


Figure 1 A PC hardware-monitor IC can also monitor weather-station characteristics.

productroundup

SWITCHES AND RELAYS



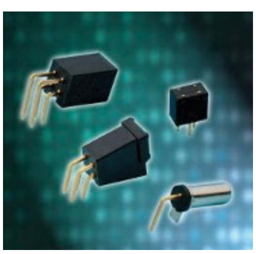
Knitter-Switch MMP/MMS 1263 switches feature automatic-return slider

The MMP/MMS 1263 series microminiature slide switches operate as on/off switches for personal multimedia products, musical instruments, and other applications requiring small switches. The one-pole, two-position switches have side- or top-actuated sliders with a latching or rest position on the right or the left of the switch. Each switch has a return force of 1 or 3.5N. The units measure 8.85 mm long and 2 mm wide, and versions are available for through-hole or surface mounting. Operating temperature is –40 to +85°C. Operational lifetime is 10,000 operations.

Knitter-Switch, www.knitter-switch.com

C&K RB-4G0124 and RB-231 rolling-ball tilt switches control safety

The RB-4G0124 and RB-231 series of rolling-ball tilt switches feature a funnel-shaped design for high accuracy and 360° detection. Targeting use in safety-control applications, such as irons, portable heaters, toys, and handheld devices, the RB-4G0124 switch features an infrared LED and a phototransistor to precisely detect the control signal. The tilt switch provides an electrical life of 1 million cycles and a mechanical life of 20 million cycles. The RB-231 rolling-ball tilt switch features a compact, shielded design that provides an angle of detection at 10°. The conductive ball inside the tube is movable to generate the signal and the contact. The RB-231 has an operating life of 100,000 cycles.



C&K Components, www.ck-components.com

E-Switch KJD17 pushbutton switch offers safety protection

The heavy-duty KJD17 series of pushbutton switches offers an industrial design and a PVC cap for dust and water protection, equivalent to an IP54 rating. The switch incorporates an electromagnet that provides automatic safety protection against power outages and restarts. The 2-hp, 16A, UL-listed switch also features a life expectancy of 10,000 cycles and a contact rating of 16A at 12V ac, 16A at 220/240V ac, ½ hp at 120V ac, and 2 hp at 220/240V ac. Minimum insulation resistance is 100 MΩ at 500V dc, dielectric strength is 1500V ac for 1 minute, and operating temperature is –25 to +55°C. Typical distributor prices start at approximately $7.90 (1000 to 1999); prices decrease with increased volumes.

E-Switch, www.e-switch.com

NKK's YB2 pushbutton switches have short above-panel dimension

The YB2 series of 24-mm², flush-mount, tamperproof-panel-seal pushbutton switches complies with IP65 standards and targets use in applications requiring a low-profile, secure, and splashproof design. Available in illuminated and nonilluminated models, the switches feature an 18-mm²-diameter actuator and a 1.8-mm above-panel dimension. The switches offer a dust-tight, splashproof panel seal, providing a defense against low-pressure jets of water from all directions. The illuminated pushbutton switches feature bright or superbright LEDs. The bright LEDs are available in red, green,

and amber, with matching color caps and built-in ballast resistors, and the superbright-LED options include blue, green, and white. Bezel options are silver or black. Cap-color options for nonilluminated models include white, red, green, yellow, or metallic silver. Ratings are 3A at 125V ac, 3A at 250V ac, or 3A at 30V dc for power models and 0.4 VA at 28V ac/dc maximum for logic-level versions. Prices for nonilluminated and illuminated models start at $10.48 and $12.92, respectively (2500).

NKK Switches,
www.nkkswitches.com

IXYS-Clare CPC1540 solid-state relay features thermal shutdown

The 350V, current-limiting, normally open CPC1540 solid-state relay replaces electromechanical devices and enhances system robustness. The optically isolated device improves survivability in harsh environments and is designed to pass regulatory voltage-surge requirements when provided with overvoltage protection. Targeting use in environmentally demanding ac or dc applications with limited PCB space, the CPC1540 has a 350V load voltage, ensuring compatibility with telephony-ringing voltages and providing 3750V rms of input-to-output isolation. The CPC1540 sells for 89 cents (25,000).

Clare Inc, **www.clare.com**

Schurter MSM metal pushbutton switch has ceramic actuator face

The metal MSM pushbutton switch has a patented ceramic actuator face and provides rugged background illumination over the full actuator surface. When the switch is not illuminated, the actuator's surface is white. Standard or customer-specified lettering is available in black and embedded directly into the ceramic material. In the illuminated versions of the switch, the actuator's face fully illuminates across the entire surface, and lettering and symbols can be applied. Positive lettering is in black; inverse lettering appears in the selected illumination color. The scratchproof labels stand up to common cleaning agents. Thanks to 1.7-mm front mounting, IP69K protection, and high impact resistance, the device is resistant to vandalism. Available mounting diameters are 19 and 22 mm. Various contact types cover 30 V-dc to 250V-ac switching voltages and 0.1 to 10A switching currents. Pricing starts at approximately $18 each (100).

