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Issue 1/2008
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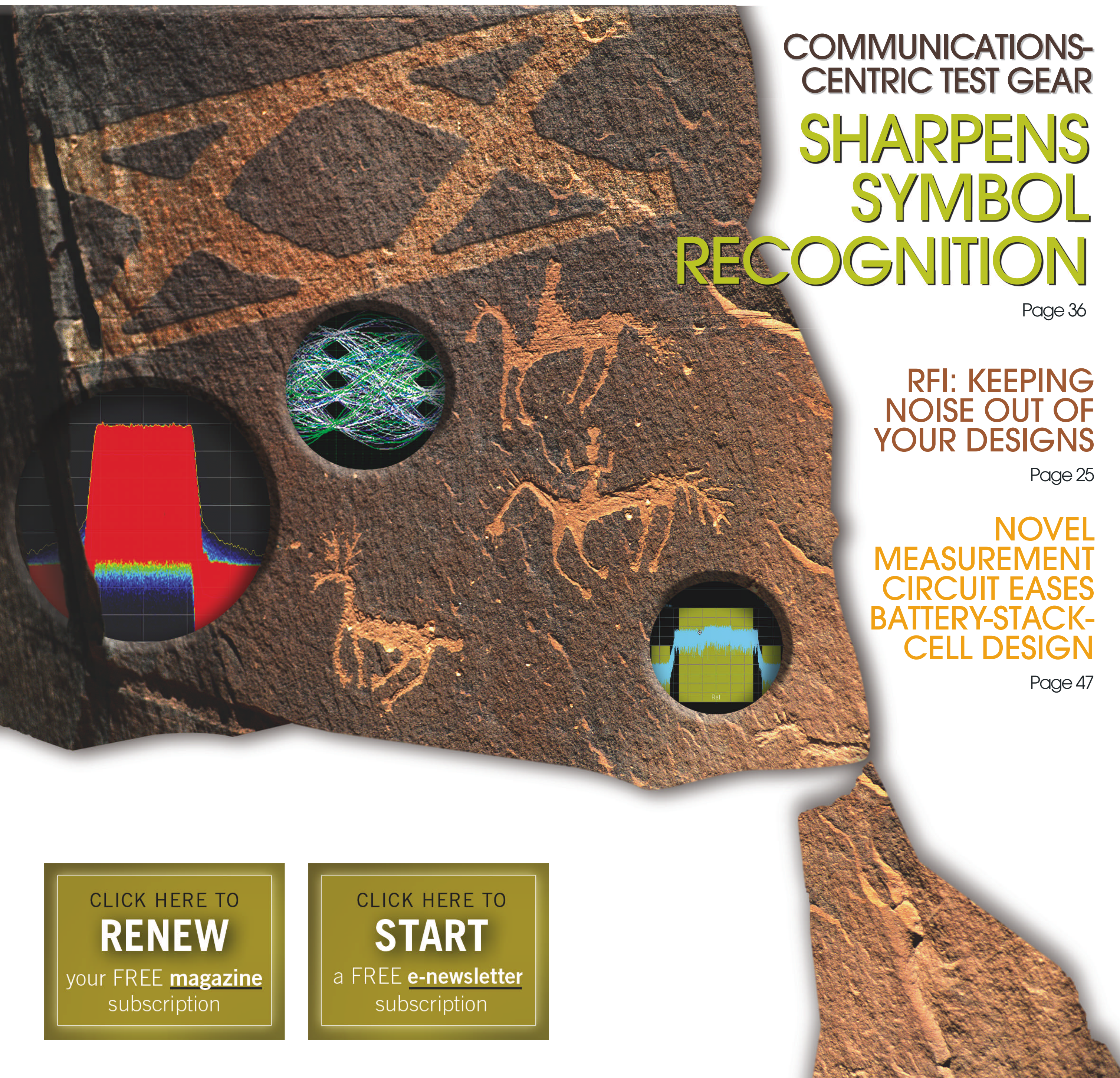

COMMUNICATIONS-CENTRIC TEST GEAR SHARPENS SYMBOL RECOGNITION

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RFI: KEEPING NOISE OUT OF YOUR DESIGNS

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NOVEL MEASUREMENT CIRCUIT EASES BATTERY-STACK-CELL DESIGN

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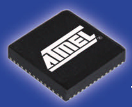

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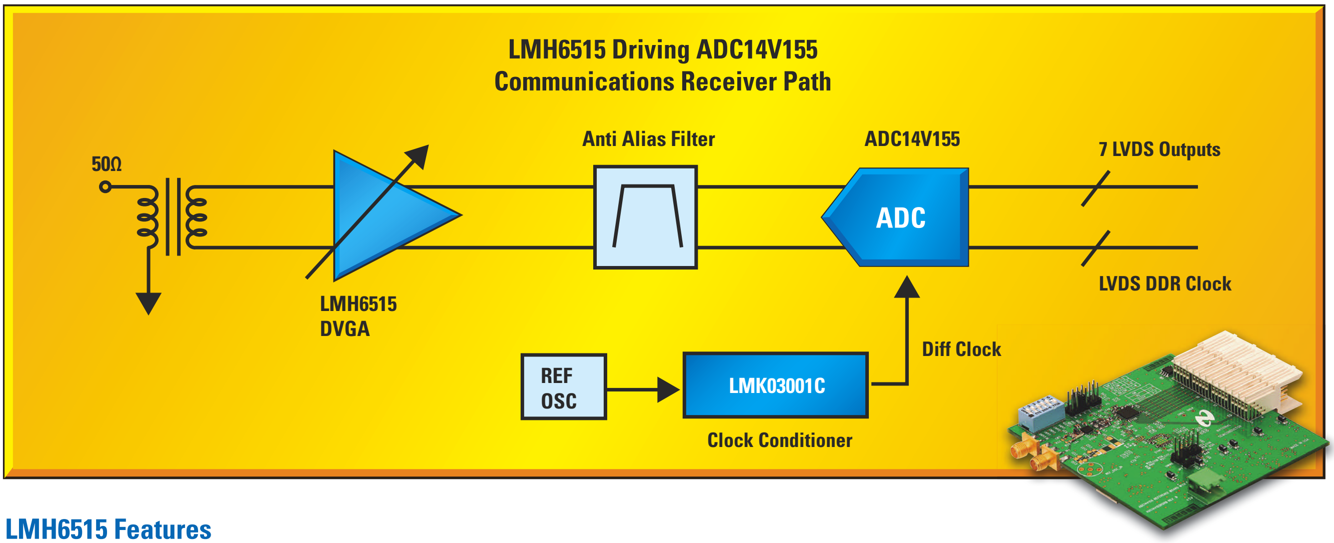

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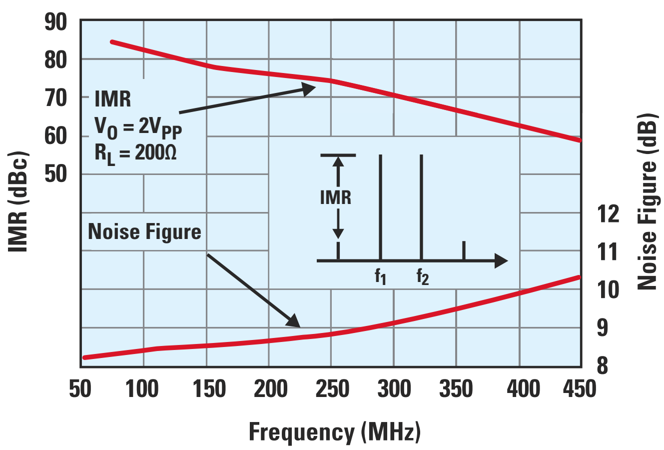

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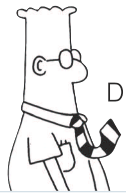

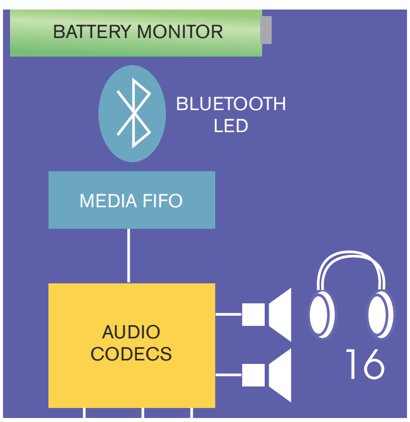

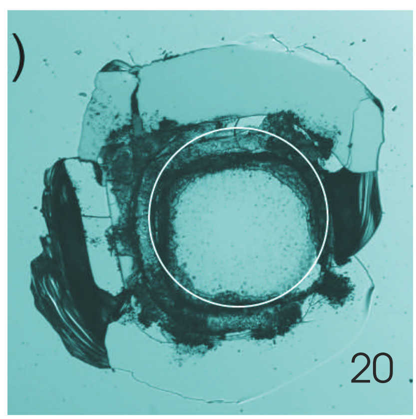

DEPARTMENTS & COLUMNS

PRODUCT ROUNDUP

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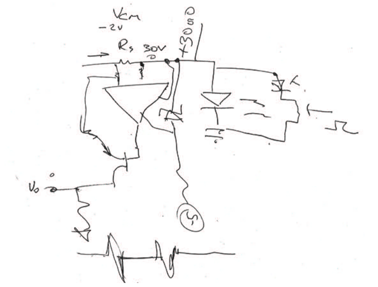

ONLINE ONLY

Check out these Web-exclusive articles:

High-side current-sense-circuit problem
Marcello Salvatierra, an applications engineer with National Semiconductor's amplifier group, has observed a rather serious problem with the classic high-side current-sense circuit.
→www.edn.com/080110toc1

AMD: fading fast, nearly fini?
→www.edn.com/article/CA6513024

Footprints of the EDA industry
→www.edn.com/080110toc2

EDA place-and-route start-up ATopTech out of the gates with Broadcom win
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Equipment "quits": Beware bad wall warts
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TSMC to qualify 65-nm mixed-signal, RF tools
→www.edn.com/article/CA6512752

SOC yield management: an emerging issue that could reshape the industry
→www.edn.com/080110toc4

ON Semi to acquire AMIS for $915M to create power-semi giant
→www.edn.com/article/CA6512742

Can Nokia compete with Apple's iPhone on music and "lifestyle?"
→www.edn.com/080110toc5

IMEC details high-k metal-gate planar CMOS progress
→www.edn.com/article/CA6511456

READERS' CHOICE

A selection of recent articles receiving high traffic on www.edn.com.

***EDN* Hot 100 Products of 2007**
EDN's editors offer up their annual list of the year's 100 most significant ICs, components, buses, boards, EDA tools, power devices, test instruments, and more.
→www.edn.com/hot100

Robots on the march: robotics platforms and development tools
→www.edn.com/article/CA6505566

Avnet's "foundry phenomenon"
→www.edn.com/article/CA6511351

Protecting interfaces from ESD
→www.edn.com/article/CA6505573

Identity crisis in the gray market
→www.edn.com/article/CA6509284

2008 capital spending to shake IC-industry foundation, IC Insights reports
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High-brightness LEDs usher in new applications and standards
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IBM uses light to build supercomputers on a chip
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Decompensating amplifiers improve performance
→www.edn.com/article/CA6505576

IBM, partners claim 32-nm high-k/metal-gate SRAM, SOI
→www.edn.com/article/CA6510863

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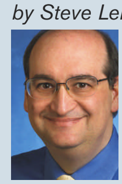
FROM *EDN*'s BLOGS

Embedded-processor recycling: Far out idea … too far out
From Leibson's Law, by Steve Leibson



The five professors who authored this proposal appear to be unaware of the last decade of SOC development, the way that consumer-electronic products are designed in the 21st century, the way complex ICs are tested and characterized, or the way designers use ASSPs in their product designs.
→www.edn.com/080110toc8

The Uncanny Valley: Beowulf's dead-end alley
From Brian's Brain, by Brian Dipert

Flesh-and-blood Hollywood actors probably don't have to worry about job security … yet. But the time of cyber-reckoning is looming on the horizon, and I suspect it'll be here sooner than some of you believe.
→www.edn.com/080110toc9

BY MAURY WRIGHT, EDITORIAL DIRECTOR

Open-cellular-network boasts lack substance

It was really quite comical watching Verizon Wireless and AT&T argue in the mainstream media about the "openness" of their cellular networks. The problem is that neither company's approach is really open, and neither company has addressed what we need to spur real innovations that can leverage cellular radios: network technology that enables embedded cellular radios that companies can deploy at a reasonable price.

If you missed the openness skirmish, here's a quick summary. First, Verizon issued a press release (http://news.vzw.com/news/2007/11/pr2007-11-27.html) stating that, by the end of 2008, the company would support devices on its network that Verizon doesn't sell. Immediately, AT&T responded in a *USA Today* article, claiming that its network has always been open (www.usatoday.com/tech/wireless/phones/2007-12-05-att_N.htm).

AT&T, I presume, is partially correct. If you have a valid AT&T SIM card, you can put it in almost any unlocked GSM (global-system-for-mobile-communications) phone, and it will work. There are exceptions in the smartphone area. For instance, if you want your Blackberry to work to its potential, then you should buy it from AT&T. And even AT&T admitted that Apple's iPhone would remain locked to the network. AT&T did say that it will unlock phones for customers that either fulfill their contracts or pay full price for a phone. That approach is new, but Internet hacks that unlock phones are widely available, and many local phone shops will unlock a GSM phone for a fee.

As for Verizon, details of its open plan were still to come at press time. But the press release notes that a third party that wants to offer a device for the Verizon network must have a new Verizon lab certify that device. I'd guess that a few such devices are already in that certification process, but wide choice probably will not happen soon. Verizon didn't say whether it would support CDMA (code-division/multiple-access) phones sold on competing CDMA networks. The CDMA community has never relied on SIM cards, although ironically, most CDMA chip sets offer SIM-card support.

> **There are dozens if not hundreds of products that might be more compelling if they integrated a cellular radio.**

But here's what is missing from both announcements: There are dozens if not hundreds of products that might be more compelling if they integrated a cellular radio. Take a handheld product such as the Sony PSP (PlayStation Portable). The PSP has Wi-Fi, but a cellular link would provide an "anywhere" connection to support multiplayer games or content downloading. You can make the same case for MP3 players. What about GPSs? Dash Navigation has integrated a cellular radio in its GPSs so that autos can send real-time traffic data back to a database that serves all Dash owners.

Today, a device with an integrated cellular radio needs an account and phone number just like a phone. But most embedded cellular applications don't need a phone number and would use only the data services that the mobile carrier supports.

The real issue, I suspect, is price and not technology. My family has an AT&T Wireless account, and we pay $6 for each additional phone number. That cost isn't much when we need only three phone numbers. But what if I had another dozen cellular radios in a variety of portable electronics? There is no way I would pay $6 for each. Nor would I buy an $80-per-month data contract specific to an embedded radio.

Now, there are applications that will pay the going rate. A cellular-linked portable medical device that helps keep a consumer alive is clearly worth a dedicated account. But to spur innovation and an explosion of new mobile radios in everyday devices, the carriers need to develop a technology and a business plan that make support for those devices less costly. I'll buy one relatively expensive wireless-data account, but the incremental cost to use that service on multiple devices needs to be almost free. And this approach would benefit the carriers. Data services aren't selling as well as they'd like. Meanwhile, the carriers pursue newer, faster data technologies. EDN

Contact me at mgwright@edn.com.

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Go to www.edn.com/080110ed and click on Feedback Loop to post a comment on this column.

RAQ's

Rarely Asked Questions

Strange but true stories from the call logs of Analog Devices

Half Full or Half Empty? Thoughts on Capacity.

Q. Are all components with just two wires as complicated as the resistors we discussed recently?

A. Capacitors certainly are.

If you put a pint of liquid into a quart pot, the optimist will declare it half full, but on the other hand the pessimist will complain that it's half empty.

Engineers, on the gripping hand[i], know that the glass is too large.

It's a matter of capacity. Capacitors, like the resistors we discussed recently, are more complex than the simplicity of their two leads suggests, and bigger is not necessarily better.

A capacitor has more characteristics than its capacity and maximum operating voltage. In parallel with the nominal capacity there will be leakage resistance and dielectric absorption. In series, there will be inductance and effective series resistance (ESR). ESR is important; the largest unintentional[ii] explosion I ever caused occurred when I was working on ultrasound cleaners and replaced a faulty mica high-frequency (HF) capacitor in the tank circuit of a 5-kW ultrasonic generator with a high-ESR oil-filled capacitor. I was lucky to survive, but the ultrasonic generator didn't.

Even low-frequency integrated circuits (ICs) contain transistors with a frequency response of hundreds or thousands of MHz. If the supply pins of the IC are not short-circuited at HF, the parasitic components formed by the printed circuit board tracks may create resonators and oscillate—possibly at such a high frequency that the oscillation is not visible on an oscilloscope. The capacitor used to create this HF short-circuit must have low inductance—and short leads. Too large a capacitance is unlikely to have sufficiently low inductance, and some types of small capacitors (such as spiral-wound plastic film) may still be unsuitable. On the other hand the precision and stability of such decoupling capacitors are comparatively unimportant.

In active filters, precision and stability are of overriding importance. In low-frequency supply decoupling, the ability to handle high ripple currents without overheating limits the types we may use.

Fifteen or twenty years ago the dielectric absorption of capacitors for use in sample and hold (SHA, S/H or, sometimes, T/H [track and hold]) circuits was very important. It is still important for SHAs that use discrete capacitors, but today these capacitors are usually integrated onto a chip, and are not separate components. Leakage is still important in RC timing circuits, though.

Even the difference between polarized and unpolarized capacitors is important in ac applications.

Choosing capacitors involves a lot more than simply calculating the required capacitance. The linked article discusses the issues in much more detail.

---

i *To learn about the Motie race, and their additional gripping hand, read "The Mote in God's Eye" (ISBN 0-671-21833-6) and its sequel "The Gripping Hand" (ISBN 0-671-79573-2) by Larry Niven and Jerry Pournelle or see http://en.wikipedia.org/wiki/Gripping_hand*

ii *Don't ask about my experiences with pyrotechnics and blasting gelatine.*

To learn more about Capacitors

Go to: http://rbi.ims.ca/5697-101

Contributing Writer James Bryant has been a European Applications Manager with Analog Devices since 1982. He holds a degree in Physics and Philosophy from the University of Leeds. He is also C.Eng., Eur.Eng., MIEE, and an FBIS. In addition to his passion for engineering, James is a radio ham and holds the call sign G4CLF.

Have a question involving a perplexing or unusual analog problem? Submit your question to:

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INNOVATIONS & INNOVATORS

USB-bridge controller supports multilevel-cell NAND flash

Last year, Cypress Semiconductor announced the West Bridge family of chips that primarily add high-speed-USB support to products such as mobile handsets. Full-speed transfers between handset memory and the USB interface, with no assistance from the handset application processor, have proved to be the primary benefit of West Bridge. Now, Cypress is launching the Astoria flavor of West Bridge, adding an MLC (multilevel-cell)-NAND-flash-memory controller.

Cypress claims that MLC flash costs a third of single-level-cell flash for the same storage capacity, making MLC support attractive in applications ranging from handsets to media players to digital cameras. Many of the standard storage modules, such as USB-memory sticks or SD (Secure Digital) cards, use MLC memory but integrate the controller, thereby hiding the complexity of the control function. But designers who wish to embed MLC flash have little choice when it comes to the control function.

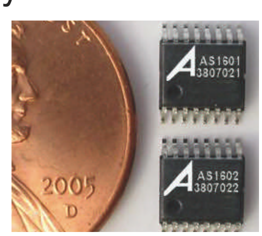
Astoria can control 16 MLC NAND memories and supports devices from all of the major flash vendors. The controller includes bad-block management, static-wear-leveling support, and 4-bit ECC (error-correction code). You can interface Astoria to all popular processors and DSPs. And, like its predecessor, the chip supports 16 USB endpoints and a host of programmable-I/O features. The IC sells for less than $5 (500,000).**—by Maury Wright**

The Cypress West Bridge Astoria chip provides a three-way interface among a processor, USB, and memory and includes a multilevel-cell-NAND-flash controller.

▷**Cypress Semiconductor**, www.cypress.com.

ICs address speedy Ethernet devices' need for EMI, ESD protection

The Ethernet communication standard is morphing into 10/100/1000-Mbps versions and gaining inherent power-delivery capability in POE (power-over-Ethernet) designs. System designers are responding with feature-packed products, such as VOIP (voice-over-Internet Protocol) phones and IP cameras. However, it is becoming increasingly difficult to protect these devices from EMI (electromagnetic-interference) noise and ESD (electrostatic discharge) without degrading system performance. Passive devices, including TVS (transient-voltage-suppression) diodes for ESD protection and external chokes for EMI, offer some protection but often at the expense of system performance. Addressing these problems, Akros Silicon has introduced two devices that it claims are the first active devices for suppressing EMI and ESD and promoting EMC (electromagnetic compatibility).



The AS1601/02 EMI/ESD-suppression ICs actively protect Ethernet devices from noise and damaging bursts of electrical energy.

The integrated AS1602 common-mode-EMI-noise- and ESD-suppression IC provides less-than-0.5Ω common-mode impedance to ground and complies with Ethernet-performance specs. The CMOS chip goes between the Ethernet PHY (physical) layer and the line transformer. External ferrites steer bursts of energy to the chip, which quickly sinks the transient energy; in less than 1 nsec, diodes steer the energy away from the PHY layer. The AS1601 version provides only EMI suppression. The AS1602 and AS1601 CMOS ICs sell for $1.60 and $1.23 (1000), respectively.

—by Margery Conner

▷**Akros Silicon**, www.akrossilicon.com.

Altera CPLD targets portable-system applications

With an eye on winning more sockets in low-power-portable-system applications and a greater share in the FPGA market, Altera has announced the Max IIZ, the latest member of its low-power Max II nonvolatile-CPLD lineup. Altera based the "zero-power" Max IIZ on the Max II four-look-up-table architecture, which the company implemented in the TSMC (Taiwan Semiconductor Manufacturing Co, www.tsmc.com) 1.8V, 0.18-nm flash technology. Altera will initially offer the device in the 240-logic-element EPM240Z and the 570-element EPM570Z with I/O counts of 54 to 260.

One of the key selling points of the device is its low power, according to Dennis Steele, director of product marketing for the Max II family. The device boasts typical standby power of 29 μA and maximum power of 150 μA. To achieve these numbers, Altera tweaked the architecture's power-on-reset circuitry to reduce standby-power consumption and slightly increased the device's transistor-threshold voltage to reduce standby leakage.

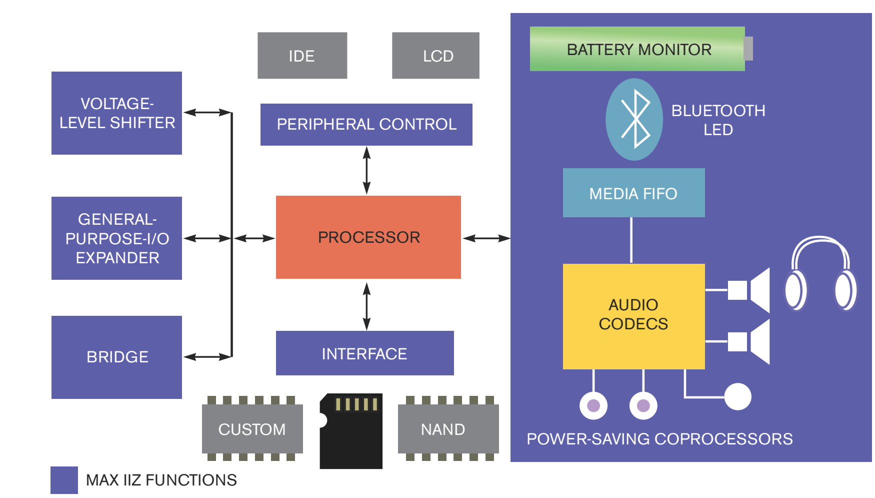
Traditionally, portable-system designers have only sparingly used low-power CPLDs as glue logic because programmable logic tends to be power-hungry. Designers typically use CPLDs to handle communications and, sometimes, power management between a system's main processor and other devices. The Max IIZ, however, boasts a combination of low power, reasonably high logic-element counts, advanced performance, and high I/O counts, allowing designers to use low-cost CPLDs for a broader number of essential tasks in portable-system applications. For example, the device can perform as a voltage-level shifter, expand general-purpose I/O, act as a bridge, serve the processor with extra I/O, and function as an interface between the processor and the system peripherals. The device also has an oscillator, which other CPLDs lack, according to Steele.

> Altera tweaked the architecture's power-on-reset circuitry to reduce standby-power consumption.