Schurter Inc,
www.schurter.com

TE Alcoswitch series suits power and signal applications

The Alcoswitch Blue series pushbutton switches for power and signal applications incorporate a snap-action mechanism that provides fast switching. In SPDT and DPDT configurations, the switches feature push-on/push-off or momentary function. Their brass internal contacts have a silver inlay, and gold plating is optional for signal transmission at 60 mA and 30V dc. The silver-inlay contacts have an initial resistance of 10 mΩ at 125V ac and 1A at 2 to approximately 4V dc. The gold-plated contacts have a resistance of 20 mΩ at 100 mA and 2 to approximately 4V dc. With silver-inlay brass contacts, the pushbutton switches feature as much as 250V ac at 1.5A for European applications and as much as 125V ac at 3A for North American applications. The silver-inlay version's electric life cycle is 25,000 cycles at full current and voltage, and the gold-plated version's electric life cycle is 50,000 cycles at full current and voltage. The switches sell for $7 each.

TE Connectivity Ltd,
www.te.com

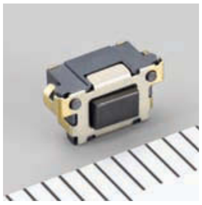
Bourns 54 and 56 panel controls are consumer-device alternatives

The ½-in. Model 54 panel control extends the vendor's Model 51/53 series with a DPDT push-pull switch module, and the ½-in. Model 56 extends the 51/53 series with an SPDT rotary switch module. Both provide alternatives to consumer-grade potentiometers with push-pull and rotary switches. Matching the requirements of a range of industrial, medical, and aerospace/avionics applications, the devices find use in test-and-measurement and communications equipment. Model 54 also targets use in medical-diagnostic and professional-audio equipment, and Model 56 works in avionics control and medical-laboratory equipment. The modules each measure 12.5 mm and feature metal bushings and shafts, splash seals, and a range of linear and audio resistance tapers. Rotational life for both models is 50,000 cycles, with contact resistance of 100 and 30 mΩ for the Model 54 and Model

56, respectively. The devices sell for $6.95 and $5.84 (1000), respectively.
Bourns Inc, www.bourns.com

Alps SKSN Tact switch targets portable audio players

The midmount Sidepush Tact switch features dust protection and dimensions of 6.2×3×3.5 mm, targeting use in small, thin products such as audio players, smartphones, blood-glucose meters, and pedometers. Operating force is 2.4N, minimum current rating is 10 µA at 1V dc, and operating life is 500,000 cycles. Maximum initial contact resistance is 100 mΩ. The series employs a midmount design for mounting into a PCB cutout, restricting the height of the switch above the PCB to 1.35 mm.



Alps Electric Co Ltd, www.alps.com

EDN ADVERTISER INDEX

EDN provides this index as an additional service. The publisher assumes no liability for errors or omissions.

EDN productmart

This advertising is for new and current products.

Copy that

DANIEL VASCONCELLOS

A colleague of mine and I were working in an engineering lab for a major medical-instrument manufacturer when we experienced an odd high-gain amplifier problem. The amplifier design was for use in a piece of custom-designed test equipment that was scheduled for release to the manufacturing-production floor. The problem would produce a random oscillation in the output signal that would last for several seconds and then disappear. We rechecked the design parameters and the circuit wiring multiple times, but the random oscillations continued to baffle us.

After exhausting every bypass, decoupling, and damping scheme we had in our collective engineering toolbox, we reluctantly called in the big gun, the department's principal engineer, for his advice. My colleague and I were confident that the senior engineer would have no better luck than we did in discovering the root of the mysterious, random oscillations, but we thought we would give it a try anyway. We explained all the design objectives, set the attenuated input-signal level to the nominal frequency of 20 kHz, and monitored the amplifier output with a 456B scope we had in the lab. We all stared at a clean-looking sine wave for several minutes with no oscillations occurring. My co-worker and I explained that we could sit for hours before noticing the troublesome anomaly and that, when it did appear, it would last for only a few seconds before vanishing again.

After quietly looking at the scope trace for a while longer, our senior engineer said he would make a copy of the schematic and run some analysis. We gave him the drawing we had been working from, and he went to the copy machine. While he was gone, we looked at the scope and wondered when the next random burst of oscillations would occur. A few seconds later, there it was: a 2-second burst of oscillation followed by a normal signal and then another 2-second burst. We couldn't believe it! No sooner had the engineering guru left the room than the circuit was mocking us again!

The principal engineer returned and told us that he had made two copies of our schematic—one for himself and a spare for us because the original had some obvious wear and tear, including coffee stains and pencil notes. My fellow engineer and I looked at each other in one of those eureka moments: "Two copies!"

WE WERE CHASING A GHOST THAT WOULD SEEM TO APPEAR RANDOMLY, ONLY TO FIND OUT THAT IT WAS COINCIDENT WITH THE USE OF THE COPY MACHINE!

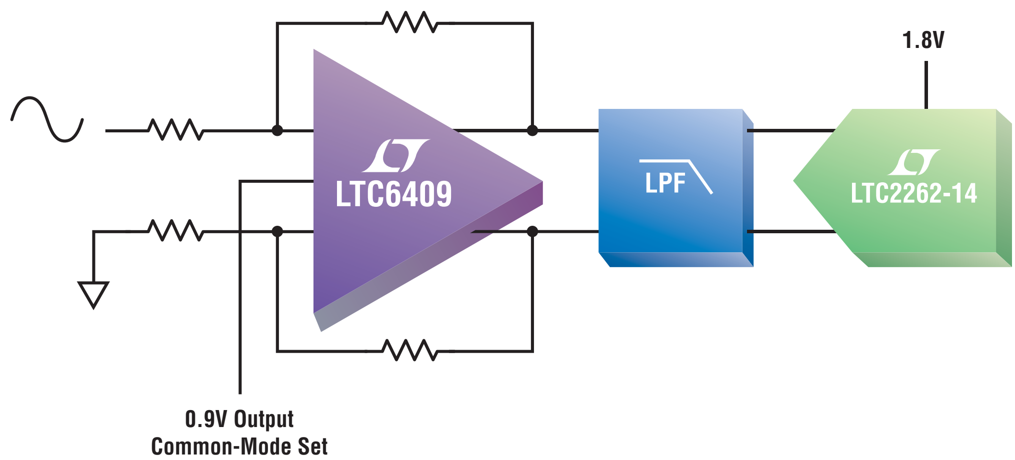
Our lead engineer looked perplexed at our excitement, and my fellow engineer dashed from the lab to the copy machine. Within a few seconds, the mysterious oscillation appeared on the scope, and I sheepishly told the lead engineer that I thought we had discovered the cause of the problem.

The copy machine was on the other side of the lab's back wall where we had our bench setup. It seems that the electrostatic corona-wire drive circuit of the copier was the source of our phantom oscillations. The amplifier front end was pushing into oscillation whenever the copier emitted RF, which lasted for about 2 seconds during the copy cycle.

We had been chasing a ghost that would seem to appear randomly, only to find out that it was coincident with the use of the copy machine! Our embarrassment was probably justified; we should have looked for external causes. However, we ensured that the equipment that was going to manufacturing had adequate RF shielding. **EDN**

This Tale is a runner-up in *EDN*'s Tales from the Cube: Tell Us Your Tale contest, sponsored by Tektronix. Read the other finalists' entries at http://bit.ly/Talesfinal_EDN.

88dB SFDR @ 100MHz



Unleash Your High Speed ADC

With 1.1nV/$\sqrt{Hz}$ input noise density and 88dB SFDR performance at 100MHz, the LTC®6409 enables your high speed ADC to achieve outstanding performance. Its input common mode range includes ground and its output common mode can be set as low as 0.5V, making the LTC6409 the perfect choice for driving AC- or DC-coupled signals into the latest 1.8V data converters. Fully specified over the –40°C to 125°C temperature range, and available in a tiny 3mm x 2mm QFN package, the LTC6409 combines excellent AC performance with flexibility, robustness and a minimal footprint.

Features

- Unity Gain Stable
- 1.1nV/$\sqrt{Hz}$ Input Noise Density
- 10GHz GBW @ 100MHz
- DC- or AC-Coupled Inputs
- 0.5V to 3.5V V_{OCM}
- –40°C to 125°C Fully Specified
- Tiny 3mm x 2mm QFN Package

Differential ADC Drivers

Part Number	80dBc HD2/HD3 (MHz)	Input Referred Noise (nV/$\sqrt{Hz}$)	Voltage Gain
LTC6409	110	1.1	R-set
LTC6406	30	1.6	R-set
LTC6404-1	15	1.5	R-set
LTC6400-20	120	1.9	20dB
LTC6416	90	1.8	0dB

Info & Free Samples

www.linear.com/6409

1-800-4-LINEAR

www.linear.com/ampsflyer

LINEAR TECHNOLOGY