This mix of functions allows designers to configure a Max IIZ to work as a low-power coprocessor in handheld devices that mix, for example, phone and MP3 functions. One of the biggest problems handheld-device designers face is that, although a device may have long battery life when a consumer uses it solely as a phone, it quickly sucks up battery power when the user employs it to play music. This consumption typically occurs because the ARM (www.arm.com)-based SOC (system on chip) that controls the system must run at full speed to communicate with the audio codec and media FIFO. The Max IIZ's internal oscillator allows designers to configure the CPLD as a coprocessor that includes and controls the codec and media-FIFO functions at lower power than the ARM-based SOC, thus saving overall battery power. The company offers each Max IIZ device in 5×5-, 6×6-, 7×7-, and 11×11-mm MBGA packages. The EPM240Z M68 will cost $1.25 (1 million), and Altera will begin shipping it this quarter.

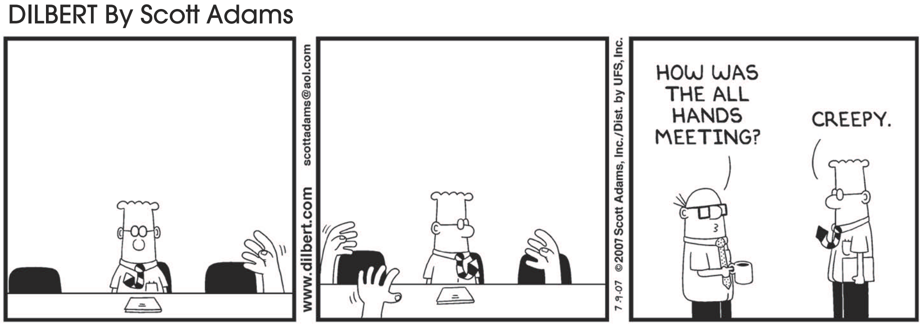
—by Michael Santarini

▷**Altera Corp**, www.altera.com.



The Max IIZ can perform as a voltage-level shifter, expand general-purpose I/O, act as a bridge, serve the processor with extra I/O, and function as an interface between the processor and the system peripherals.

DILBERT By Scott Adams



National Instruments aims at high-volume applications

Integrating hardware that includes an embedded real-time processor and a reconfigurable FPGA, National Instruments' new cRIO-9072 and cRIO-9074 CompactRIO systems target high-volume industrial applications. The systems extend NI's FPGA-based deployment platforms that share common hardware architecture and I/O modules. Using this standard architecture and LabView FPGA and Real-Time tools, engineers can design and prototype industrial-monitoring-and-control machines with PXI (peripheral-component-interconnect-extensions-for-instrumentation), PC, or standard CompactRIO hardware and then move to the cRIO-907x CompactRIO systems to reduce deployment costs. Because engineers can reuse the same LabView code during prototyping and deployment, they can shorten time to market and increase machine reliability.

To reduce costs, the cRIO-907x integrates the processor and the FPGA chip on the same PCB (printed-circuit board). The cRIO-9072 system combines an industrial, 266-MHz real-time processor; 64 Mbytes of DRAM; 128 Mbytes of nonvolatile storage; and an eight-slot chassis with a reconfigurable, 1 million-gate FPGA chip. Prices start at $1999. The cRIO-9074 contains a 400-MHz real-time processor, 128 Mbytes of DRAM, 256 Mbytes of nonvolatile storage, and an eight-slot chassis with a 3 million-gate FPGA chip. Prices start at $2999.

—by Warren Webb

▷**National Instruments**, www.ni.com/compactrio.

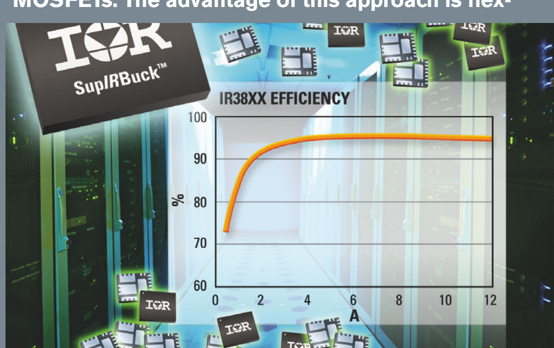
The new cRIO-907x CompactRIO systems integrate a controller and a chassis; the integration lowers recurring costs for high-volume OEM applications.

INTEGRATED DC/DC REGULATORS IMPROVE EFFICIENCY IN SERVER, EMBEDDED-SYSTEM APPLICATIONS

Energy efficiency continues to be a major concern for server-farm operators, who can expect to pay three times the cost of the servers in operating costs over the life of the equipment. Further, the Environmental Protection Agency estimates that 1.2% of the total US electricity usage goes into powering server farms. Schemes for improving efficiency often center on power conversion within the server motherboard. Designs for high-density POL (point-of-load) converters fall into one of two camps. One approach uses a power-conversion IC with separate, discrete, power-switching MOSFETs. The advantage of this approach is flexibility; many parts are available to fine-tune a design. The disadvantages are the increase in design time and in parts count and the lack of standardization across the motherboard and product line. The other approach uses a monolithic converter that incorporates the regulation electronics and the power MOSFETs on one die. This approach results in a lower parts count and simplified design but at the expense of flexibility and increased inefficiency at 12V if the part targets use with 5V supplies.

International Rectifier's SupIRBuck family takes a third approach and incorporates a PWM (pulse-width-modulation) IC with switching MOSFETs into a tiny 5×6-mm module, achieving efficient power conversion and regulation for both 5 and 12V power rails. Providing 4, 7, and 12A of output-load current at a 600-kHz switching frequency, the IR38XX operates from an input-voltage range of 2.5 to 21V and provides output voltage as low as 0.6V. Common features include pre-bias start-up, fixed 600-kHz switching frequency, hiccup-current limit, thermal shutdown, and precise output-voltage regulation. Optional features include tracking, a programmable power-good signal, and a 300-kHz switching frequency to provide 2A more output-current capability. Prices for the SupIRBuck IR38XX devices begin at $2.25 (10,000) each.—by Margery Conner

▶**International Rectifier, www.irf.com.**



International Rectifier's 5×6-mm SupIRBuck dc/dc-converter module achieves high efficiency in power conversion and regulation.

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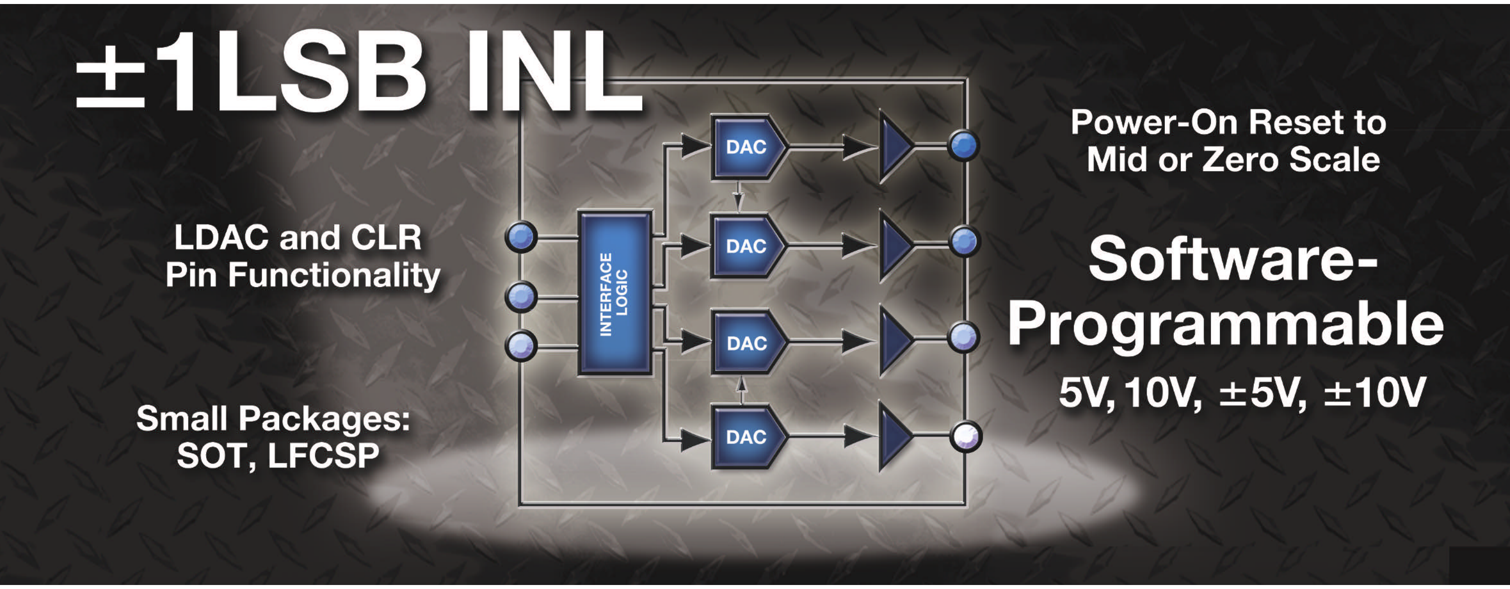

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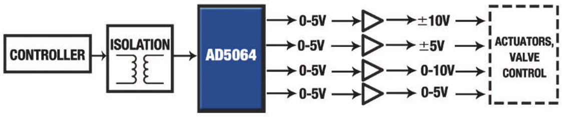

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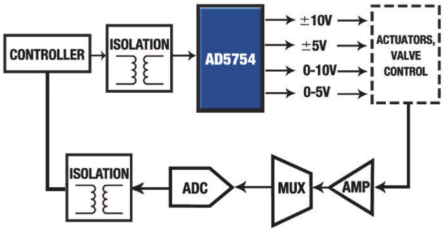

Part No.	Description	Price
Ideally Suited to Open-Loop		
AD5060	Single, 5 V, ±1 LSB INL (max), 1 mA @ 5 V	$7.50
AD5065	Dual, 5 V, ±1 LSB INL (max), 2.3 mA @ 5 V	$11.25
AD5064	Quad, 5 V, ±1 LSB INL (max), 5 mA @ 5 V	$15.95
AD5764	Quad, ±15 V, ±1 LSB INL (max)	$35.70
Ideally Suited to Closed-Loop		
AD5752	Dual, software-programmable output range of 5 V, 10 V, ±5 V, ±10 V in 24-lead TSSOP	$6.95
AD5754	Quad, software-programmable output range of 5 V, 10 V, ±5 V, ±10 V in 24-lead TSSOP	$10.05
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ANALOG DEVICES

RESEARCH UPDATE

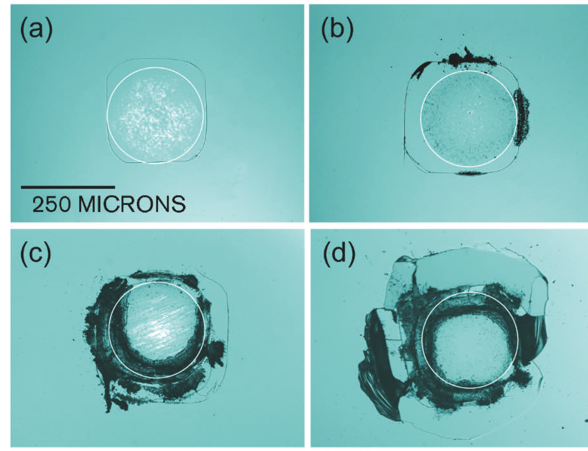
BY MATTHEW MILLER

Silicon fatigue: not a myth

In work with ramifications for MEMS (microelectromechanical systems), researchers at NIST (National Institute of Standards and Technology) claim to have proved that, contrary to conventional wisdom, bulk silicon crystals are vulnerable to fatigue from cyclic stresses.

The scientists used 3-mm-diameter tungsten-carbide spheres to apply pressure to the surfaces of test crystals. Simply pressing, even for days at a time, caused no discernible damage. But cycling the test hundreds of thousands of times, even at low pressure, resulted in a gradually worsening damage pattern.

NIST claims that this clear evidence of mechanical stress resolves a debate about cracks, which scientists observed in some MEMS structures, by ruling out a competitive theory that fingered chemical corrosion as the culprit. The team proposes that its test found damage that conventional tensile-strength tests miss because it induced shear stress—causing crystal planes to slide against each other. And shear stress, the team notes with concern, is not uncommon in real-world applications. The next step for the research team is to scale down the testing from the current scale of hundreds of microns to the submicron level.
▷**National Institute of Standards and Technology**, www.nist.gov.

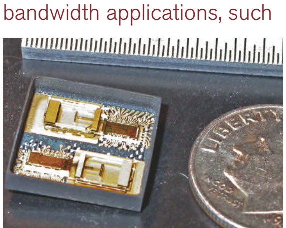


A silicon crystal exhibits increasingly obvious mechanical damage after 1000 (a), 5000 (b), 20,000 (c), and 85,000 (d) cycles of a stress test.

IBM millimeter-wave wireless technology inches toward commercialization

IBM and Taiwan-based fabless chip maker MediaTek recently announced an agreement to develop chip sets based on IBM Labs' 60-GHz mmWave wireless technology. Prototype mmWave chips that IBM unveiled in early 2006 achieved throughput of 630 Mbps with a maximum range of 10m, but the company touts the technology as potentially suitable for even higher bandwidth applications, such as ferrying uncompressed high-definition video streams from set-top boxes to displays. In this application, the limited range, which arises due to oxygen absorption, would be a feature, not a bug. Hollywood studios and other content owners prefer not to have their valuable content traveling in uncompressed form for long distances.

In addition to chip development, IBM is researching IC packaging and antenna designs for the 60-GHz band. The IEEE (www.ieee.org) is working toward standardization of applications in the 60-GHz band through the IEEE 802.15.3c working group. For more information, visit www.research.ibm.com/mmwave.
▷**IBM Corp**, www.ibm.com.
▷**MediaTek**, www.mtk.com.tw.



Prototype mmWave chips that IBM unveiled in early 2006 achieved throughput of 630 Mbps with a maximum range of 10m.

STMicroelectronics claims first 45-nm CMOS-RF chips

STMicroelectronics has announced the production of its first fully functional ICs using a 45-nm CMOS-RF process. The prototype devices integrate a complete signal chain, from detection of an RF signal through digital output, according to the company. Measuring 0.45 mm square, including a low-noise amplifier, a mixer, an ADC, and filtering, the devices operate at 1.1V.
▷**STMicroelectronics**, www.st.com.

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SILICON NANOCRYSTALS SHOW PROMISE FOR SOLAR CELLS

Speaking of qualities of silicon that scientists once thought nonexistent (see "Silicon fatigue: not a myth," above), researchers at the US Department of Energy's National Renewable Energy Laboratory have shown that silicon nanocrystals exhibit multiple-exciton generation, meaning that they emit more than one electron per absorbed photon. In theory, solar cells harnessing this effect could achieve efficiency of 44% using sunlight and as much as 68% using sunlight that lenses or mirrors have concentrated. Conventional solar cells deliver 33 and 40% efficiency, respectively.
▶**National Renewable Energy Laboratory**, www.nrel.gov.

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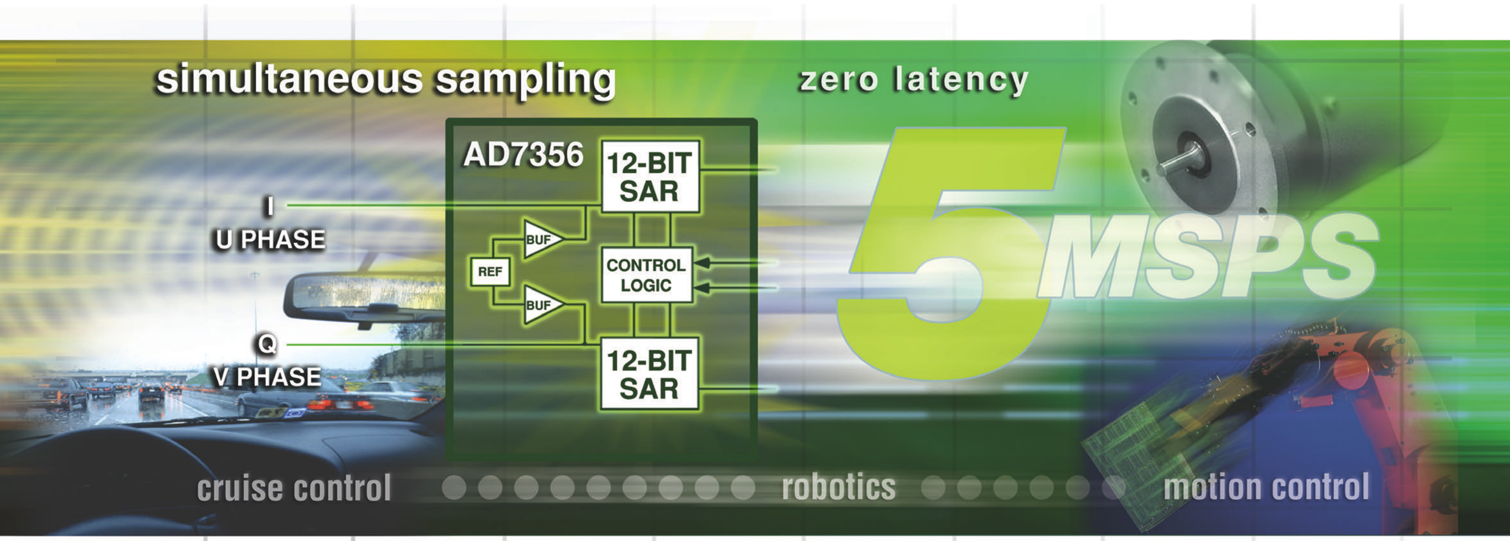

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ANALOG DEVICES

BY HOWARD JOHNSON, PhD

Initial condition

The PCB (printed-circuit-board) transmission line in **Figure 1a** lacks an end termination. If you leave switch S_1 closed for a long time, the line comes to rest in a state with precisely 0V at all points. The transmission line in **Figure 1b** behaves similarly. With S_2 closed, it also comes to rest in a state with 0V at all points. The voltages in the two situations are the same, but the currents differ. In the first case, the line at rest carries no current. In the second case, the end termination supplies a substantial current as long as you hold the line in a low state. To make the numbers easy, assume 2V logic, a perfect switch at the source, and values of 100Ω for both R_1 and R_2. Those values produce a steady-state current of 20 mA for **Figure 1b**.

At time zero, with both lines in their respective steady-state conditions, open both switches. In the case of **Figure 1a**, just before you open the switch, no current flows through it. Opening S_2 therefore changes nothing; it has no effect on the circuit. Opening S_1 in **Figure 1b** has a different effect. In the steady-state condition, 20 mA spills continuously through the switch. When you interrupt that state of events by opening S_2, the current at the left end of the line changes from 20 mA to 0A. You can emulate that effect with a superposition of two linear-current sources, I_B and I_C, which connect (**Figure 1c**).

Current source I_B replaces the 20 mA of steady-state current flowing through S_2 in **Figure 1b**. It sets the initial conditions before your switching event, and it perpetually sinks 20 mA. At time zero, a 20-mA step of current from source I_C cancels the current from source I_B, bringing the net current to 0A. The combination of two sources duplicates the conditions at the left of **Figure 1b** the moment S_2 opens. The linear-current-source model clarifies the actions that occur at time zero. Directing a positive step of 20 mA into the line must create a positive-step-voltage waveform moving to the right with an amplitude of 20 mA×50Ω=1V. In a 2V system, that scenario makes a half-sized step.

If your goal is to inject a total voltage step of 2V into the line, making a full-sized step, which initial state do you prefer? Starting with **Figure 1a**—that is, with no termination—you must do all the work with the top half of your totem-pole driver, sourcing a full 40 mA to create a full-sized signal. Most drivers can't source that much current. On the other hand, a circuit with a symmetric end termination enjoys the benefit of sinking 20 mA the entire time it holds low. When the bottom half of the totem-pole driver lets go, the line voltage at the source automatically jumps up halfway. The top half of the totem-pole driver then needs only to source the other half of the current (20 mA) to bring the line up to full voltage. A symmetric end termination biases the line at a halfway voltage, so that the driver need source or sink only enough current to swing the line halfway either direction. That's why I like it. **EDN**

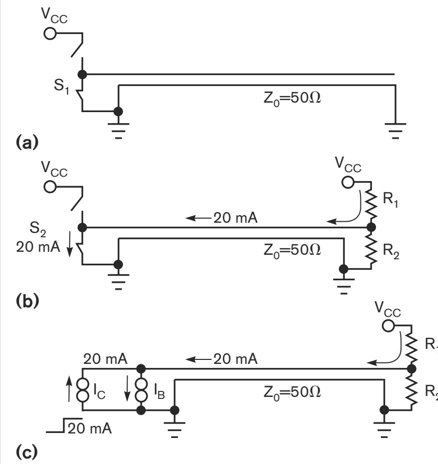

Figure 1 End termination R_1/R_2 establishes an initial current before switching high. If you leave switch S_1 closed for a long time, the line comes to rest in a state with precisely 0V at all points (a). The end termination supplies a substantial current as long as you hold the line in a low state (b). When you interrupt that state of events by opening S_2, the current at the left end of the line changes from 20 mA to 0A. You can emulate that effect with a superposition of two linear-current sources, I_B and I_C, which connect (c).

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Howard Johnson, PhD, of Signal Consulting, frequently conducts technical workshops for digital engineers at Oxford University and other sites worldwide. Visit his Web site at www.sigcon.com or e-mail him at howie03@sigcon.com.

NOISE FROM CELL PHONES, DIGITAL OSCILLATORS, AND EVEN FLUORESCENT LIGHTS IS ASSAILING YOUR ELECTRONIC DESIGNS. LEARN WHAT CAUSES THIS NOISE AND WHAT YOU CAN DO TO INCREASE YOUR SYSTEM'S IMMUNITY TO RADIO-FREQUENCY INTERFERENCE.

RFI: KEEPING NOISE OUT OF YOUR DESIGNS

BY PAUL RAKO • TECHNICAL EDITOR

Steady streams of RF energy constantly engulf your electronic system. Some of this energy comes from the accidental byproduct of a system; other RF sources, such as radios and radar, intentionally radiate energy. Some RF sources are so strong and so insidious that they create noise in simple wires, such as the magnet wire that forms the voice coil of a speaker. It is merely annoying for consumers to hear noise in their home-audio systems. However, RF noise that causes a machine to go haywire or an airplane's instruments to malfunction could imperil or even kill people. For this reason, the European Union and the United States instituted RFI (radio-frequency-interference) testing for products that vendors sell there. When the European Union more than a decade ago instituted the CE (Conformité Européenne) immunity-compliance tests, engineers soon learned that passing them is more difficult than passing the US FCC (Federal Communications Commission) noise-radiation tests. "Engineers don't think it is a problem until it is a problem for them," says Steve Bible, Microchip Technology's technical-staff engineer. "They are in a real time crunch. They have made a bad design, and it's hard to convince them that it's bad. They want to find that one silver bullet—the one thing they can do so they can pass—except there is no silver bullet."

To provide your systems with robust RFI immunity, you must understand just how many RF sources your system is subject to. The electric-power industry broadcasts 50- or 60-Hz radio waves as it sends power to your house. Your watch has a 32-kHz crystal that emits energy. Electronic ballasts for fluorescent lights operate at 40 kHz. Traffic lights use loop sensors that energize at 50 to 100 kHz. At higher frequencies, you soon encounter "intentional radiators," which the FCC defines as radio stations; TV stations; and various private, public, and military radios, some of the most troublesome of which are cell phones. Radar systems and exotic military systems lie even beyond cell phones on the frequency spectrum. Cosmic rays also cause problems (**Reference 1**). It is difficult to help a customer with an RFI-susceptibility problem because hundreds of ways exist to hook up an amplifier in a signal path, according to Steve Sockolov, product-line director for Analog Devices' precision-linear-products group. You also must worry about a continuum of source frequencies. To help customers with precision-measurement circuits, Analog Devices has developed the AD8556 sensor-signal amplifier, a functional equivalent of the AD8555 amplifier, except that the AD8556 has EMI (electromagnetic-interference) filters on the input pins, the reference pin, and the clamp pin. These filters help suppress RFI across a wide range of frequencies.

Not all RFI sources are causes for concern. The aforementioned watch crystal operates at a relatively low frequency and transmits minuscule power levels. Other sources may or may not be problematic. For example, you may use a FET as a low-side switch in a synchronous buck regulator. The FET's package case connects to the switch node and swings the entire power-supply voltage (**Figure 1**). Because this node operates at the power-supply frequency, you would think that it would radiate RF energy, but it may not. To radiate RF, current must be flowing. By using the package pin to carry the current and using the package tab to absorb the heat of the circuit, a clever designer can cool the FET and minimize RF radiation.

One way to solve an immunity problem is to stop the RF source. Automotive engineers decades ago learned this technique when they first installed radios into automobiles (see **sidebar** "Insidious RF" at the Web version of this article at www.edn.com/080110df). It soon became evident that barring noise from the radio was a difficult process, whereas killing the noise at its source was an effective technique. The engineers achieved this goal by adding capacitors to the alternator. The capacitors suppressed the diode-switching spikes, minimizing circulating currents and, thus, noise (**Reference 2**). The use of these techniques, along with tight layouts, will help you pass FCC radiation tests. Using these methods also subtracts one source of RFI that may cause immunity problems.

The biggest problem in RFI arises because you often have no control over the RF source that is polluting your system, such as the source you encounter in cell phones, which operate at high frequencies. This RFI can enter many parts of your design: the cables, the PCB (printed-circuit-board) traces, and even the ICs themselves. In addition, cell phones are everywhere, often sitting next to or atop your design while you are working on it. A few anecdotes tell the story: Bob Thomas, an engineer with Cisco Systems, reports that, when he sets his cell phone in the package tray of his 2006 Honda, the noise it radiates into the radio is louder than the music that the radio emits when it is on. Another Cisco engineer, Steve Abe, notes that placing his cell phone on his Palm Zire causes the Zire to reboot whenever he receives an incoming call. Francis Lau, an engineer with FM-transmitter manufacturer Aerielle, says that the stereo in his home makes a buzzing sound when he is about to get a call on his cell phone.

To understand why cell phones can be sources of RFI at audio frequencies, you must examine the RF-transmission protocols. The NADC (North American digital-cellular)-phone system uses the TDMA (time-division/multiple-access) protocol, which multiplexes digital-traffic channels—that is, voice data—into time slots. A sequence of six time slots makes up a 40-msec frame. In a full-rate traffic channel, a user transmits twice in each frame, meaning that a user assigned to the first time slot transmits again in the fourth time slot. By transmitting twice in each frame, the cell phone picks up EMI that looks like a square wave with a 20-msec, 50-Hz period (**Figure 2**).

AT A GLANCE

- RF sources can transmit energy into cables, PCB (printed-circuit-board) traces, and ICs.
- Symptoms of RF susceptibility can be tricky to diagnose.
- The best technique is to kill noise at its source.
- Shielding is a high cost Band-Aid.
- Careful layout and good system design can provide the best protection from RFI (radio-frequency interference).

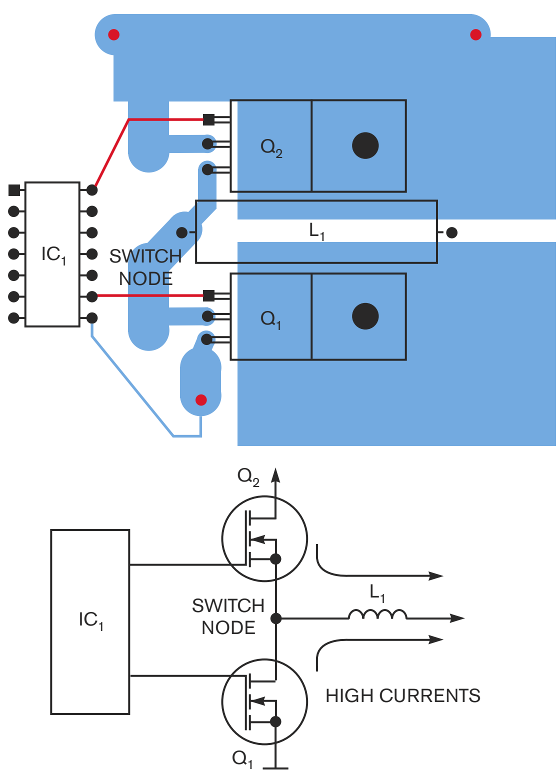

Figure 1 A copper pour forms a large heat sink that may look problematical from an EMI perspective. Because it carries no current, however, the heat sink does not radiate large amounts of RF energy.

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Max Readings/s (continuous to PC)	19	1,000	10,000	50,000
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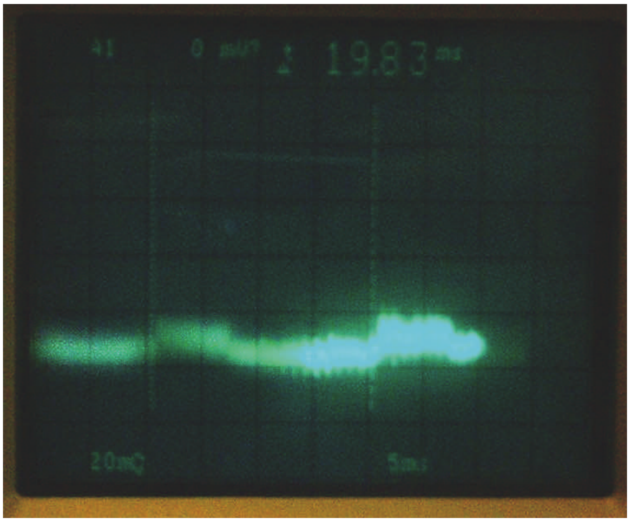

Figure 2 The TDMA phone standard uses radio protocols that result in bursts of RF at 50 Hz. You hear the demodulation of the signal envelope in stereos and clock radios.

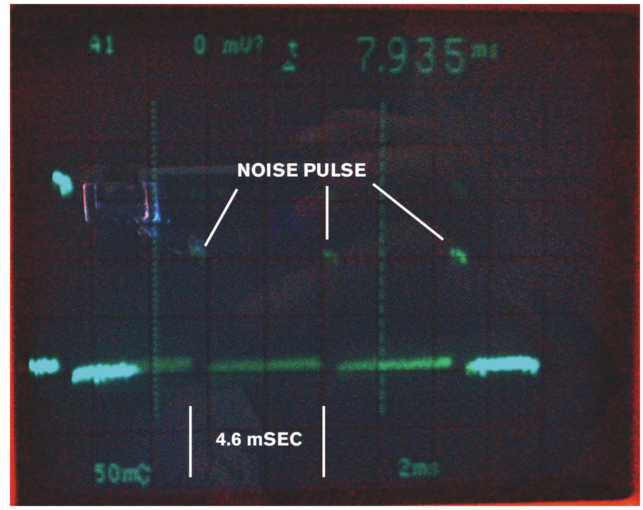

Figure 3 The GSM standard has a signal envelop with a 217-Hz frequency. Because power levels are higher and the human ear is more sensitive at 217 Hz, these phones can produce large interference problems.

In contrast, the GSM (global-system-for-mobile)-communication protocol specifies a 33-dBm transmission once every 4.6 msec, causing greater interference than the TDMA protocol, which transmits at 20 dBm (**Figure 3**). **Figures 2** and **3** represent interference in a real-world system, and, in this case, the GSM interference is 100 mV versus 5 mV for the TDMA phone. The interference you hear in your car stereo and clock radios is not a 900-MHz burst but a repetitive envelope of those bursts that occur in ICs and even in wire due to the nonlinearity in the system. RF consultant James Long advises that all electronic devices have a transfer function that is a power series of the input signal. That is, $V_{OUT}=V_{IN}\times k1+V_{IN}^{2}\times k2+V_{IN}^{3}\times k3$, a series that continues to infinity, with k representing a constant. As a result, many extra frequencies, including the demodulated baseband of the interfering signal, occur. Nonlinear circuits include those that depend on feedback to reduce distortion. At higher frequencies, the feedback effect is nonexistent, and the system does not suppress RFI (**references 3**, **4**, and **5**).

Input-protection diodes and other junctions in analog ICs demodulate the frequencies that PCB traces and ground and power planes pick up, and this demodulated signal appears as audio-frequency noise. At 1 GHz, the IC itself is not an effective antenna for typical RF emissions. The tiny bond wires and capacitances are more susceptible to frequencies in the tens of gigahertz, far above the excitation frequencies that cell phones cause. Different ICs of the same type or from different manufacturers behave differently, depending on variations in input capacitance or lead-frame inductance, but they are still susceptible to RFI. To combat the problem, National Semiconductor designed the LMV851 op amp to reject RFI. The company has devised the EMIRR (EMI-rejection-ratio) figure of merit that quantifies how well various pins of the IC reject RFI (**Reference 6**).

FET and CMOS op-amp input structures are less prone to demodulation effects than bipolar amplifiers are. Still, Kumen Blake, principal applications engineer at Microchip Technology, points out that CMOS parts can detect RF if you drive the inputs hard enough. "Even CMOS will reverse-bias and create a transistor junction [under RF radiation]," he says. "Any op amp can convert RF or microwave energy into a dc signal. Many customers don't understand what symptoms they will see if they have an EMI problem. A dc shift can be a symptom. A change in power level means there's a good chance that RFI caused some oscillation. Another symptom is distortion of the signal, whether the frequency changes or whether harmonic distortion appears. The worst symptom is erratic behavior: The circuit just does not work right all the time."

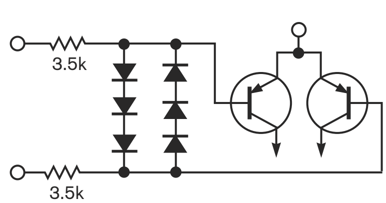

Figure 4 The input pins of this op amp have series resistors and large capacitive-clamp diodes to protect it from ESD. An added benefit is that the part is more immune to RFI (courtesy Maxim Integrated Products).

Some ICs use the resistance of the input structure to decouple the RF from inside the amplifier. Even a small input resistance can work with the stray capacitance of the amplifier's ESD (electrostatic-discharge)-protection diodes and other structures to effectively bypass the RF to ground. For example, Maxim uses this technique to provide ESD protection on the LMX324 op amp and to provide RFI immunity (**Figure 4**). The downside is that the resistors limit bandwidth and slightly reduce phase margin.

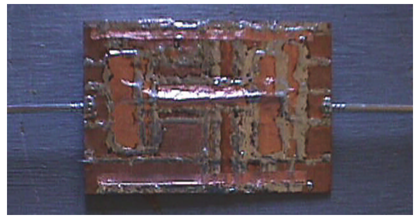

Figure 5 This copper-clad board has two antennas soldered to opposite sides of the same ground plane. When you operate circuits with fast edges on the board, the antennas radiate significant amounts of RF, even though they galvanically connect (courtesy Glen Dash).

A ground or power plane has more than enough impedance to cause RFI reception or transmission through the wires that attach to the plane. You cannot assume that a 20×20-cm PCB with a ring-style ground plane is equipotential—that is, that every point in the plane is at the same potential (**Reference 7**). Glen Dash, the author of numerous papers on the laws and standards applicable to electronic equipment, soldered two antennas onto the sides of a copper-clad PCB and produced a significant amount of EMI by misrouting the digital chips on the board, causing large, fast-changing currents (**Figure 5**). Experienced engineers looking at the telescopic antennas soldered to a common plane would think that the system would not radiate RF, but they would be wrong.

RF-SUSCEPTIBILITY RULES

To understand the theory behind RF susceptibility, you need to know three general design rules: Low impedance is preferable to high impedance, small loop areas are preferable to large ones, and short wires are preferable to long ones. Some engineers believe that, when everything else fails to solve the problem, they must put the system into a shielded enclosure, but this option is costly and often impractical. "If designers want to avoid that expense, they have to do a good PCB layout," says Microchip's Bible. Consider that a wire in space is an antenna. If the wire's connection to ground is a 1-MΩ resistor, then the wire's voltage will vary more widely than if its connection to ground is a 5Ω resistor. Gaussian law dictates routing two signal-carrying wires close together rather than in a big loop because using bigger loops means that the wire will pick up more voltage for a given RF-field strength. An antenna also works better when it is the same length as the wavelength of the RF field. A 1-cm wire with one side that attaches to earth ground has a 0V signal all along its length for frequencies of less than 1 GHz. At 900 MHz, a 3-in.-long wire becomes a quarter-wave antenna. Even an eight-wave antenna can bring significant RF energy into your systems. These facts highlight the importance of using short traces and tight layouts. The following rules detail ways that you can minimize both susceptibility and RF emissions:

- Attach all cables to ground, the power plane, or both at the same point.
- Connect the sensor ground near where the sensor wire connects to the input chip.
- Run sensor wires next to each other as pairs, even if one side of the sensor is ground or power. This approach ensures that common-mode interference does not become single-ended noise that an amplifier cannot reject.
- Route the sensor wires between the ground and power planes, and arrange the decoupling capacitors in a uniform pattern across the planes.
- Keep the circuit's impedances as low as possible within the limits of the components' power dissipation and the product's power consumption.
- Lay out the circuit using as little space as possible and the smallest components possible within the limits of manufacturability and power dissipation.
- Keep a uniform ground plane, and use discipline in placement and routing to ensure that digital noise stays outside the analog circuits.
- Reference power-supply circuits with large ac circulating currents to a topside copper pour, and then tie them to the ground plane at the output capacitor's common terminal.

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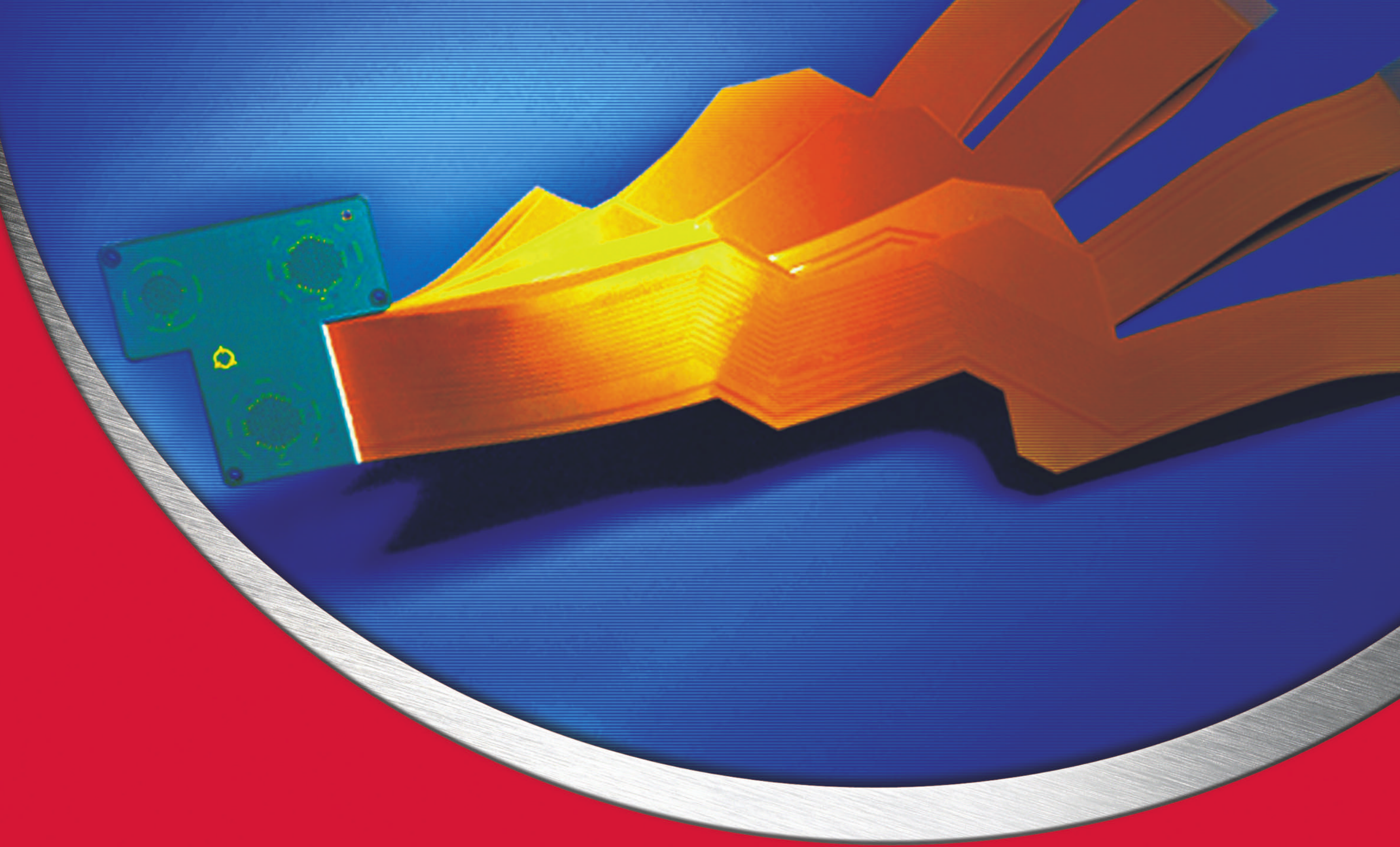

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- Create a filtered power supply for each IC that requires it. Any power plane measuring larger than 1 in. is susceptible to RFI.
- Send low-impedance signals over any long cable runs.
- Run signals in a stripline between two planes.
- Use differential signals that don't depend on ground or power if possible.
- Use 100-pF capacitors to filter out RF. The self-inductance of a 0.1-μF capacitor makes it useless at RFs. Use the manufacturer-supplied impedance chart to ensure that the capacitor you select has low impedance at the frequencies you want to suppress (**Reference 8**). The layout can have footprints for low-value capacitors between op-amp input pins, on signal-path power pins, and on other sensitive nodes.

The art of analog design is knowing how to make trade-offs to achieve the desired result. Many designers do a basic debugging of their PCBs with the signal layers on the outside. After meeting the fundamental requirements, they then make the prototype board with the power and ground planes on the outside. This approach puts all the long traces that might radiate or be susceptible to EMI into a gaussian cage that the outer layers form. You can stitch vias along the edges and to separate areas. The vias can connect two outer ground planes on a six-layer board and can feed to decoupling capacitors on a four-layer board on which power is one of the outside planes. A tight, low-impedance layout with careful thought about how the signals tie into the digital system takes considerable work, but this work is essential to ensure that a system has good RFI and EMI immunity.

If you can do nothing to eliminate the source of the RFI, you must ensure that as little of it as possible couples into your circuits. After that step, judicious choice and diligent characterization of the ICs you pick for the design can improve RFI immunity. **EDN**

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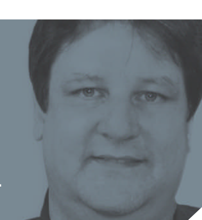

ANALOG edge℠

Noise Figure Analysis – Fully Differential Amplifier

Application Note AN-1719

Mike Ewer, Application Engineer
Robert Malone, Design Engineer

Fully Differential Feedback Amplifiers (FDA) such as National's LMH6550, LMH6551, and LMH6552 are used to provide balanced low-distortion amplification and level shifting to wide bandwidth differential signals. A simplified conceptual diagram of an FDA is shown in *Figure 1* where two forward paths amplify the two complementary halves of the differential signal. A separate common mode feedback circuit controlled by the V_{CM} control input sets the output common mode voltage independent of the input common mode, as well as forcing the O_N and O_P outputs to be equal in magnitude and opposite in phase.

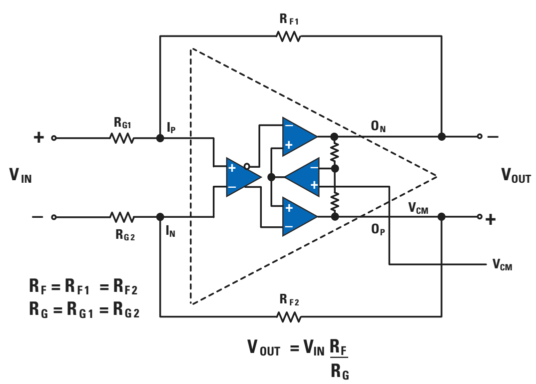

Figure 1: Simplified Conceptual Diagram of Fully Differential Amplifier

The LMH6552 is a 1.5 GHz device which allows operation at gains greater than unity with exceptional gain flatness without sacrificing bandwidth. With 450 MHz of 0.1 dB unity gain flatness the device is ideally suited to driving a range of 8- to 14-bit high-speed ADCs.

In designing an FDA to drive an ADC it is required to ensure that the FDA does not degrade the ADC's Signal-to-Noise and Distortion (SINAD) performance. A key element of this analysis is determining and optimizing the noise performance of the FDA. Voltage Feedback (VFB) FDAs have historically been constrained to operating at low gain due to their poor noise performance at higher gains. The LMH6552 CFB architecture overcomes this constraint, delivering a noise advantage as well as a gain bandwidth advantage over alternative VFB devices.

Output Noise Calculation for Fully Differential Amplifiers

A general purpose FDA noise model is shown in *Figure 2*. I_{NP} and I_{NM} are the input-referred noise currents for the FDA's positive and negative input terminals respectively,

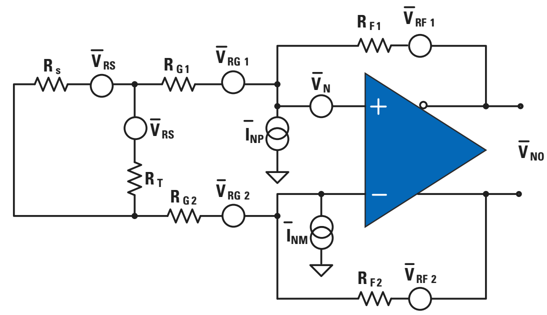

Figure 2: Fully Differential Amplifier Noise Model

and V_N is its input referred noise voltage. Included in the model are noise sources associated with resistive elements in the feedback and source termination networks.

The total output referred noise density V_{NO} in nV/√Hz, is calculated by taking the root square sum (rss) of the output referred noise from each source in the model. Separate the equation for V_{NO} into two components; the first being due to the input referred noise from the FDA, V_{NOFDA}, and the second due to thermal noise from the resistive feedback network, V_{NOFB}.

$$\overline{V_{NO}} = \sqrt{\overline{V_{NO_{FDA}}}^2 + \overline{V_{NO_{FB}}}^2}$$

CMRR and balance error are key. The differential feedback network is balanced by selecting $R_{F1}=R_{F2}=R_F$ and $R_{G1}=R_{G2}=R_G$, so both positive and negative feedback factors are matched and symmetric. Replacing RS and RT with their Thevenin equivalent source resistance, $R_{STH}=R_S||R_T$, the FDA and feedback network output noise densities are:

Equation 1

$$\overline{V_{NO_{FDA}}}^2 = \overline{V_N}^2\left(\frac{R_F + R_{G_{EQ}}}{R_{G_{EQ}}}\right)^2 + \overline{I_{NP}}^2 R_F^2 + \overline{I_{NM}}^2 R_F^2$$

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Equation 2

$$\overline{V_{NO_{FB}}}^{2} = 4kT(2R_F) + 4kT(2R_G)\left(\frac{R_F}{R_{G_{EQ}}}\right)^2 + 4kTRs(R_{S_{TH}})\left(\frac{R_F}{R_{G_{EQ}}}\right)^2$$

$$R_{G_{EQ}} = R_G + \frac{R_S \| R_T}{2}$$

The impact of external resistor noise is determined by the differential feedback topology ***(Equation 2)***, regardless of whether a CFB or VFB FDA is chosen. However, the influence of the FDA on total output noise density ***(Equation 1)*** can largely be influenced by the choice of FDA architecture.

In a VFB FDA, the differential input impedance is very high (usually hundreds of KΩ to several MΩ), and noise sources internal to the FDA will tend to refer to the input as voltages. Consequently, input referred noise currents will be quite small, on the order of a few pA/√Hz, and will only contribute a significant portion of the total output noise when RF is large, which is usually not the case. Note that the gain term for V_N in ***Equation 1*** is simply the reciprocal of the equivalent feedback factor β_{EQ} which is related to the differential amplifier's closed loop gain G by:

$$G = \frac{R_F}{R_{G_{EQ}}} = \frac{1}{\beta_{EQ}} - 1$$

In other words, operating a VFB FDA at high values of gain is necessarily accompanied by a proportional increase in output noise density, and can lead to degradation of overall noise performance when the FDA is a significant source of noise in a system.

A very different result arises when a CFB FDA, such as the LMH6552, is considered. Here the differential input stage is essentially a current controlled current source, with ideally zero differential-input impedance. As a consequence, noise sources internal to the amplifier tend to refer to the inputs as currents, rather than as voltages, and the total FDA output noise will be dominated by the sum of input noise currents I_{NP} and I_{NM} multiplied by the feedback resistor squared.

Unlike a VFB FDA, the output noise of a CFB FDA depends on the value of R_F rather than on the amplifier's gain. Hence, increasing the gain by reducing R_G does not appreciably degrade the noise performance of the circuit. This is an extremely important result and highlights one of the key advantages of using a CFB FDA over a VFB FDA in differential signaling applications.

Noise Figure Calculation for Fully Differential Amplifiers

Noise performance is often described in terms of the system noise figure, which is 10 log of the signal-to-noise ratio at the system's input, divided by the signal to noise ratio at its output. Noise figure is a quantitative measure of how much noise is added to a given signal as it propagates through a processing chain. For amplifiers it can be conveniently expressed as the ratio of output noise density to source noise density by the following equation.

The product GD_T is the voltage gain of the amplifier from V_S to V_O including the signal attenuation of the input termination network.

To highlight the difference in noise performance between CFB and VFB FDAs, the application circuit of ***Figure 3*** is used to calculate the output noise spectral density and noise figure at various values of gain using both the LMH6552 (CFB) and LMH6550 (VFB) FDAs in a 100Ω system. R_F is held at 301Ω and the termination resistor R_T is adjusted at each value of gain to maintain a 100Ω differentially terminated input. The results are presented graphically in ***Figure 3***.

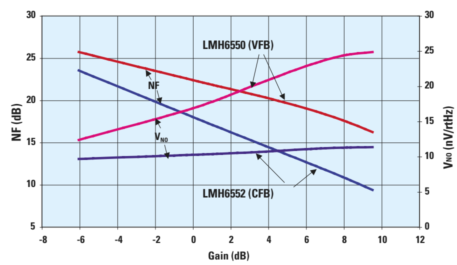

Figure 3: Noise Figure and Voltage Noise Spectral Density vs Gain

Conclusion

The choice between a current or voltage mode FDA may depend on many factors and will ultimately come down to which amplifier works better within a given system specification. Where low-noise, wide-bandwidth applications require the FDA to be configured for larger than unity gain CFB FDAs can offer an elegant solution.

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BY MAURY WRIGHT • EDITORIAL DIRECTOR

DESIGNERS PURSUE NEXT-GENERATION WIRELESS DEVELOPMENTS WITH MODULATION-AWARE TEST TOOLS, THOUGH EVOLVING STANDARDS PRESENT PROBLEMS FROM THE PHY TO THE DATA LAYERS.

Designers working on wireless systems face a moving problem: In applications including 3G/4G cellular, WiMax, Wi-Fi, and UWB (ultrawideband), there is a constant progression to new, more complex standards. The development work—especially at the chip level—happens concurrently with standards development. Test-equipment companies are still finding ways to deliver products that allow development to proceed. The test tools increasingly include standards-specific capabilities at the PHY (physical) and higher layers of the network stack. A look at some sample tools and usage scenarios may help your next design project—whether you are working on one of these wireless standards, on a custom project in the ISM (industrial/scientific/medical) bands, or on a wired connection.

From the test-equipment manufacturers' perspective, the challenge centers on anticipating the market. Jennifer Stark, WiMax program manager at Agilent, points to three constant trends. "The technology is moving to higher frequencies, wider bands, and more complex modulation schemes," she says.

Clearly, the more complex modulation schemes offer the stiffer tests, as the most effective test gear includes the ability to handle the modulation schemes in real time. The incredible amount of digital-processing power readily available in baseband ICs makes the advances in modulation possible. But what you can accomplish in a baseband IC provides no comfort to the test-equipment company. With standards being moving targets, the test vendors use a combination of DSPs, FPGAs, and software to essentially model the transmitting and receiving ends of a communications link. Indeed, most of the test companies agree that they must virtually overdesign every instrument to allow a margin for use with emerging standards.

Justin Panzer, manager of product marketing at Rohde & Schwarz, states, "In a design environment, engineers use test equipment to try to simulate a real-world environment." But again, how do you simulate a technology in flux? Panzer points out that standards typically build upon one another. He uses the emerging LTE (long-term-emulation) standard as an example. The 3GPP (Third Generation Partnership Project) is developing LTE as a 3.5 or a 4G follow-on technology in the GSM (global-system-for-mobile)-communications family of cellular standards. "You see a lot of similarities to WiMax [in

AT A GLANCE

- Wireless technologies push center frequency, bandwidth, and modulation complexity.
- Test companies scrutinize standards bodies but must anticipate the market.
- A signal generator, a signal analyzer, and modulation software can simulate a wireless network in the lab.
- Communication-test gear allows you to optimize the design of critical functions, such as the power amplifier.

LTE],” says Panzer. It appears that LTE will employ the OFDM (orthogonal-frequency-division-multiplexing) and OFDMA (OFDM-access)-modulation schemes that WiMax uses, but the frequency bands and channels differ. Most observers believe that LTE deployment is at least two years away, but chip designs are well under way (**Reference 1**).

MILITARY SCHEMES

“Most things that are tried in the commercial space have been tried in the military space,” says Agilent’s Stark. She claims that military LMDS (local-multipoint-distribution-service) and MMDS (multichannel-multipoint-distribution-service) systems were forerunners of the fixed flavor of WiMax. But, Stark adds, “Mobile WiMax is an enormous build on fixed WiMax.” Mobile WiMax requires that base stations hand off calls as the client moves. But a Mobile WiMax system can’t rely on channel assumptions that develop over time with a fixed client.

All of the test companies participate at some level in the standards bodies and therefore enjoy some visibility in shaping the direction of and even having influence over some decisions. “You can see two, three, or even four years out sometimes in the standards bodies,” says Graham Celine, senior director of marketing at Azimuth Systems. He also notes that disruptive standards can arise. For example, on a standard for the 700-MHz spectrum, the FCC (Federal Communications Commission) will hold an auction in the United States in February. TV broadcasters are about to vacate this spectrum. The highest bidder could for years potentially influence the course of US broadband history. “Until someone wins that auction, nobody knows,” says Celine.

As an example of how test companies influence standards, consider a WiMax case. Antonio Policek, senior marketing manager in Tektronix’s communications-business unit, claims that Tektronix influenced the inclusion of a metering port in base-station designs. The company implements the metering port at the output of the baseband stage and allows a protocol analyzer to gather data without having an RF receiver in the instrument. It seems that the test community largely seeks to ensure that standards are testable. “Azimuth wants to make sure that the test models make sense and can reasonably be implemented in instruments,” says Celine.

MODELING WIRELESS SYSTEMS

It’s amazing how easy it is to model a wireless-communication system with modern test equipment in a development lab. National Instruments, for instance, offers a number of RF-signal-generator and -analyzer products in the PXI (peripheral-component-interconnect-extensions-for-instrumentation) and PXIe (PCI Express-extensions-for-instrumentation) form factors, which are essentially ruggedized versions of PCI and PCIe (PCI Express). You can use what’s essentially a PC with these hardware modules installed and completely model a cellular system using the company’s Modulation Toolkit software running on the LabView graphical-development environment. **Figure 1** depicts a symbol constellation and 3-D eye diagrams from a 16-QAM (quadrature-amplitude-modulation) system.

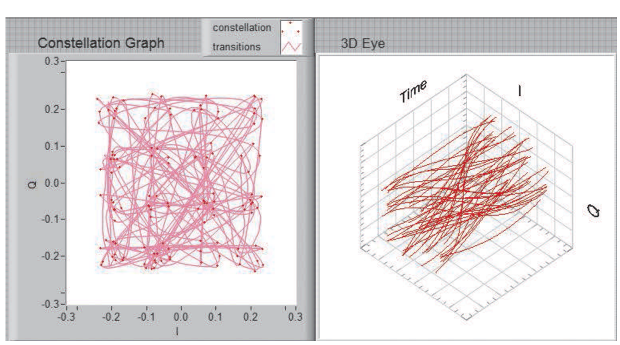


Figure 1 The Modulation Toolkit, which runs on National Instruments’ LabView, allows designers to quickly model wireless systems and offers diagnostic tools, such as this constellation and eye diagram.

A number of case studies illustrate the usage of the National Instruments tools. For instance, **Reference 2** describes a joint project between the University of Texas and Drexel University focusing on modeling MIMO (multiple-input/multiple-output) systems. The University of Texas also used LabView in 2003 to model early WiMax systems.

The modularity of National Instruments’ products also lends the tools to fieldwork. Recording RF energy in the field is one common task designers use to test products in the lab. It turns out that it’s tough to synthetically create the difficult environment that’s a reality in the field. David Hall, National Instruments product manager, points out that you can use one of the company’s VSAs (vector-signal analyzers) in a system with a hard drive to record five hours of a real-life environment that you can subsequently replay in the lab.

PUSHING FREQUENCY

To support testing and modeling of state-of-the-art wireless systems, the test companies must push their hardware design and add the software-based modulation tools. Going back to the three dimensions in which wireless technologies progress, Agilent’s Stark notes that individual standards tend to push in one or two of the dimensions but not in all three. She cites examples in WiMax and UWB. Stark claims that UWB, the most prevalent WiMedia flavor, uses a relatively simple modulation scheme but relatively wide 500-MHz channels. WiMax, conversely, uses relatively narrow 10-MHz channels but a complex modulation scheme. In both cases, the standards specify operation in the 5- to 6-GHz range.

Just the center frequency of a new standard can lead to the need for new hardware. Panzer of Rohde & Schwarz points out that the company’s CMU200 mobile-radio tester can work with virtually every cellular standard. But it operates only to 3 GHz, and, to support WiMax, the company had to develop the 6-

GHz CMW500 tester. And the hardware push doesn't stop there. To test a MIMO system, you would need two of the 6-GHz units.

Azimuth's Celine claims that MIMO was a difficult technology to support in test tools. Azimuth has focused on Wi-Fi and WiMax and bet on MIMO expertise early on as a way to differentiate the company. Celine points out that the channel emulator in a MIMO test instrument differs from the one in a traditional instrument. "In SISO [single input/single output], the emulator acts as an interference source," says Celine. "In MIMO, multipath is what makes the technology work."

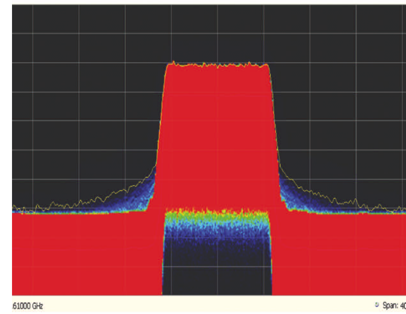


Figure 2 By continuously performing FFTs, Tektronix's real-time-spectrum-analyzer family can catch transients as short as 24 µsec, allowing the instruments to display overlapping-channel noise in OFDM systems.

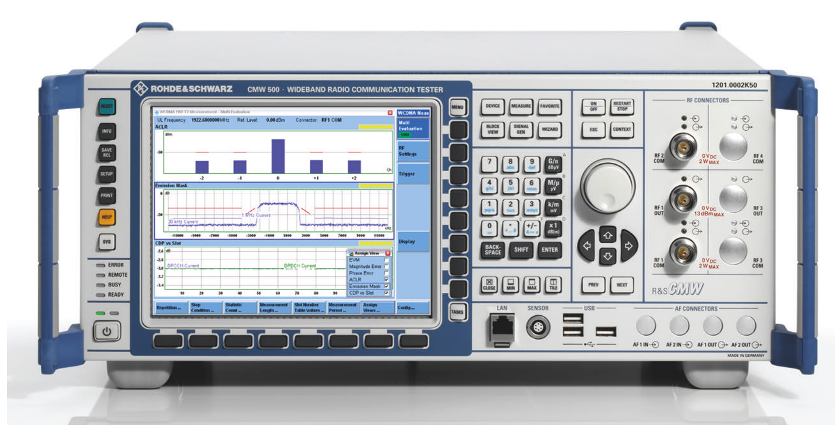
AMP OPTIMIZES EXPERIENCE

Some usage scenarios help illustrate other instrument features and design challenges and detail just how you might use such an instrument in the lab. Agilent's Stark points at the power amplifier as a crucial part of an OFDMA radio design for a standard such as Mobile WiMax. She claims that a poor power-amp design can result in poor battery life, range, and data rate—attributes of a product that ultimately matter a lot to the consumer.

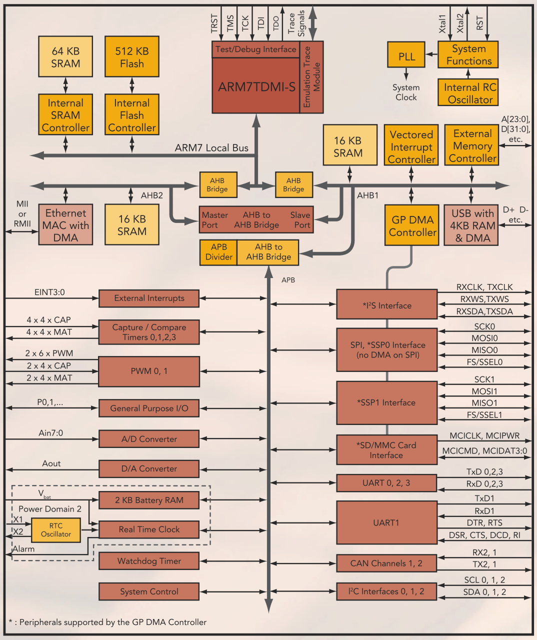
According to Stark, the power amplifier is an issue in the Mobile WiMax case, because the modulation scheme causes the design to drive the amp in a nonlinear range. Moreover, the output signal must change erratically and has a high peak-to-average ratio. The client side of a WiMax design also has space and heat constraints.

In this age of simulation and computer tools, you needn't build hardware to start a power-amp development. You can design and simulate the amp using Agilent's EEsof RF-modeling EDA tool. The EEsof tool can feed a signal generator, and you can use the 89600 VSA software on a PC to characterize your design. The VSA package runs on a PC and interfaces with a variety of Agilent oscilloscopes and signal-analyzer instruments.

Stark offers several examples of specifications that you can characterize and tune in this scenario. For example, a spec in WiMax and cellular standards that's commonly called either EVM (error-vector-magnitude) or RCE (relative-constellation-error) measures constellation accuracy. The power amplifier is one component that adds to EVM/RCE errors. A simple system that uses, say, BPSK (binary phase-shift keying) or 4-



With a frequency range to 3.3 GHz and optionally to 6 GHz, the Rohde & Schwarz CMW500 mobile-radio tester supports evolving standards, such as Mobile WiMax.



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QAM (four-phase QAM), widely spaces the modulation symbols, and such a system can tolerate a high EVM/RCE figure. But a 64-QAM (64-phase QAM) system has a tight error budget, and, according to Stark, the amplifier's design often contributes a maximum of 1% of that error budget.

You can perform EVM/RCE tests only on a working radio. But the simulation component in Stark's scenario allows testing and optimizing before committing the design to hardware.

AMPS POSE PROBLEMS

Darren McCarthy, worldwide RF-technology-marketing manager in Tektronix's instrument-business unit, agrees that power-amplifier design is crucial to battery life and performance in wireless clients. McCarthy points out the need in an OFDM or OFDMA system to minimize power leakage from one channel into another. The test for such an occurrence is the ACPR (adjacent-channel-power ratio), a measurement of the linearity in a system.

As noted, however, systems such as Mobile WiMax and LTE drive power amplifiers into nonlinear regions—negatively impacting the ACPR. Increasingly, designers are turning to techniques such as DPD (digital predistortion) to minimize ACPR. But DPD introduces a new problem: memory effects, which result from electrical traits, such as source and load impedance and electrothermal coupling.

Traditionally, designers use spectrum analyzers and software tools to measure ACPR. But McCarthy claims that such ACPR measurements measure average power and that traditional spectrum analyzers using a swept-spectrum approach miss transient signals, such as those that memory effects cause. Tektronix offers a family of real-time spectrum analyzers that continuously perform frequency-domain transformation to catch memory-effect transients. **Figure 2** shows a Tektronix digital-phosphor-spectrum display.

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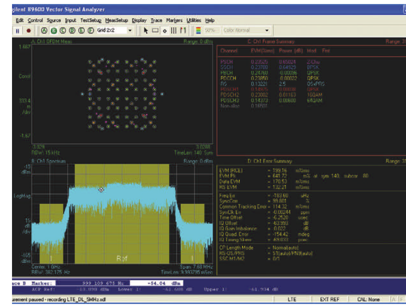

The 89601A LTE signal-analysis package from Agilent performs an EVM (error-vector-magnitude) measurement on an LTE downlink signal, and the package displays a constellation diagram.

The yellow curve indicates the maximum occurrence of noise in the adjacent channels. McCarthy claims that the instrument will capture any transient that lasts 24 µsec or longer.

Equally important, according to McCarthy, is the ability to tie the occurrence of a problem transient with the root cause. The instruments support frequency-masked triggering, and you can connect that trigger to a variety of other instruments. McCarthy claims that you can use such a trigger to locate the software instruction that caused a gain change in the amplifier and, therefore, the transient.

UWB AND OTHER STANDARDS

Wide-area wireless technologies aren't the only technologies that are changing. And designers certainly need good test gear for standards such as UWB. Tektronix's McCarthy claims that standards such as UWB and IEEE 802.11n offer special challenges because they offer "cognition of the environment." Such cognitive radios are especially important in standards that use the unlicensed spectrum, because the radios must avoid interfering with other transmitters.

The UWB community has developed the DAA (detect-and-avoid) technique to ensure that the broad transmissions don't interfere. Europe, Japan, and some other regions will mandate DAA. McCarthy points out that, although UWB's transmitting power is far lower than that of, say, a cellular transmitter, a UWB transmitter could still interfere with a cellular receiver. So, DAA basically specifies listening for a transmitter and

avoiding frequencies in which a transmitter is operating.

Several operational modes exist for DAA implementations. UWB features three 500-MHz channels among which UWB radios hop. In the simplest form, DAA does not use one of the three channels when another transmitter is present. In many cases, however, a system can take a more granular approach to avoiding interference. Using a tone-nulling technique, a transmitter simply avoids a narrow range of subcarriers within one of the 500-MHz bands. According to McCarthy, the Tektronix AWG7000 signal generator with optional UWB software allows design teams to test all DAA modes.

THE RUSH TO LTE

Looking forward, all of the test vendors are working feverishly on LTE products in the lab and shipping some products, as well. Panzer from Rohde & Schwarz claims that the company early on engaged with a leading chip vendor and has delivered gear that can handle PHY and RF tests. Indeed, the CMW500, which also supports WiMax, offers LTE support.

Azimuth's Celine maintains that the challenge everyone will face is effective MIMO support. He believes that the MIMO experience the company has gained with WiMax will serve it well in an upcoming LTE product. "LTE is in a very different frequency band," he says. "We are redesigning the RF front end, but that's easier than handling a new modulation scheme."

Regardless of what type of system you are working on, you might consider one common thought that all of the test vendors have voiced: Standards for technologies such as wireless communications don't provide design advice. "A standard document defines system performance," says Agilent's Stark. "It doesn't tell the engineer how to design." You probably knew that fact. But it means that you had better thoroughly test your design and that wireless channels probably offer more unknowns than any other environment in which you will ever work. EDN

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BY JIM WILLIAMS AND MARK THOREN • LINEAR TECHNOLOGY

Novel measurement circuit eases battery-stack-cell design

A TRANSFORMER AND DIODE ON EACH CELL ALLOWS ISOLATED MEASUREMENT.

Automobiles, aircraft, marine vehicles, uninterruptible power supplies, and telecom hardware use series-connected battery stacks. These stacks of individual cells may contain many units, potentially reaching hundreds of volts. In such systems, it is desirable to accurately determine each individual cell's voltage. Obtaining this information in the presence of the high common-mode voltage that the battery stack generates is more difficult than you might suppose.

The "battery-stack problem" has been around for a long time. Its deceptively simple appearance masks a stubborn problem. Designers have tried various approaches to isolated-cell-voltage measurement with varying degrees of success (see **sidebar** "Some battery-cell-measurement techniques just don't work" at the Web version of this article at www.edn.com/ms4255).

Figure 1's voltmeter measures a single-cell battery. Beyond the obvious benefits, the arrangement works because no voltages other than the single cell lie in the measurement path. The ground-referred voltmeter encounters only the voltage it is measuring.

Figure 2's stack of series-connected cells is more complex. The voltmeter must switch between the cells to determine each cell's voltage. Additionally, the voltmeter, normally composed of relatively low-voltage breakdown components, must withstand input voltages relative to its ground terminal. This common-mode voltage may reach hundreds of volts in large series-connected battery stacks, such as those in an automobile. Such high-voltage operation is beyond the voltage-breakdown capabilities of most practical semiconductor components, particularly if the application requires accurate measurement. The switches present similar problems. Attempts at implementing semiconductor-based switches encounter difficulty due to voltage-breakdown and leakage limitations. A practical method is necessary that would accurately extract individual cells' voltages and reject common-mode voltages. This method should not draw any battery current and should be simple and economical.

Figure 3's concept addresses these issues. To determine battery voltage, $V_{BATTERY}$, a pulse excites a transformer, T_1, and records its primary clamp voltage after settling occurs. The diode and the battery-voltage shunt primarily set this clamp voltage and similarly clamp T_1's secondary. The diode and a small transformer term are predictable errors, and the circuit's final stage substracts them out, leaving the battery voltage as the output.

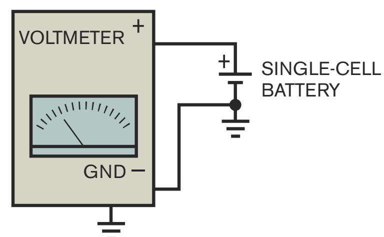


Figure 1 Common-mode voltage does not affect a voltmeter measuring a ground-referred single cell.

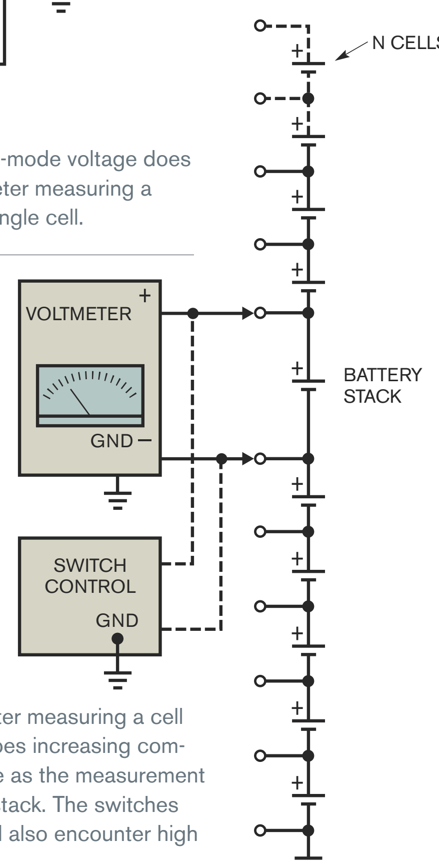


Figure 2 A voltmeter measuring a cell in a stack undergoes increasing common-mode voltage as the measurement proceeds up the stack. The switches and switch control also encounter high voltages.

DETAILED CIRCUIT OPERATION

Figure 4 details the transformer-based sampling voltmeter. It closely follows **Figure 3** with some minor differences, which

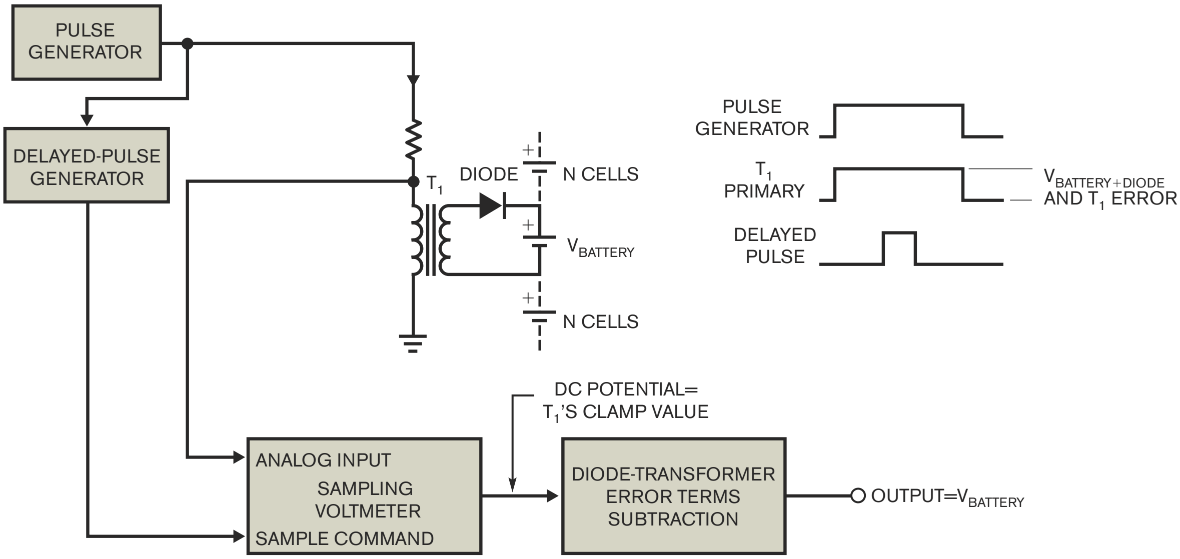


Figure 3 A transformer-based sampling voltmeter operates independently of high common-mode voltages. The pulse generator periodically activates T_1. The delayed pulse triggers a sampling voltmeter, capturing T_1's clamped value. Residual error terms are corrected in the following stage.

this article later describes. The pulse generator produces a 10-µsec-wide event (Trace A, **Figure 5**) at a 1-kHz repetition rate. The pulse generator's low-impedance output drives T_1 through a 10-kΩ resistor and triggers the delayed-pulse generator. T_1's primary, Trace B, responds by rising to a value representing the sum of the diode voltage and the battery voltage, along with a small fixed error that the transformer contributes. T_1's primary becomes clamped at this value. After a time, the delayed pulse, Trace C, generates a pulse, Trace D, closing S_1, allowing C_1 to charge toward T_1's clamped value. After a number of pulses, C_1 assumes a dc level identical to the voltage on T_1's clamped primary. A_1 buffers this potential and feeds differential amplifier A_2. A_2, operating at a gain near unity, subtracts the diode- and transformer-error terms, resulting in a direct reading of battery-voltage output.

Accuracy critically depends on transformer-clamping fidelity over temperature and clamp-voltage range. The carefully designed, specified transformer yields **Figure 6**'s waveforms. Primary, Trace A, and secondary, Trace B, clamping details appear at a highly expanded vertical scale. Clamping flatness is within millivolts; trace-center aberrations derive from S_1-gate feedthrough. Tight transformer-clamp coupling promotes good performance. Circuit accuracy at 25°C is 0.05% over a 0 to 2V battery range with 120 ppm/°C drift, degrading to 0.25% at a battery voltage of 3V. Designers of this circuit used a floating variable-potential battery (see **sidebar** "Floating-output, variable-potential battery simulator" at the Web version of this article at www.edn.com/ms4255).

Several details aid circuit operation. The circuit substitutes the transistor's base-emitter voltage for diodes, providing more consistent initial matching and temperature tracking. The 10-µF capacitor at Q_1 maintains low impedance at frequency, minimizing cell-voltage movement during the sampling interval. Finally, synchronously switched Q_2 prevents T_1's negative-recovery excursion from deleteriously influencing S_1's operation.

This approach's advantage is that its circuitry does not encounter high common-mode voltages; T_1 galvanically isolates the circuit from common-mode potentials associated with the battery voltage. Thus, you can employ conventional low-voltage techniques and semiconductors.

MULTICELL VERSION

The transformer-based method is inherently adaptable to the multicell-battery-stack-measurement problem. **Figure 7**'s conceptual schematic shows a multicell-monitoring version. Each channel monitors one cell. You can read any channel by biasing its appropriate enable line to turn on a FET switch, enabling that channel's transformer. The hardware for each channel typically includes only a transformer, a diode-connected transistor, and a FET switch.

AUTOMATIC CONTROL AND CALIBRATION

This scheme suits digital techniques for automatic calibration. **Figure 8** shows pulse generators, calibration channels, and measurement channels, which feed **Figure 9**'s PIC-16F876A microcontroller. As before, even though the cell stack may reach hundreds of volts, the transformer's galvanic isolation allows the signal-path components to operate at low voltage. The design includes an automatic calibration-circuit microcontroller and reset sections (**Figure 9**) and an automatic calibration-circuit USB interface for development only (**Figure 10**).

A further benefit of processor-driven operation is the elimination of **Figure 4**'s base-emitter-voltage diode-matching requirement. In practice, engineers tested a processor-based

board at room temperature with known voltages at all input terminals. They then read the channels, which furnished the information necessary for the processor to determine each channel's initial base-emitter voltage and gain. The engineers then stored these parameters in nonvolatile memory, permitting a one-time calibration that eliminates both base-emitter-voltage-mismatch- and gain-mismatch-induced errors.

Channels 6 and 7 provide 0 and 1.25V reference voltages, representing cell-voltage extremes. The room-temperature values reside in nonvolatile memory. As temperature changes occur, you use readings from channels 6 and 7 to calculate a change in offset and a change in gain that you apply to the six measurement channels. The calibration continues as temper-

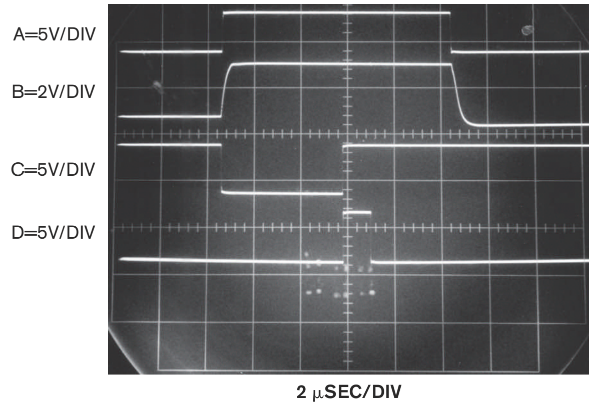


Figure 5 Figure 4's waveforms include the pulse-generator input (Trace A), the T_1 primary (Trace B), the 74HC123's $\overline{Q2}$ delay-time output (Trace C), and S_1's control input (Trace D). Timing ensures that sampling occurs when T_1 settles in the clamped state.

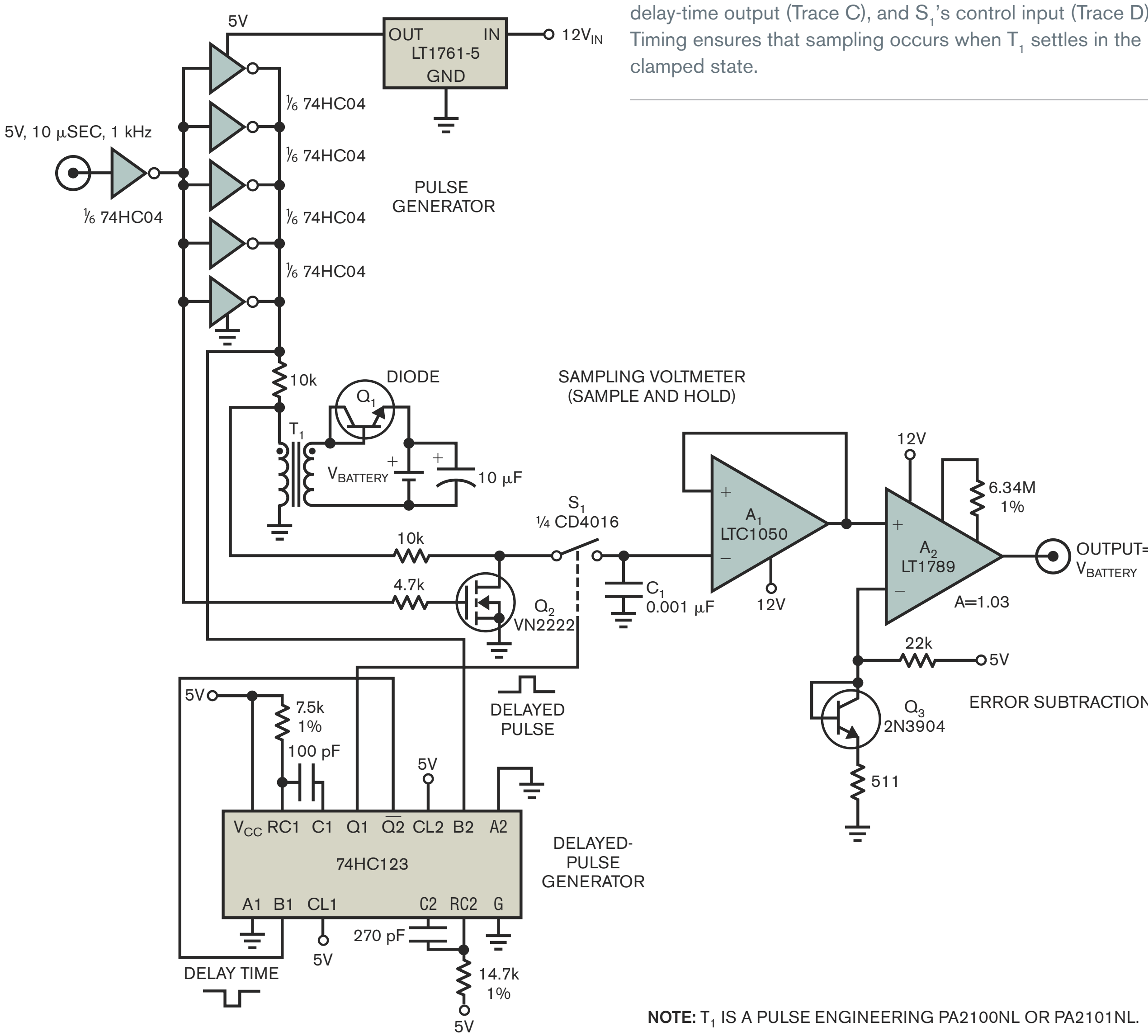
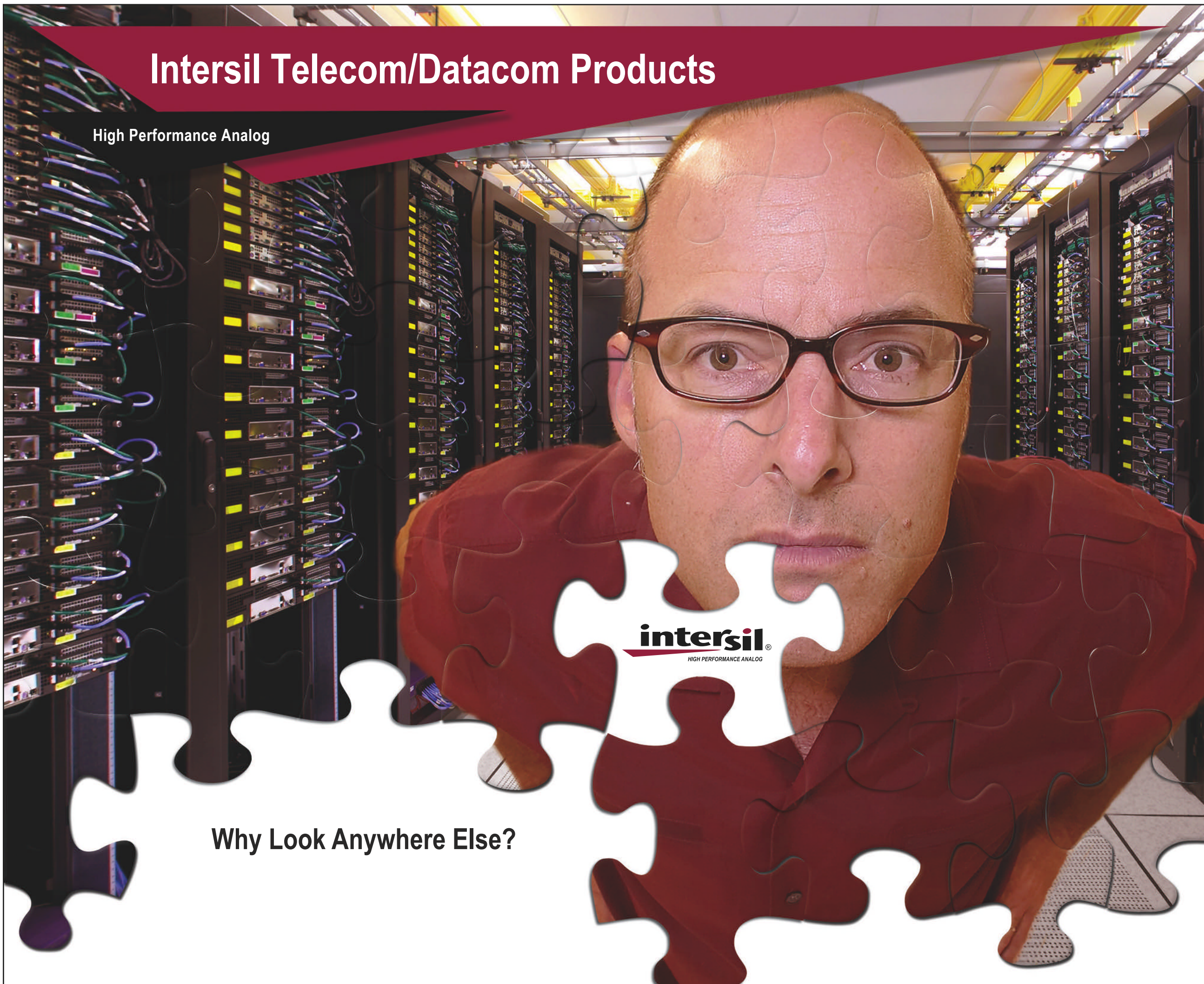


Figure 4 This transformer-fed sampling voltmeter closely follows Figure 3's concept. Error-subtraction terms include Q_3's compensation for Q_1 and resistor/gain corrections for errors in T_1's clamping action. Transistors Q_1, Q_2, and Q_3 replace diodes for more consistent matching. Q_2 prevents T_1's negative-recovery excursion from influencing S_1.



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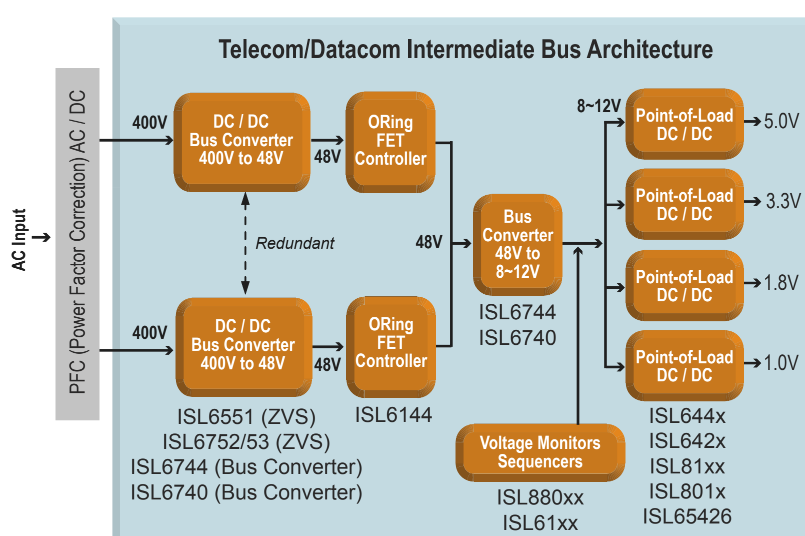

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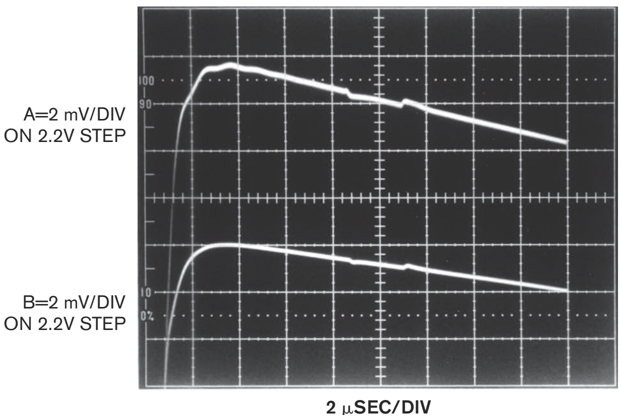

Figure 6 T_1's primary (Trace A) and secondary (Trace B) clamping details have a highly expanded vertical scale showing the primary's and secondary's clamping flatness to be within millivolts. The trace aberrations at the center derive from S_1's gate feedthrough.

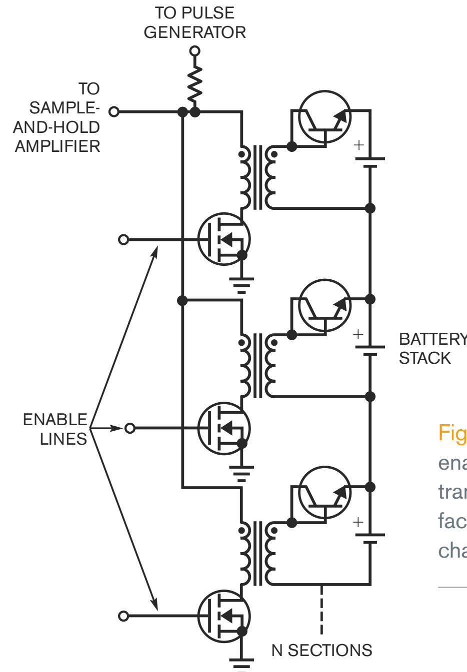

Figure 7 Adding enable lines and transistor switches facilitates multiple channels.

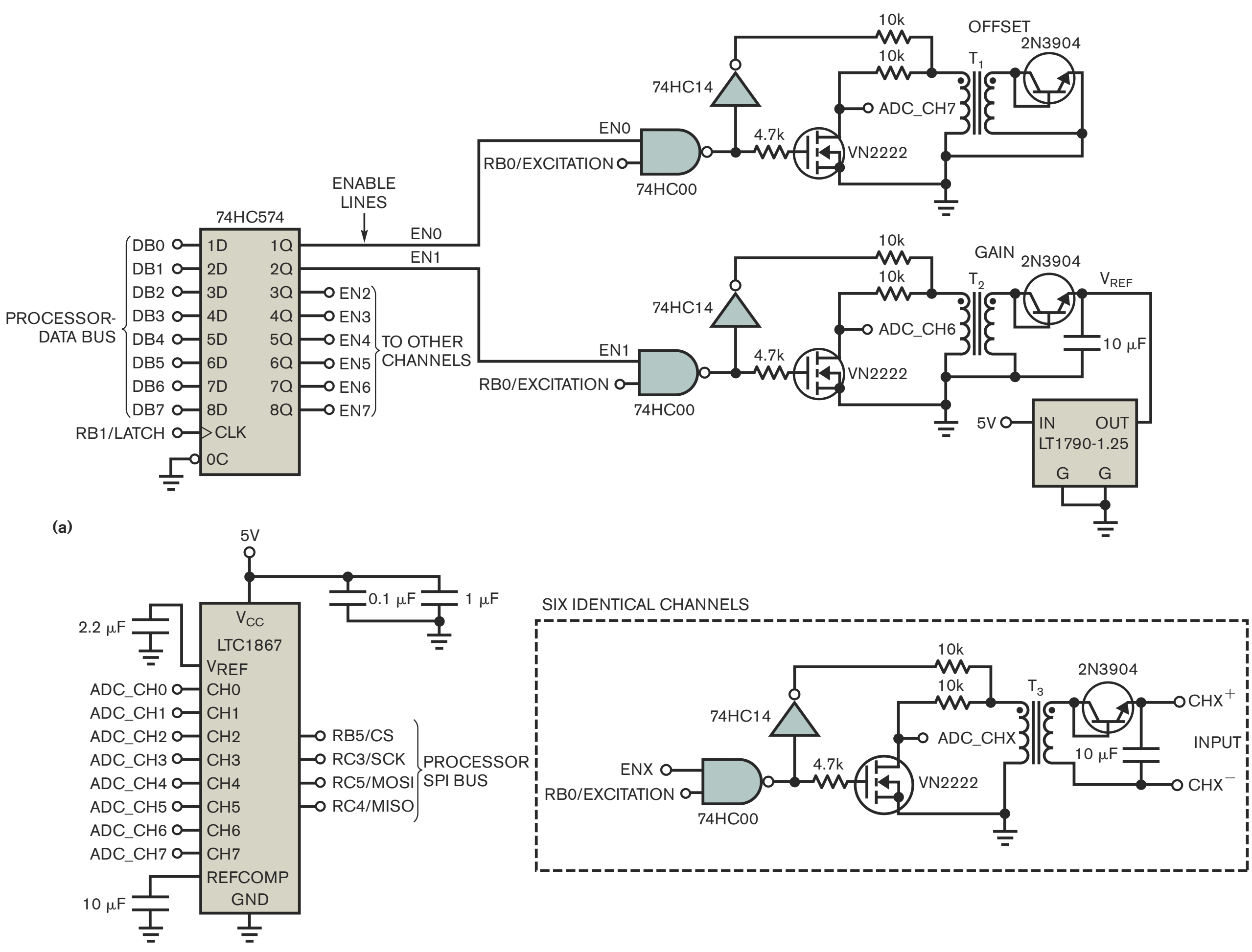

Figure 8 ADC-calibration channels eliminate base-emitter-voltage-matching requirements (a) and compensate for temperature-dependent errors (b).


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ature varies because each channel's −2-mV/°C base-emitter-voltage-drift slopes are nearly identical. Similarly, gain errors from channel to channel are nearly identical.

Because you are continuously calibrating the gain and offset, the gain and offset of the LTC1867 drop out of the equation. The only points that must be accurate are the 1.25V reference voltage, which an LT1790-1.25 IC provides, and the 0V measurement, which is easy: Just short the Channel 6 inputs together. The LTC1867 internally amplifies its internal 2.5V reference to 4.096V at the reference-comparator pin, which sets the full scale of the ADC: 4.096V for unipolar mode and ±2.048V in bipolar mode. Thus, the absolute maximum cell voltage that you can measure is 3.396V. And, because the offset measurement is nominally 0.7V at the ADC input, it is never in danger of clamping at 0V. A 0V reading results if the LTC1867 has a negative offset and the input voltage is any positive voltage less than or equal to the offset. Accuracy of the processor-driven circuit is 1 mV over a 0 to 2V input range at 25°C. Drift drops to less than 50 ppm/°C—almost three times lower than that in in **Figure 4**.

The complete firmware code, **Listing 1**, is available with the Web version of this article at www.edn.com/ms4255. The code for this circuit is a good starting point for an actual product. Data appears on a PC screen through an FTDI (Future Technology Devices International, www.ftdichip.com) FT242B USB-interface IC. The PC has FTDI's virtual-communications-port drivers installed, allowing control through any terminal program. Data for all channels continuously appears on the terminal, and simple text commands control program operation.

A timer interrupt occurs 1000 times per second. It controls the pulse generators and ADC and stores the ADC readings in an array that you can read at any time. Thus, if the main program is reading the buffer, the most out of date any reading is is 1 msec.

The software also includes automatic calibration routines. Two functions store a zero reading and a full-scale reading for all channels, including the calibration voltages you apply to channels 6 and 7, to nonvolatile memory. You subsequently use these functions to calibrate out the initial gain and offset errors, as well as the temperature-dependent errors. The entire procedure is to apply 0V to all inputs and issue a command to

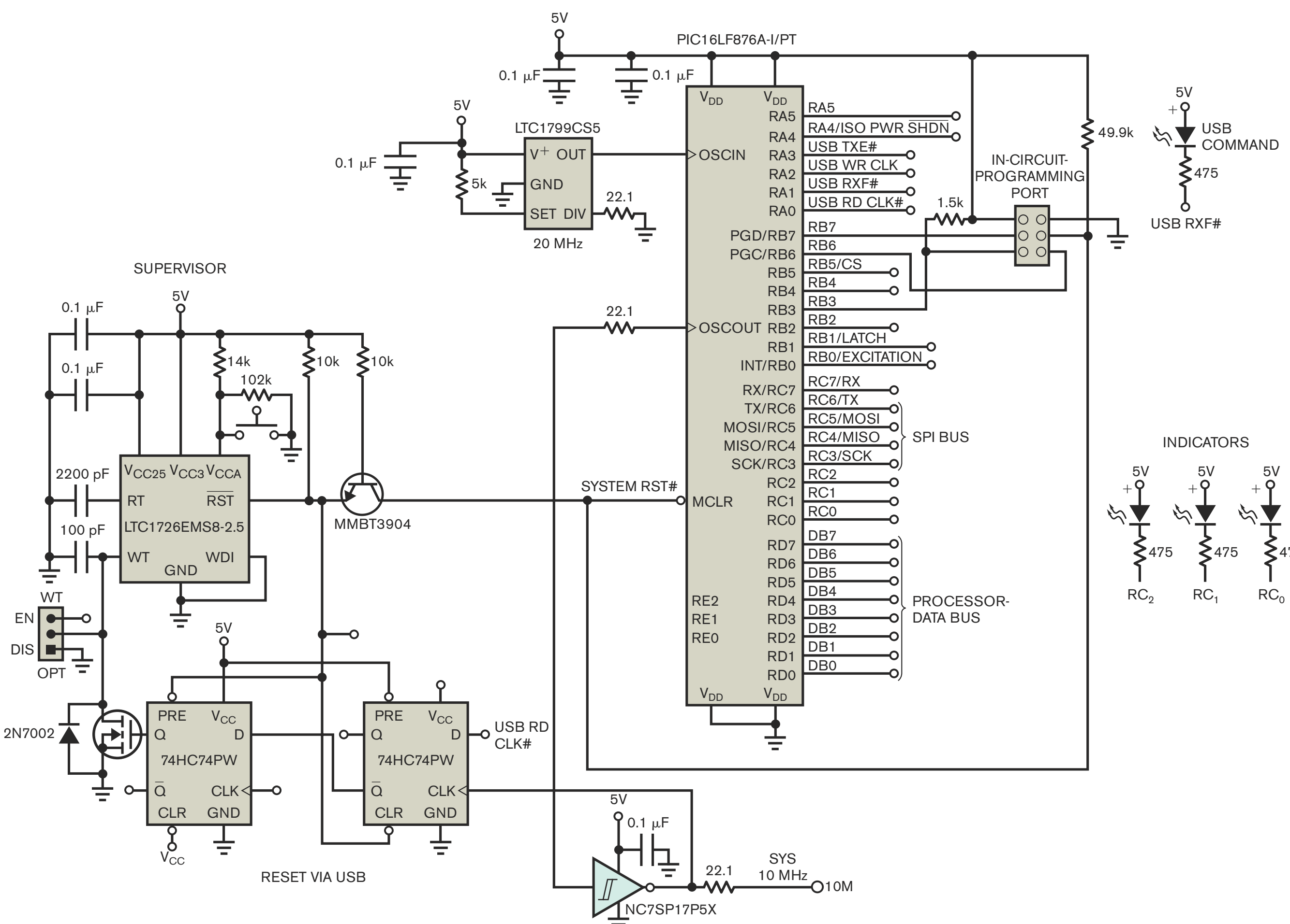


Figure 9 The design includes an automatic-calibration-circuit microcontroller and reset sections.

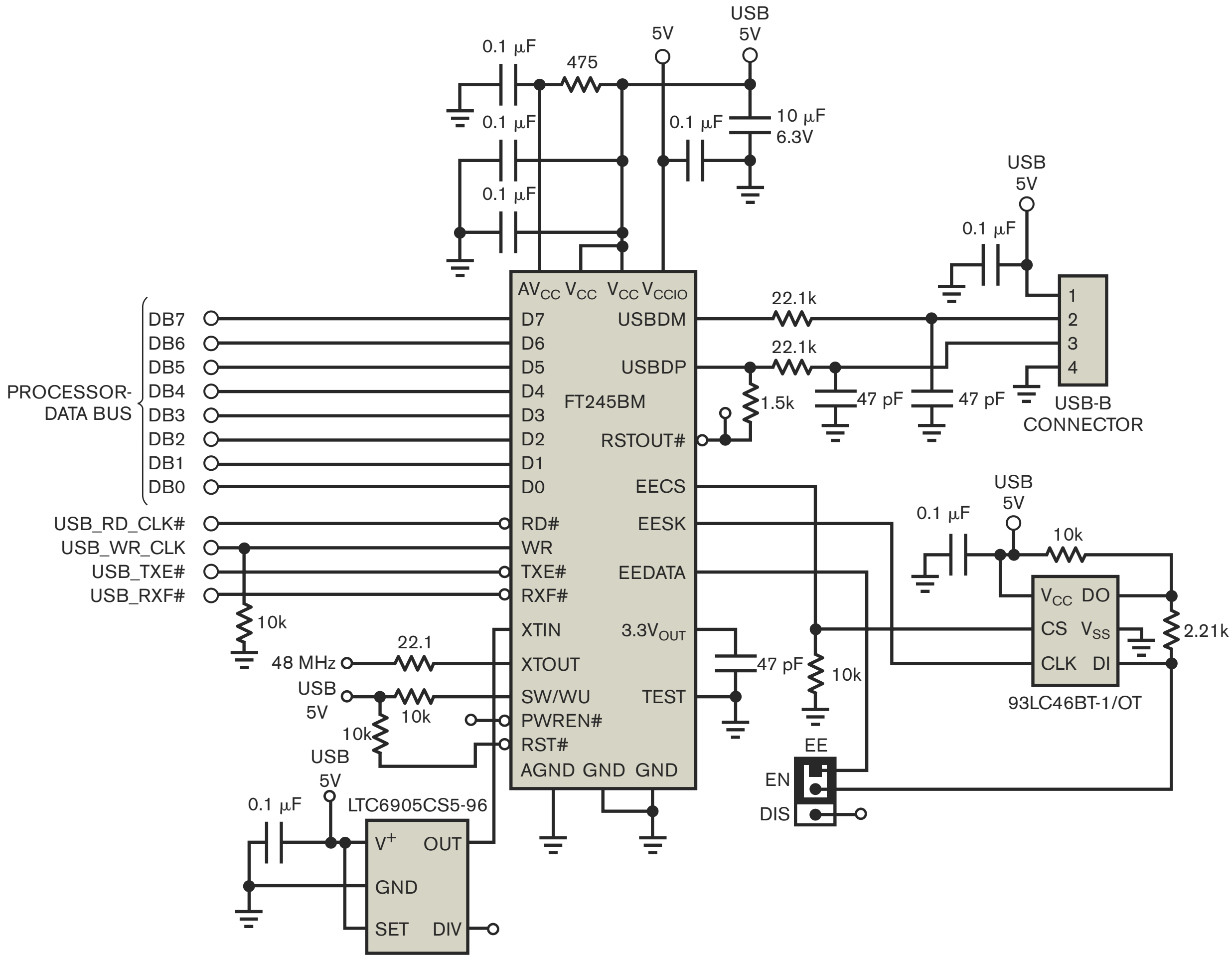


Figure 10 The design includes an automatic-calibration-circuit USB interface for development only.

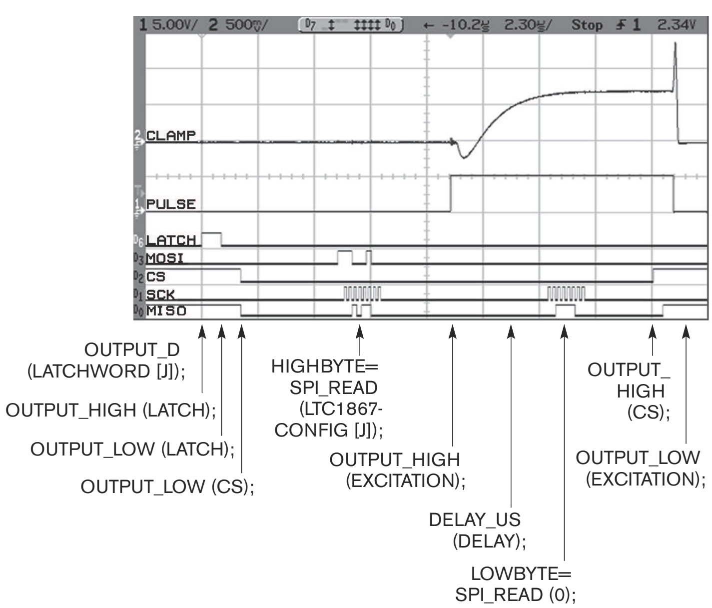


Figure 11 The interrupt-service routine monitors digital signals, excitation pulse, and clamp voltage at the ADC input along with the C code that performs these operations.

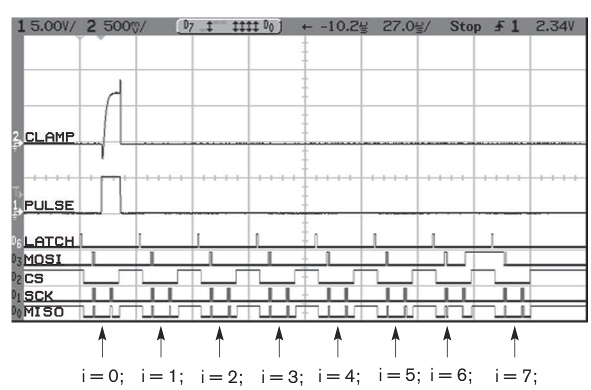
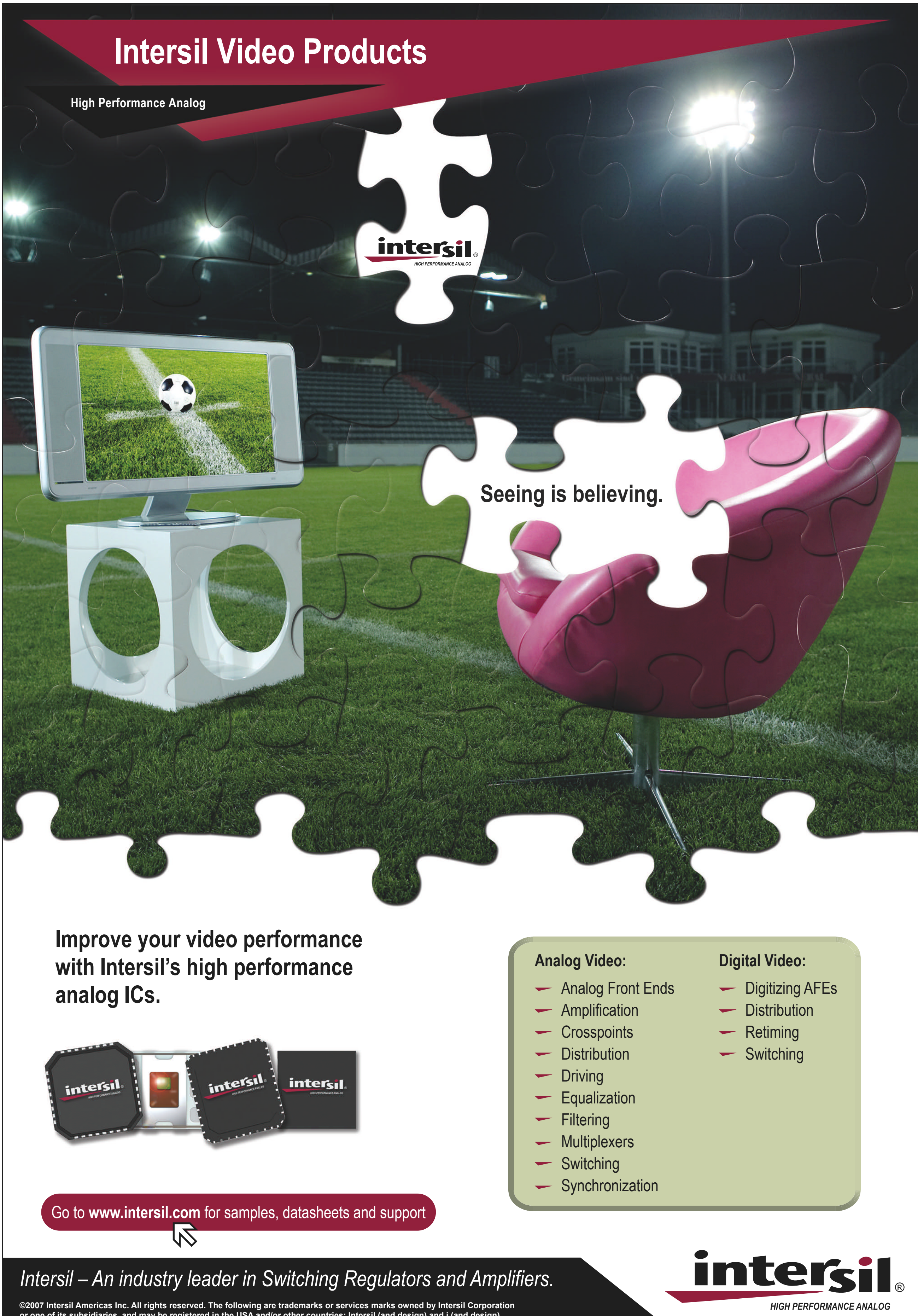


Figure 12 The interrupt-service routine scans eight channels.

store the zero calibration, then apply 1.25V to all inputs and issue a command to store the full-scale calibration. Note that this procedure is no more complicated than a basic performance test that would be part of any manufacturing process. The 1.25V factory-calibration source can be from a voltage calibrator or from a selected LT1790-1.25 that you keep at a stable temperature.

The software also includes a digital filter for testing purpos-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es. The filter is a simple exponential IIR (infinite-impulse-response) filter with a constant of 0.1. This filter reduces the noise in the readings by a factor of the square root of 10.

MEASUREMENT DETAILS

To take a reading from a given channel, the processor must apply the excitation to the transformer, wait for the voltage signal to settle out, take a reading with the ADC, and then remove the excitation. To perform these tasks, an interrupt-service routine occurs once every millisecond. For the details, see **Listing 1** at www.edn.com/ms4255. **Figure 11** shows the digital signals, excitation pulse, and clamp voltage at the ADC input along with the C code that performs these operations. Loading a 3-bit byte high into the 74HC574 latch enables individual channels.

Note that you apply the excitation after 8 bits of the LTC1867 data are read out. This situation is perfectly acceptable, because no conversion is taking place, and all of the data in the LTC1867 output register is static. Depending on the timing of the processor you use, you can apply excitation before reading any data, in the middle of reading data, or after reading the data but before initiating a conversion. If the serial clock is slow—1 MHz, for instance—applying excitation before reading any data would result in the excitation being applied for 16 μsec, which is too long. The only constraints are that the voltage at the ADC input must have enough time to settle properly and that you do not leave the excitation on for too long. **Figure 12** shows the same signals over the entire interrupt-service routine. Similar analog signals are at each transformer and the other LTC1867 inputs.

Many ways exist to add channels to this circuit. **Figure 13** shows a 64-channel concept that decodes the 64 channels in-

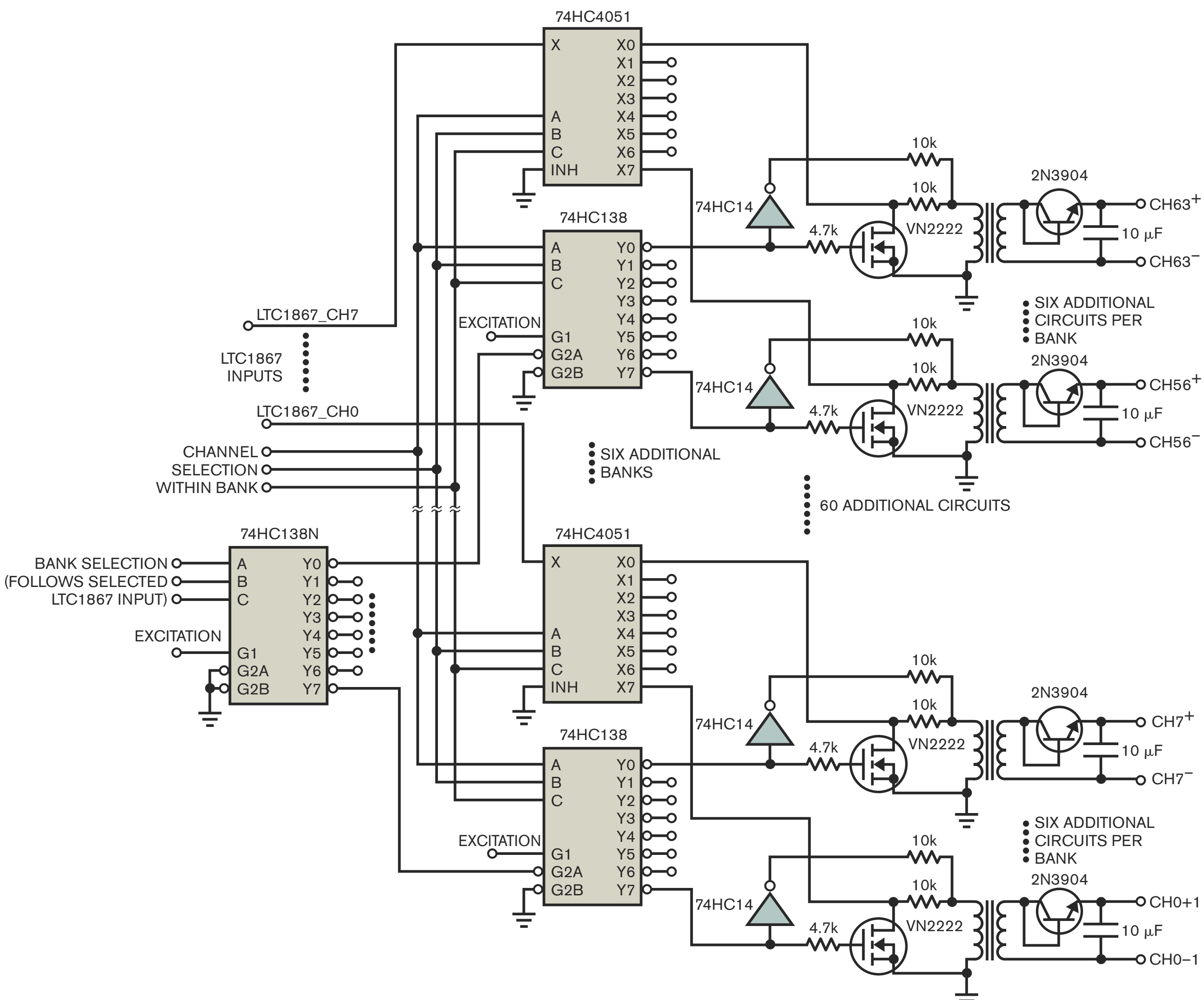

Figure 13 A 64-channel concept decodes the 64 channels into eight banks of eight channels using 74HC138 address decoders.

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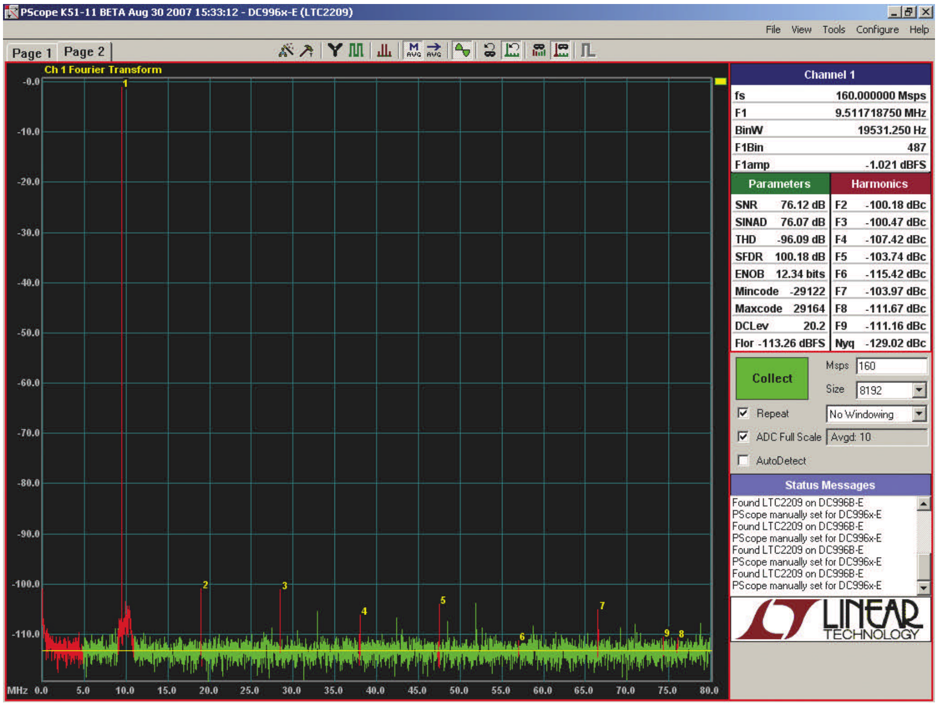

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to eight banks of eight channels using 74HC138 address decoders. The selected bank corresponds to one LTC1867 input that is programmed through the SPI. Some 8-to-1 74HC4051 analog switches perform the additional analog multiplexing. A single 74HC4051 feeding each LTC1867 input gives 64 inputs. The LTC1867, rather than a single-channel ADC, is still a great choice in high-channel-count applications, because it is good idea to break up multiplexer trees into several stages to minimize total channel capacitance. The LTC1867 takes care of the last stage. With a maximum sample rate of 200k samples/sec, it can digitize as many as 200 channels at the maximum 1k-sample/sec limitation of the sense transformer. That's a lot of batteries. **EDN**

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AUTHORS' BIOGRAPHIES

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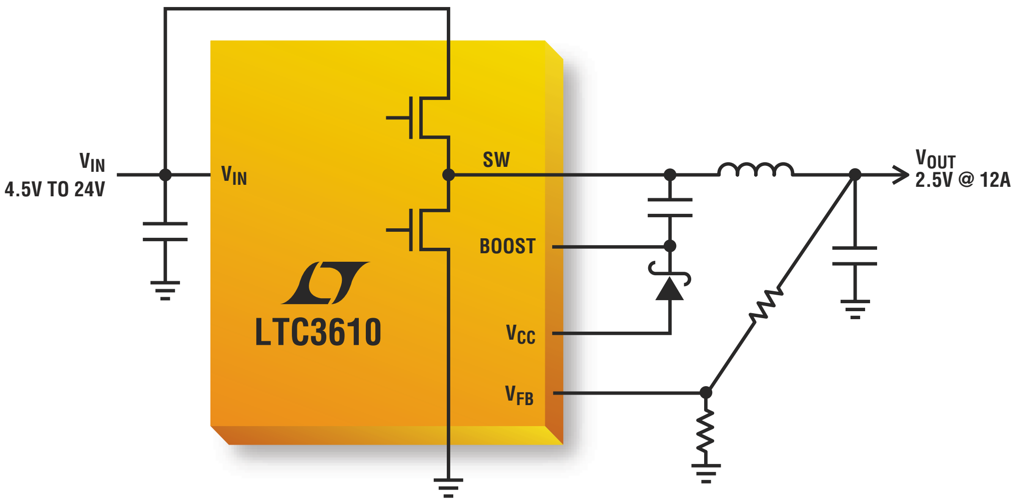
12 Amps, $24V_{IN}$ Synchronous Buck FETs Inside



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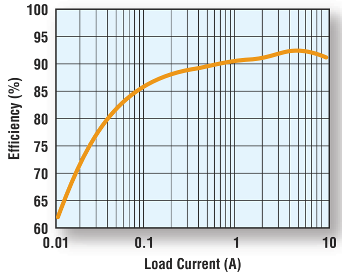

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DESIGN NOTES

Programmable Baseband Filter for Software-Defined UHF RFID Readers

Design Note 432

Philip Karantzalis

Introduction

Radio frequency identification (RFID) is an auto-ID technology that identifies any object that contains a coded tag. A UHF RFID system consists of a reader (or interrogator) that transmits information to a tag by modulating an RF signal in the 860MHz–960MHz frequency range. Typically, the tag is passive—it receives all of its operating energy from a reader that transmits a continuous-wave (CW) RF signal. A tag responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal to the reader.

Tag signal detection requires measuring the time interval between signal transitions (a data "1" symbol has a longer interval than a data "0" symbol). The reader initiates a tag inventory by sending a signal that instructs a tag to set its backscatter data rate and encoding. RFID readers can operate in a noisy RF environment where many readers are in close proximity. The three operating modes, single-interrogator, multiple interrogator and dense-interrogator, define the spectral limits of reader and tag signals. Software programmability of the receiver provides an optimum balance of reliable multitag detection and high data throughput. The programmable reader contains a high linearity direct conversion I and Q demodulator, low noise amplifiers, a dual baseband filter with variable gain and bandwidth and a dual analog-to-digital converter (ADC). The LTC6602 dual, matched, programmable bandpass filter can optimize high performance RFID readers.

The LTC6602 Dual Bandpass Filter

The LTC6602 features two identical filter channels with matched gain control and frequency-controlled lowpass, and highpass networks. The phase shift through each channel is matched to ±1 degree. A clock frequency, either internal or external, positions the pass band of the filter at the required frequency spectrum.

The lowpass and highpass corner frequencies, as well as, the filter bandwidth are set by division ratios of the clock frequency. The lowpass division ratio options are 100, 300 and 600 and the highpass division ratios are, 1000, 2000, 6000. Figure 1 shows a typical filter response with a 90MHz internal clock and the division ratios set to 6000 and 600 for the highpass and lowpass, respectively. A sharp 4th order elliptical stopband response helps eliminate out-of-band noise. Controlling the baseband bandwidth permits software definition of the operating mode of the RFID receiver as it adapts to the operating environment.

An Adaptable Baseband Filter for an RFID Reader

Figure 2 shows a simple LTC6602-based filter circuit that uses SPI serial control to vary the filter's gain and bandwidth to adapt to a complex set of data rates and encoding. (The backscatter link frequency range is 40kHz to 640kHz and the data rate range is 5kbps to 640kbps.)

For fine resolution positioning of the filter, the internal clock frequency is set by an 8-bit LTC2630 DAC. A 0V to 3V DAC output range positions the clock frequency between 40MHz and 100MHz (234.4kHz per bit). The lowpass and highpass division ratios are set by serial

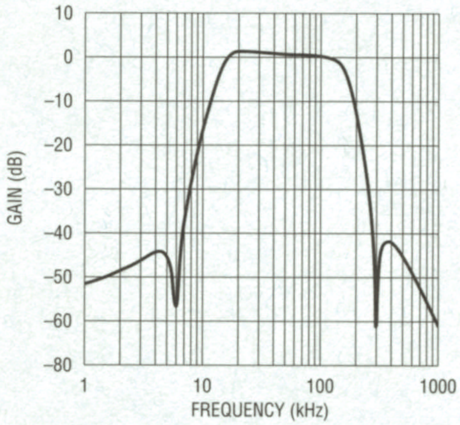

Figure 1. Filter Response for a 15kHz–150kHz Passband

SPI control of the LTC6602. The cutoff range for the highpass filter is 6.7kHz to 100kHz and 66.7kHz to 1MHz for the lowpass filter. The optimum filter bandwidth setting can be adjusted by a software algorithm and is a function of the data clock, data rate and encoding. The filter bandwidth must be sufficiently narrow to maximize the dynamic range of the ADC input and wide enough to preserve signal transitions and pulse widths (the proper filter setting ensures reliable DSP tag signal detection).

Figure 3 shows an example of the filter's time domain response to a typical tag symbol sequence (a "short" pulse interval followed by a "long" pulse interval). The lowpass cutoff frequency is set equal to the reciprocal of the shortest interval (f_{CUTOFF} = 1/10µs = 100kHz). If the lowpass cutoff frequency is lower, the signal transition and time interval will be distorted beyond recognition. The setting of the highpass cutoff frequency is more qualitative than specific. The highpass cutoff frequency must be lower than the reciprocal of the longest interval (for the example shown, highpass f_{CUTOFF} < 1/20µs) and as high as possible to decrease the receiver's low frequency noise (of the baseband amplifier and the down-converted phase and amplitude noise). The lower half of Figure 3 shows the filter's overall response (lowpass plus highpass filter). Comparing the filter outputs with a 10kHz and a 30kHz highpass setting, the signal transitions and time intervals of the 10kHz output are adequate for detecting the symbol sequence (in an RFID environment, noise will be superimposed on the output signal). In general, increasing the lowpass f_{CUTOFF} and/or decreasing the highpass f_{CUTOFF} "enhances" signal transitions and intervals at the expense of increased filter output noise.

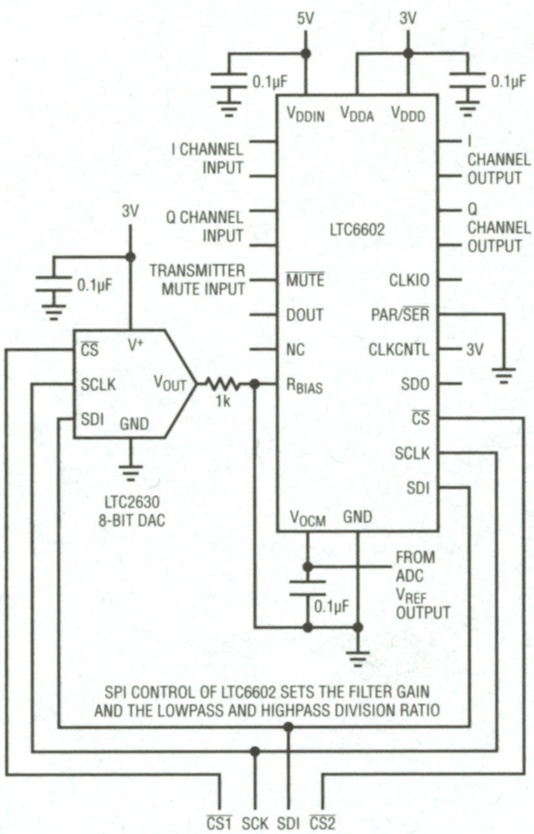

Figure 2. An Adaptable RFID Baseband Filter with SPI Control

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Conclusion

The LTC6602 dual bandpass filter is a programmable baseband filter for high performance UHF RFID readers. Using the LTC6602 under software control provides the ability to operate at high data rates with a single interrogator or with optimum tag signal detection in a multiple or dense interrogator physical setting. The LTC6602 is a very compact IC in a 4mm × 4mm QFN package and is programmable with parallel or serial control.

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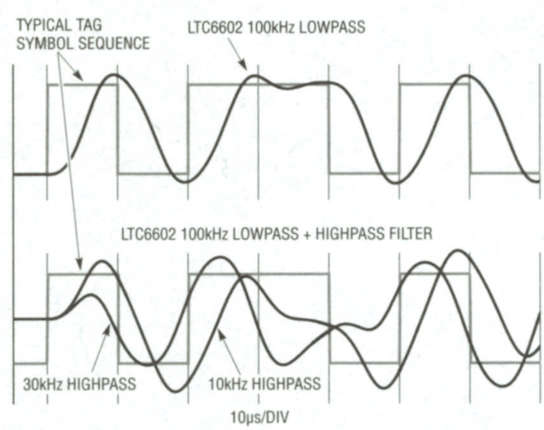

Figure 3. Filter Transient Response to a Tag Symbol Sequence

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Use the MCLR pin as an output with PIC microcontrollers

Antonio Muñoz, Laboratorios Avanzados de Investigación, Huesca, Spain, and Pilar Molina, Universidad de Zaragoza, Zaragoza, Spain

Although microcontroller manufacturers try to offer designers products that almost exactly fit the needs of their designs, another output pin is often necessary. This situation is particularly true in small designs using microcontrollers with eight pins or fewer. This Design Idea employs the Microchip (www.microchip.com) PIC10F222. The PIC10F222 comes in an SOT23-6 package and offers three I/O pins, one input pin, RAM, flash, and an ADC module. You must program these tiny microcontrollers, just as you do with their big brothers. To program these microcontrollers, you need the MCLR, two I/O pins (data and clock), and supply pins (V_{CC} and GND). To enter programming mode, you need MCLR and supply. Because the microcontroller must differentiate between normal and programming mode, the MCLR pin usually reaches a voltage of approximately 12V to enter programming mode. Thereafter, in normal operation, you can configure the MCLR pin either as an external reset or as an input-only pin.

This design uses one pin for analog input and the other three as outputs. The design thus requires an additional output. For that reason, this circuit uses the MCLR pin as an output. For simplicity, **Figure 1** shows only the GP3/MCLR output circuit. To allow the GP3/MCLR pin to act as an output, the circuit uses the configurable weak pullups that this microcontroller offers. The selected function for the GP3/MCLR pin is input, and you must enable the global weak-pullup bit in the microcontroller's configuration word. Although you cannot individually configure weak pullups, this inability is not a problem because you configure all other pins as analog inputs or digital outputs.

The weak pullups have a resistance of 20 to 150 kΩ, depending on supply voltages, so this circuit uses transistor Q_1 to drive higher loads, such as the depicted LED. R_1 drives the transistor off when you deactivate the pullups. Because the transistor's gate is resistance-driven, the maximum toggle frequency depends on the chosen transistor. The worst-case scenario occurs when you need to switch off Q_1. R_1 and Q_1's gate-to-source capacitance determine the transistor's switch-off time.

Programming voltages for the MCLR pin are about 12V. Therefore, Q_1 must withstand a gate-to-source voltage higher than this value. This design uses a MOSFET having a ±18V withstand voltage. For this reason, you should not use digital MOSFETs. You can use this circuit with other PIC microcontrollers and with most RS08KA family microcontrollers from Freescale.EDN

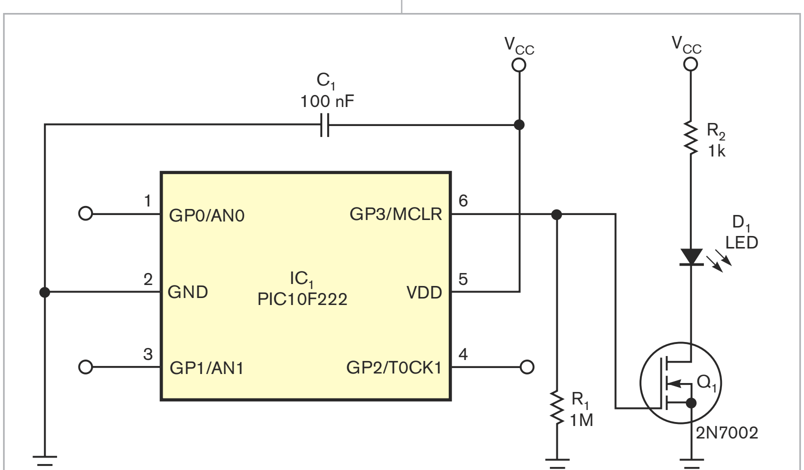

Figure 1 Adding a MOSFET and associated circuitry to a PIC microcontroller's MCLR input pin transforms the pin into an output.

High-speed clamp functions as pulse-forming circuit

Marián Štofka, Slovak University of Technology, Bratislava, Slovakia

Amplifiers with positive feedback are the bases of signal-grade pulse-forming circuits. This setup ensures a triggerlike operation in which the input signal crosses the input-threshold level; in most cases, the input signal is a voltage signal. The most well-known of these triggers is the Schmitt trigger, which, by the way, will this year celebrate its 70th birthday. British scientist OH Schmitt in 1938 originated the Schmitt trigger in the form of a two-stage amplifier with current feedback. The two active devices were vacuum tubes.

The operation of a Schmitt trigger has the advantage of fast, almost-constant transition times of the output regardless of the slope of the input signal. One consequence of this type of operation is the hysteresis in the I/O characteristic. In other words, the threshold shifts to a higher value before the positive-output transition, and it shifts to a lower value after switching to the positive-output level. You can set the amount of hysteresis—from zero to latch-up—for Schmitt-trigger circuits comprising discrete parts. Schmitt circuits find wide use in logic ICs, in which the hysteresis is rather high and fixed.

As an alternative, you can use a circuit—a fast-response voltage limiter, or clamper—as a pulse-forming circuit. The input-voltage range is narrower than that of Schmitt-trigger circuits, because, at low input voltages, the voltage limitation becomes inactive, and the circuit operates as a linear amplifier. On the other hand, because of its nonhysteretic behavior, the decision threshold of the input voltage is precise and equal for both directions of output-level transitions. **Figure 1** shows one example of such as circuit. The voltage limiter in **Figure 1** is an inverting amplifier with a highly nonlinear negative feedback. For output voltages ranging from −0.3 to +0.6V, the feedback impedance is high because each of the diodes is nonconducting. The forward-voltage drop of the selected Schottky-barrier diodes determines these voltage limits (**Reference 1**). The voltage gain of the inverting amplifier is thus almost that of the op amp's open-loop gain.

Whenever the output voltage exceeds these limits, diode D_1, D_2, or D_3—depending on the polarity of the output voltage—starts to conduct. The differential gain of the amplifier then drops to the value of $-R_I/2R_D$ and $-R_I/R_D$, respectively, where R_D is the equivalent-series resistance of a single diode. The action clamps the output voltage to approximately 0.8V and to −0.4V even for large input voltages. The **figure** uses an Analog Devices (www.analog.com) AD8045 VHSIC (very-high-speed integrated-circuit) op amp because its slew rate exceeds the value of 1V/nsec (**Reference 2**).

Figure 1's circuit has an asymmetrical-limiting configuration to compare the single feedback diode with two series-connected diodes having a transverse resistor, R_{T1}, between their midpoints and ground. The clamping circuitry comprising D_1, D_2, and R_{T1} offers higher off-isolation between the output and the input of the op amp than that of the single diode, D_3. When D_3 is on, you can observe small, weakly damped oscillations at approximately 200 MHz in the output waveform. Oscillations manifest themselves less at the beginning of turn-on of the D_1 and D_2 diodes. EDN

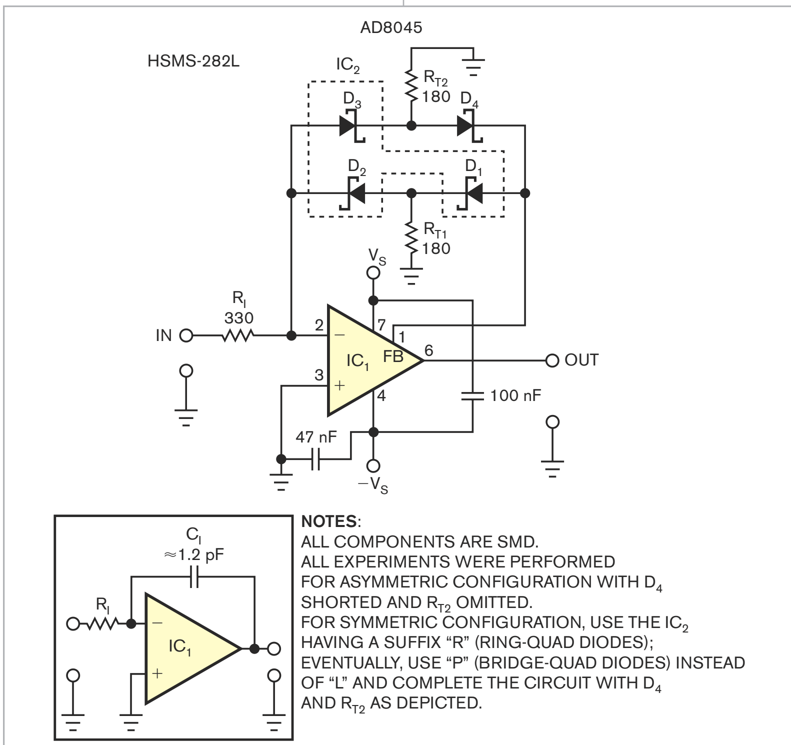

Figure 1 This clamping circuit uses diodes to achieve nonlinear feedback. The circuit employs a single diode in one feedback path and two diodes in the other. The dual-diode configuration offers cleaner switching.

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Depletion-mode MOSFET kick-starts power supply

Gregory Mirsky, Milavia International, Buffalo Grove, IL

Many switch-mode power supplies use "kick-start" circuits to initialize their offline operation. These circuits may be simple resistors, such as International Rectifier's (www.irf.com) IRIS4015, or more complicated arrangements built with bipolar transistors or MOSFETs (**Reference 1**). These transistors provide the initial current for the flyback or PFC (power-factor-correction) IC. When such a power supply starts operating in normal mode, a supply voltage from a dedicated winding keeps supplying the PFC IC, thus reducing power consumption of the kick-start circuitry.

Such schemes reduce—but do not eliminate—the power consumption of the kick-start circuitry, because the active component is usually a high-voltage bipolar transistor or high-voltage enhancement-mode MOSFET. These transistors' base or gate requires forward-biasing with respect to the emitter or the source for normal operation. Therefore, a power loss always occurs in the circuits that keep the transistors in the off state. Unfortunately, engineers pay too little attention to depletion-mode MOSFETs, which require no forward-biasing for normal operation and, moreover, require gate potentials below the source. These valuable properties of depletion-mode MOSFETs suit them for a role in no-loss kick-start circuits for power supplies.

Figure 1 shows a conventional PFC circuit whose IC initially receives power from the output through a depletion-mode MOSFET, Q_2, a DN2470 from Supertex (www.supertex.com, **Reference 2**). Q_2's source feeds PFC IC_1 with an initial supply current of approximately 10 to 15 mA or less depending on the IC model. A brief power dissipation of approximately 4 to 6W can do no harm to the MOSFET soldered to a copper pour. If you have concerns about the MOSFET's health, you can use an IXTY02N50D from Ixys (www.ixys.com, **Reference 3**). Resistors R_3 and R_4 set up Q_2's working point to obtain the minimum required current. Zener diode D_5 limits its voltage across IC_1 to approximately 15V for an input voltage of 18V, which is usually necessary for most PFC ICs and is less than the maximum for MOSFET Q_2.

When IC_1 starts working normally, the secondary winding of the PFC inductor, L, generates the IC's supply voltage, which diodes D_1 and D_3 and capacitors C_1 and C_2 condition. Transistor Q_2 keeps feeding zener diode D_5 and IC_1 for a short interval. Eventually, bipolar transistor Q_3 gets its base supply through resistor R_5 from diode D_2, turning on and clamping Q_2's gate to ground. Q_3's power source is the IC's positive-supply potential of approximately 15V, which is more than enough to shut off Q_2. The residual thermal current of 10 to 20 μA produces no substantial power loss. EDN

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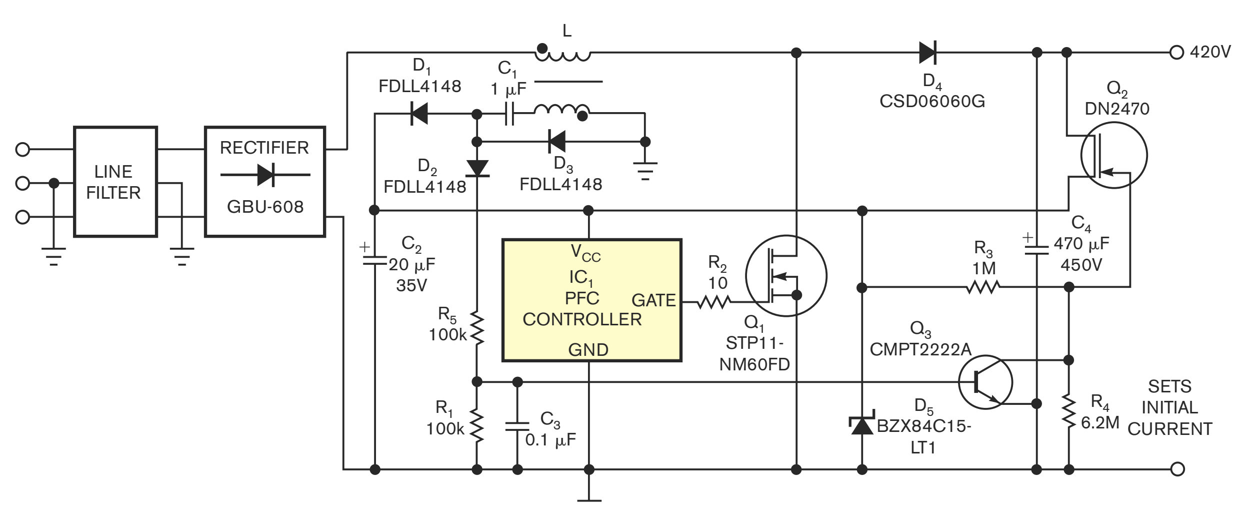

Figure 1 A depletion-mode, high-voltage MOSFET provides a kick-start for a PFC IC. During normal operation, the MOSFET switches off and dissipates negligible power.

Simple continuity tester fits into shirt pocket

Tom Wason, Phoenixville, PA

This Design Idea describes a handy continuity tester with two modes of operation: It may sound if it detects continuity between its two probes, or it may sound when it detects no continuity. The second option permits testing for intermittent cable breaks. Response must be sufficiently fast to permit swiping a probe across perhaps 100 pins to instantly find a connected pin. The tester may also identify microfarad or larger capacitance between two conductors.

To properly test for continuity, the tester's voltage and current are limited so that low-power semiconductors do not suffer overstress or appear as a connection between two conductors. The tester must protect itself if you accidentally connect it across an energized circuit or a charged capacitor. Power consumption must be low so that if you accidentally leave the tester on overnight, it will not discharge the battery. The tester must operate even with low battery voltage.

Continuity requires a threshold of less than 200Ω. Depending on battery voltage, that threshold may even be 80Ω. The tester's open-circuit voltage is less than 0.5V. Its short-circuit current is approximately 1 mA. Values are low so that the tester doesn't mistake a Schottky-barrier rectifier for continuity. When the tester is silent, it draws slightly more than 1 mA of current from a 9V battery. You can connect the probes for a few seconds across any voltage from −50 to +200V without damage.

A feedback circuit comprising Q_1 PNP and Q_2 NPN transistors maintains voltage on the gate of IGFET (insulated-gate field-effect transistor) Q_3 at less than 1.4V despite a 680-kΩ pullup resistor, R_4, and current from D_2 (**Figure 1**). When you short the probes, you divert more Q_1 base current to the probes, and less current flows through D_2. Eventually, Q_2 can no longer maintain a low Q_3 gate voltage. As the gate voltage exceeds 1.8V, Q_3's drain-to-source current causes Q_4 to become nonconductive. A 1-MΩ pullup resistor, R_6, then applies 9V to Q_5's gate, causing the tester to sound, announcing continuity.

Without a conducting Q_2 collector, Q_3's gate voltage approaches 9V. Current would then leak through Q_1's collector-to-base path. Diode D_2 blocks Q_3's gate voltage from leaking to the shorted probes.

The tester detects instantaneous continuity even when you quickly swipe a probe across 100 pins. Capacitor C_1 and pullup resistor R_5 extend Q_5's low gate-voltage response by 20 msec. Thus, the tester sounds slightly longer to indicate that it has established connectivity and does not miss a conductive pin during a fast swipe.

Probe current charging a capacitor may also create a short beep. The 20-msec extended beep means that the tester detects even 10-µF or smaller capacitors. With practice, you can estimate capacitance within decades from the beep's period.

Diodes D_3 through D_5 block destructive currents if probes touch an energized circuit. Resistor R_3 must be at least ½W to withstand current from an energized circuit for a few seconds without damage.

To test for cable continuity, the tester sounds only during a broken connection. In this case, firmly connect the probes to both ends of the cable. Switching S_2 changes the tester's function so that Q_4 drives the buzzer during a cable break.

You can modify the circuit to be a better cable tester by reducing the value of resistor R_1 to 4.7 kΩ and omitting capacitor C_1. With these modifications, detecting loss of continuity occurs at a threshold resistance of less than 100Ω.

Unfortunately, a continuity tester may create noise currents that feed back into the sensitive Q_1/Q_2 detector. Three circuit features minimize that noise. First, capacitor C_2 connects across the buzzer. Second, IGFET Q_3 acts as a buffer. Last, diode D_5 grounds Q_4 and Q_5 separately from ground for Q_2 and Q_3.

The circuit performs even when a battery voltage is less than 6.5V. However, lower battery voltage means that the tester detects continuity at a higher threshold resistance. You may install the entire tester in a plastic case smaller than a pack of cigarettes. EDN

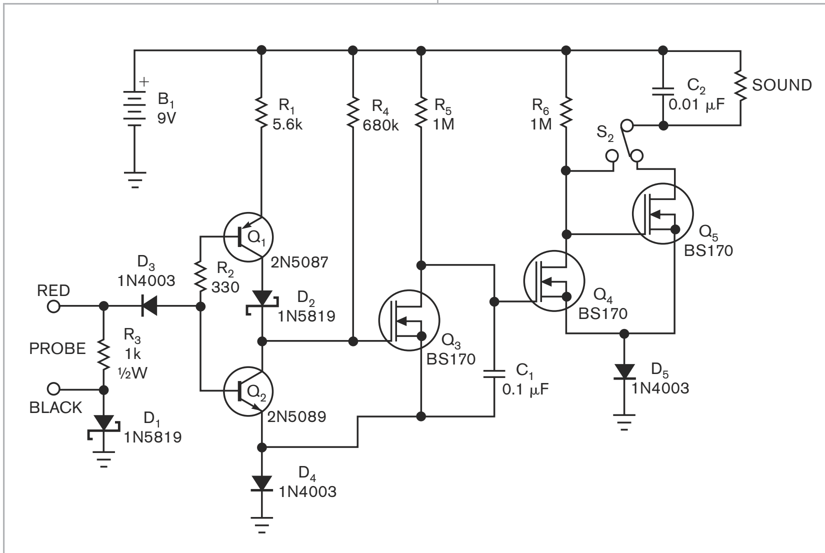

Figure 1 This simple continuity tester is switch-selectable to sound on either shorts or opens. It prevents a user from accidentally connecting it across live circuits.

White LED shines from piezoelectric-oscillator supply

TA Babu, Chennai, India

LED drivers that receive their power from a single cell are receiving a great deal of attention. To generate the high voltage for illuminating a white LED from a low-voltage power supply basically requires some form of an electronic oscillator, and one of the simplest is a piezoelectric buzzer. An unusual application of a piezoelectric transducer serves as an oscillator and drives a white LED (**Figure 1**). The piezoelectric diaphragm, or bender plate, comprises a piezoelectric ceramic plate, with electrodes on both sides, attached to a metal plate made of brass, stainless steel, or a similar material with conductive adhesive. The circuit uses a three-terminal piezoelectric transducer. In this transducer, the diaphragm has a feedback tab on one of its electrodes. The oscillation is a result of the resonance between the inductor and the element, which is capacitive. The frequency of operation is: $f_{OSC}=1/(2\pi\sqrt{LC})$, where L is the value of the inductor and C is the capacitance of the piezoelectric element.

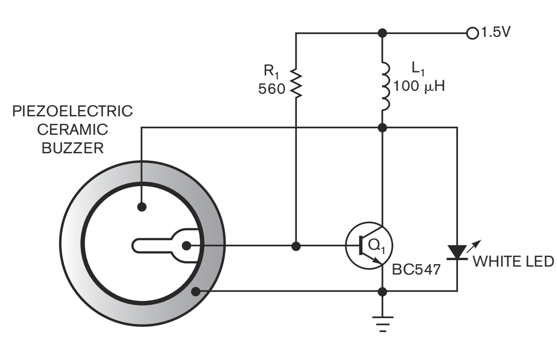

Figure 1 A piezoelectric ceramic buzzer serves as the oscillator in this flyback supply that lights a white LED using a single cell (not shown).

With the initial application of potential to the circuit in **Figure 1**, transistor Q_1 turns on. When the transistor conducts, the current through inductor L_1 increases gradually, and the potential across the plates flexes the piezoelectric ceramic. This flexing generates a negative potential at the feedback tab, which feeds back to the base of the transistor. The transistor then switches off. When turn-off occurs, the stored energy in the inductor dumps into the LED. This flyback voltage is sufficient to light the LED. EDN

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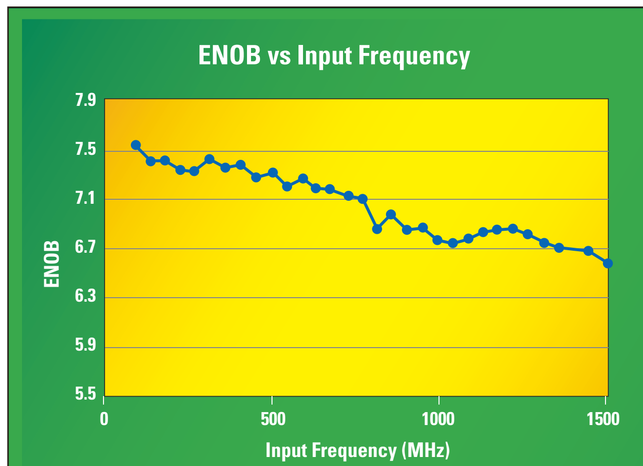

ADC083000 Benefits

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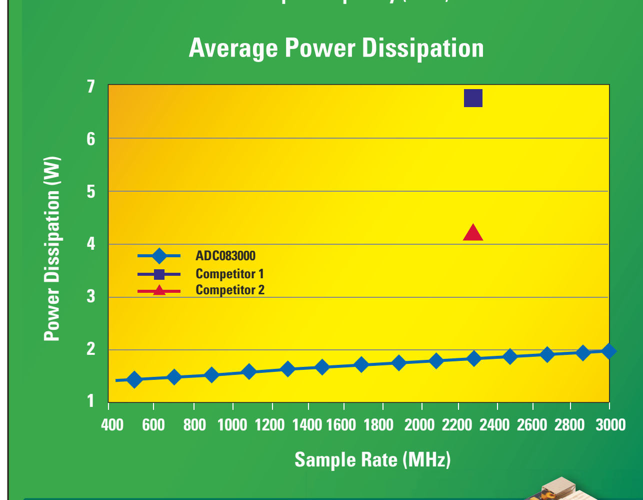

Applications

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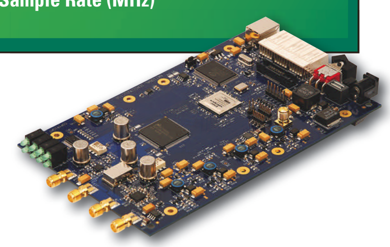

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2007: a less-than-memorable year for DRAM

If there were ever proof that optimism doesn't necessarily lead to success, the 2007 DRAM market is such proof. Microsoft's Vista spurred hopes of increased demand for 1-Gbyte DRAM, but those hopes went unfulfilled, even though vendors ramped up capacity in preparation. "A lot of it had to do with how 2006 ended," says Paul Zecher, commodity manager for memory at independent distributor Converge (www.converge.com). "There was so much capacity coming onboard … that, once we got into the holidays and consumption started to slow down, those guys were up and running. A lot of it had to do with their expectation that Vista would take off going into the first half of '07, as well. They were banking on that to happen, and it didn't."

According to Zecher (**photo**), 1-Gbyte DRAM is the "module of choice" for Vista PCs, and, as such, vendors heavily ramped up production. Overcapacity led to deteriorating market prices, many of which fell below cash costs in the final quarter of 2007. That oversupply is expected to bleed into 2008's first—and, possibly, second—quarter. "The DRAM recovery will be driven by the supply side, with inventory dwindling and growth in bit production decreasing," says Nam Hyung Kim, director and chief analyst for memory ICs and storage systems at iSuppli (www.isuppli.com). "This [decrease] will cause availability to tighten and prices to rise. However, this scenario assumes that suppliers' behavior will be rational, and they will not engage in any massive production increases that could send DRAM pricing into a new dive."

Zecher also notes the possibility of corporate upgrades finally adjusting to Vista systems in 2008 but warns that this adjustment depends heavily on global economies (see "Demand-driven downturn possible in 2008," right). "If companies are hurting or there are layoffs, more than likely they are not going to start upgrading their systems. And Vista is not as easy as a lot of the other Microsoft upgrades," he says.

GREEN UPDATE

CALIFORNIA VETOES ROHS-EXPANSION BILL

California Governor Arnold Schwarzenegger has vetoed an assembly bill that would have more closely aligned California's ROHS (restriction-of-hazardous-substances) law and regulations with the EU (European Union) ROHS directive. The bill, AB 48, would have expanded California ROHS to include all electrical and electronic equipment, as opposed to its current requirements for "covered electronic devices," which include nine video-display devices that the state's Department of Toxic Substances Control (www.dtsc.ca.gov) regulations list. The bill also aimed to require that all electrical and electronic equipment that manufacturers sell in California as of Jan 1, 2010, comply with EU ROHS stipulations for lead, mercury, cadmium, and hexavalent cadmium.

Schwarzenegger sent the bill back to the California legislature in the fall, stating in a memo that the bill's approach "is largely unworkable and instead of the benefits it seeks to accomplish, could ultimately result in unintended and potentially more harmful consequences."

The governor noted the exemption language for spare parts and refurbished products, claiming that, as written, the bill would make many electronic products prematurely obsolete and force their retirement years earlier than necessary. The California legislature is expected to try to pass this or a similar bill again in 2008.

OUTLOOK

DEMAND-DRIVEN DOWNTURN POSSIBLE IN 2008

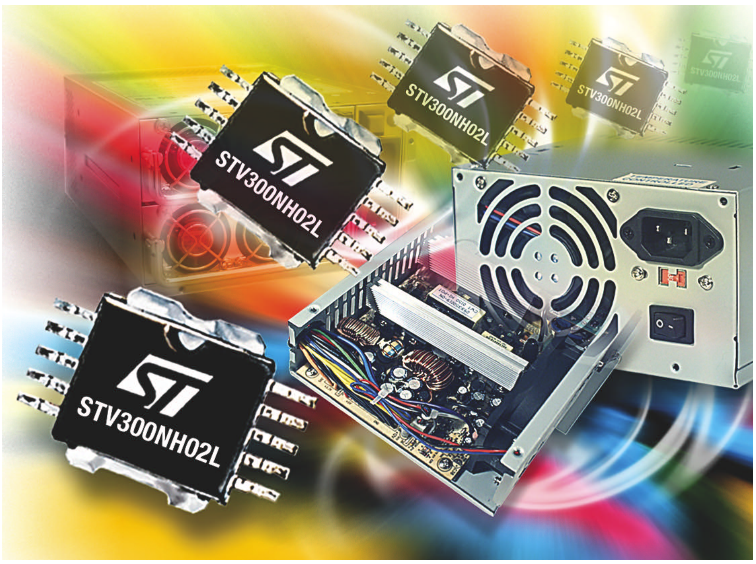
The new year could bring a demand-driven downturn, Gartner Inc (www.gartner.com) cautions. Government economists and financial counselors have warned that the United States could experience a recession due to subprime-rate-mortgage debt and the US-initiated, and now global, "credit crunch." As a result, Gartner believes the semiconductor industry could see this downturn in 2008.

Although the effects of such a downturn would be milder than those of the 2001 bubble burst, they depend on the electronics segment in the supply chain, Gartner says. The research company notes that the downside risk is lower for semiconductor companies, given a slow 2007, and higher for capital-equipment companies, given the substantial memory-related capacity investments in 2007.

According to Gartner, equipment companies' revenue in a mild recession could drop as much as 15 to 20% in 2008, whereas chip-company revenue may decline in the mid-single-digit range. Gartner predicts that, if a recession were to hit the United States, the possible semiconductor-industry down cycle would likely extend into 2009, depending on the impact on other global economies and the severity and speed of the US recovery.

productroundup

DISCRETE SEMICONDUCTORS



Power MOSFET suits ORing applications

Targeting MOSFET ORing applications, the STV300NH02L power MOSFET claims to increase system reliability in paralleling-configuration power-server applications. The 20V device provides a typical 0.8-mΩ on-resistance. Available in a PowerSO-10 package, the STV300NH02L MOSFET costs $4.50 (1000).

STMicroelectronics, www.st.com

N-channel MOSFETs target mobile electronics

Aiming at dc/dc-converter applications for mobile electronics, the 30V OptiMOS3 M series N-channel-MOSFET family targets applications with a 5V drive. The BSC100N03MS G with a 10-mΩ on-resistance provides an 11-nC maximum gate-charge rating. The MOSFETs are available in a 30-mm² SSO8 (SuperSO8) package or in a 3×3-mm S3O8 (shrink SuperSO8) package. The SSO8 achieves a 2-mΩ on-resistance at 4.5V and 1.6-mΩ on-resistance at 10V, and the S3O8 achieves a 4.3-mΩ on-resistance at 4.5V and 3.5-mΩ on-resistance at 10V. The SSO8 OptiMOS3 M series costs 88 cents for the 1.6-mΩ device; the S3O8 packaging costs 56 cents for the 3.5-mΩ device.

Infineon Technologies, www.infineon.com

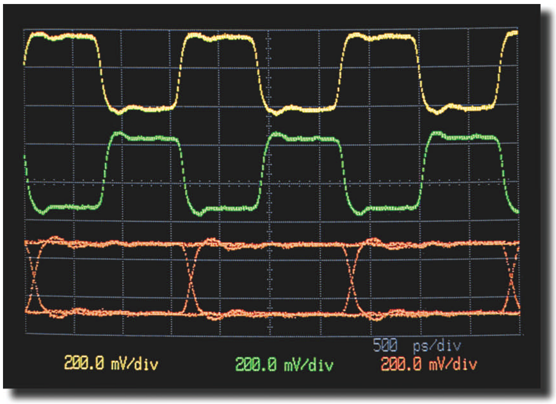
Switching MOSFETs provide higher drain currents for synchronous dc/dc converters

Extending the vendor's UMOS V-H high-speed switching-MOSFET series, the TPCA8012-H and the TPCA8019-H N-channel MOSFETs suit synchronous dc/dc converters in power supplies for servers, desktop and mobile computers, and portable-electronics devices. The TPCA8012-H features a 40A maximum drain current, a maximum 30V drain-to-source voltage, and a 4.9-mΩ on-resistance with a 10V maximum gate-to-source voltage. The TPCA8019-H provides a 45A maximum drain current, a maximum 30V drain-to-source voltage, and a 3.1-mΩ on-resistance with a 10V maximum gate-to-source voltage. Available in SOP-Advanced packages with a 5×6-mm footprint, the TPCA8012-H and TPCA8019-H cost 45 and 60 cents, respectively.

Toshiba America Electronic Components, www.toshiba.com/taec

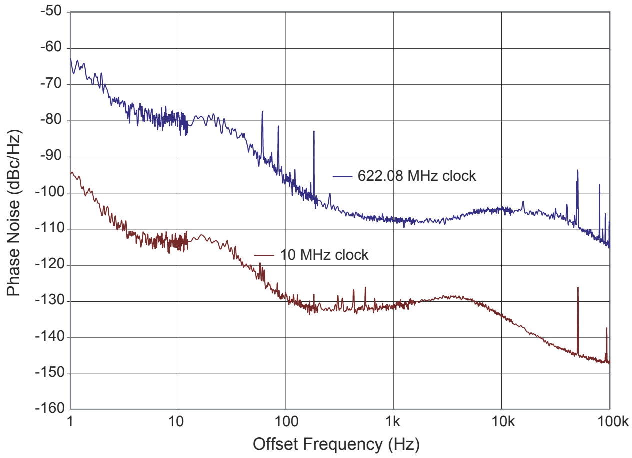
You need this clock generator

CG635 – Precise, low jitter clocks from DC to 2.05 GHz

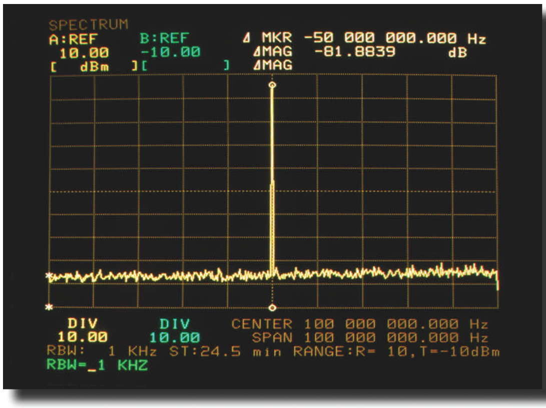


Clock and PRBS signals at 622.08 MHz

Plot shows complementary clock and PRBS (opt. 1) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).



Phase noise for 10 MHz and 622.08 MHz outputs



RF Spectrum of a 100 MHz clock

Graph shows a 100 MHz span around a 100 MHz clock. Only two features are present: the clock at 100 MHz, and the spectrum analyzer's noise floor (around –82 dBc).

- ***Square wave clocks from DC to 2.05 GHz***
- ***Random jitter <1 ps (rms)***
- ***80 ps rise and fall times***
- ***16-digit frequency resolution***
- ***CMOS, LVDS, ECL, PECL, RS-485***
- ***Phase adjustment and time modulation***

The CG635 Synthesized Clock Generator provides square wave clocks between DC and 2.05 GHz that are clean, fast and accurate. With jitter less than 1 ps, transition times of 80 ps, and 16 digits of frequency resolution, the CG635 will meet your most critical clock requirements.

The instrument can provide clocks at virtually any logic level via coax or twisted pairs. The outputs have less jitter than any pulse generator you can buy, with phase noise that rivals RF synthesizers costing ten times more.

Optional OCXO and rubidium timebases improve frequency stability by 100× and 10,000× over the standard crystal timebase. And an optional PRBS helps you evaluate high-speed serial data paths.

Whether you are trying to lower the noise floor of an ADC, increase SFDR of a fast DAC, or squash the bit error rate in a SerDes, the CG635 is the tool you need to get the job done.

SRS **Stanford Research Systems, Inc.**

Phone: (408)744-9040
www.thinkSRS.com

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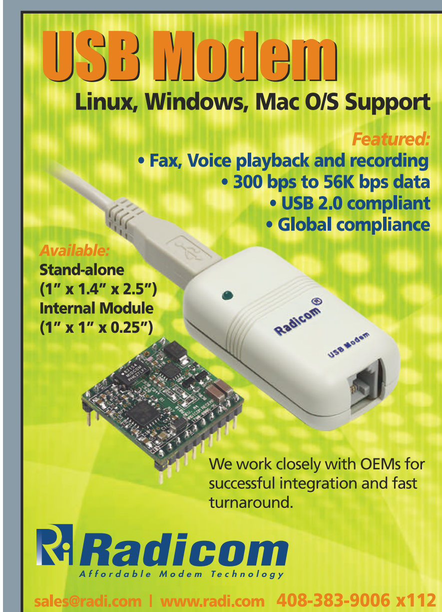
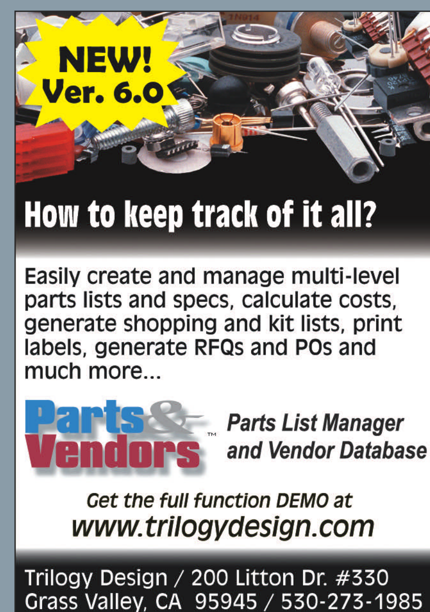
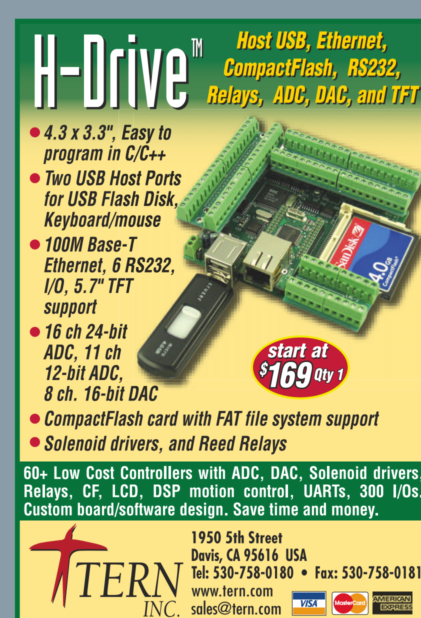






EDITED BY RON WILSON

scope

CHART YOUR COURSE

LOOKING AHEAD

TO APEC 2008

The 2008 Applied Power Electronics Conference will happen February 24 to 28 in Austin, TX. Take your pick of controversies, tutorials, and papers on advanced topics in power-electronics design; they'll all be there. Highlights will include a number of sessions on digital control of power circuits, including theory, modeling, and prototyping; on the quest for greater efficiency; on electromagnetic analysis for power-supply folks; and (inevitably) on power electronics in alternative-energy applications.

LOOKING AROUND

AT THE IMPLICATIONS OF THE CREDIT CRISIS

What does the global credit crisis that grew out of the US subprime-mortgage fiasco have to do with electronics? Unfortunately, there are several close links. Directly, any time less money is available to households—such as with the drying up of home-equity loans in the United States—demand falls for the big-ticket consumer items that carry a lot of electronics content. What's more pernicious is that the spreading credit crunch and conscious tightening of business credit in China are making credit scarcer for businesses as well, reducing capital spending on electronics. In particular, that most capital-intensive purchase—a production fab—may become impossible without smoothly functioning global credit markets. The situation could improve if a country were willing to step up and pay the bill on its own, perhaps using a sovereign-wealth fund to invest directly in capital equipment. But that's a step no one has taken yet.

LOOKING BACK

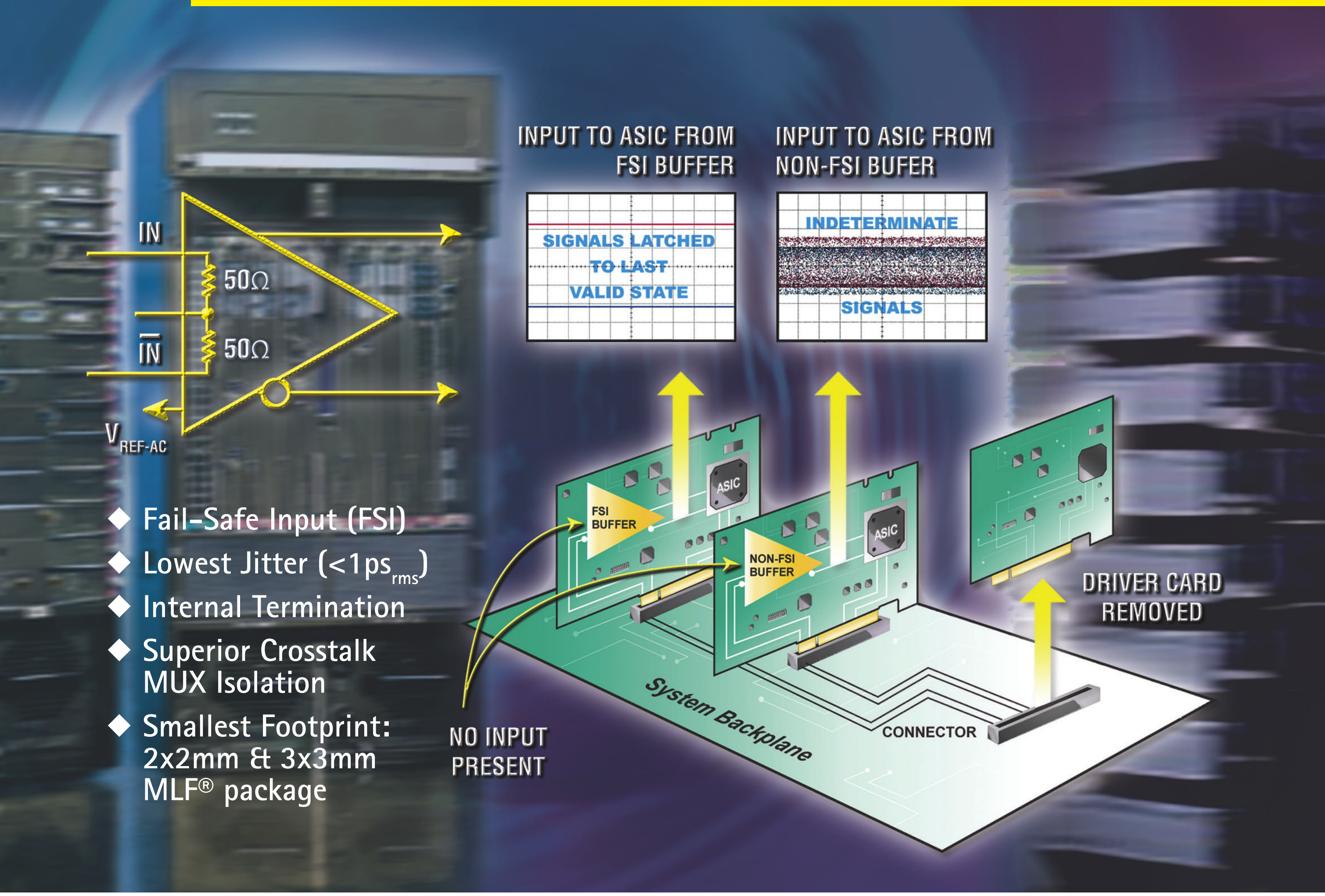
AT A COMPUTER-BASED COMBAT AUTOPILOT

An airborne digital computer now in production can fly a jet aircraft through all phases of supersonic combat and is small enough to fit in the cabinet of a 21-in. table-model TV. The computer can make 9600 arithmetical computations in one second and 6250 decisions in a minute. Combining information from ground-control stations and the aircraft's radar, the computer takes in 61 types of information and outputs 30 types, in the process monitoring 16 navigation and flight-control functions on a 1.8-second cycle. Instead of tubes, the computer contains 4000 diodes, and 75% of its wiring is etched circuitry.

—*Electrical Design News*, January 1958

4.25 Gbps Buffers and MUXes Provide Valid Output When Input Fails

CML/LVPECL/LVDS Buffers Prevent Metastable Conditions With Fail-Safe Input (FSI)



- Fail-Safe Input (FSI)
- Lowest Jitter (<$1ps_{rms}$)
- Internal Termination
- Superior Crosstalk MUX Isolation
- Smallest Footprint: 2x2mm & 3x3mm MLF® package

Micrel's new buffers, fanouts, multiplexers, and dividers include a special Fail-Safe Input (FSI) circuit that senses invalid or no input signal. When the input signal fails, the FSI latches the output to the last state and this will eliminate metastable conditions and guarantee a stable output.

FSI is an ideal feature for Hot Swap applications in rack-based equipment. No metastable or indeterminate state will occur at the output under these conditions. For more information, contact your local Micrel sales representative or visit us at: www.micrel.com/ad/fsi.

FSI Parts	Description	Fmax	1K Price*
SY58603/4/5U New!	1:1 CML/LVPECL/LVDS Buffer	4.25 Gbps	$1.70
SY58606/7/8U New!	1:2 CML/LVPECL/LVDS Buffer	4.25 Gbps	$1.95
SY58609/10/11U New!	2:1 CML/LVPECL/LVDS Buffer	4.25 Gbps	$1.95
SY89835U New!	1:2 LVDS Fanout Buffer	3.2 Gbps	$1.85
SY89464/5U	1:10 LVPECL/LVDS Fanout w/ 2:1 MUX	2 GHz	$3.92
SY89837/8U	1:8 LVPECL/LVDS Fanout w/ 2:1 MUX	2 GHz	$3.94
SY89843/4U	1:2 LVPECL/LVDS Fanout w/ 2:1 MUX	2 GHz	$2.31
SY89228/9U New!	÷3 and ÷5 LVPECL/LVDS Divider w/ Internal Term	1.5 GHz	$1.85
SY89230/1U New!	÷3 and ÷5 LVPECL/LVDS Divider w/ Internal Term	3.2 GHz	$2.69
SY89467/8U New!	1:20 LVPECL/LVDS Fanout w/ 2:1 MUX	2 GHz	$6.15
SY89846/7U New!	1:5 LVPECL/LVDS Fanout w/ 2:1 MUX	2 GHz	$2.49

1,000 piece suggested resale unit price. FOB. USA.

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