CANON COMMUNICATIONS LLC

EDN®

MAY 13

Issue 9/2010

www.edn.com

VOICE OF THE ENGINEER

Tales from the Cube: The turn of the screwdriver Pg 68

EDN.comment: Can the United States continue to innovate? Pg 9

Signal Integrity: Stub termination Pg 19

Design Ideas Pg 43

PUNCHING THROUGH THE ETHER WITH RF-RANGE EXTENDERS

Page 24

A SIMPLE CALIBRATION FOR MEMS GYROSCOPES

Page 21

INNOVATION AWARD WINNERS: A CELEBRATION OF EXCELLENCE

Page 32

SPECIAL SECTION: what's new in power efficiency

Page 53

Powerful, Versatile and Affordable...

100 kHz Dynamic Signal Analyzer

***SR785 .... $11,950** (U.S. list)*

- ***DC to 100 kHz frequency range***
- ***100 kHz real-time bandwidth***
- ***Dynamic range***
  - ***90 dB (FFT)***
  - ***145 dB (swept-sine)***
- ***Low-distortion (–80 dBc) source***
- ***Up to 32 Mbyte memory***
- ***GPIB and RS-232 interfaces***

FFT analyzers starting at $4950

The SR785 Dynamic Signal Analyzer offers state-of-art performance at a fraction of the cost of competitive analyzers. Standard features include swept-sine mode, order tracking, octave analysis, curve fit/synthesis, and arbitrary waveform source.

When compared to the Agilent 35670A, the SR785 comes out on top. It offers twice the frequency range (2 ch.) and 10 times the real-time bandwidth at less than half the price of the 35670A.

The SR785 is ideal for filter design, control systems analysis, noise measurement, audio or acoustical test, and mechanical systems analysis.

Take a close look at the SR785.

SRS **Stanford Research Systems**
1290-D Reamwood Ave., Sunnyvale, CA 94089 • e-mail: info@thinkSRS.com
Phone (408) 744-9040 • Fax (408) 744-9049 • **www.thinkSRS.com**

United for a better world

NEC Electronics Corporation and Renesas Technology Corp. have combined their businesses to launch

Renesas Electronics Corporation.

Renesas Electronics has integrated the microcontroller, power and analog semiconductors, as well as the advanced technologies and strong experience of both companies, to provide system solutions for the global market. As the #1 supplier of microcontrollers in the world*, the new Renesas Electronics has a corporate vision to harness the power of semiconductors to realize intelligent devices that can enable a sustainable planet and improve the lives of both current and future generations. Together we can realize a society where life can be enjoyed in harmony with the planet.

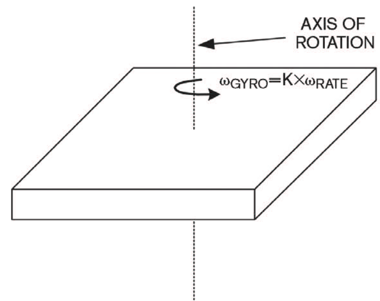
* Source: Gartner, "Semiconductor Applications Worldwide Annual Market Share: Database" 25 March 2010
This is the 2009 ranking based on revenue.

www.renesas.com

Renesas Electronics

RENESAS

EDN 5.13.10 contents



Punching through the ether with RF-range extenders

24 RF-front-end chips make it easier for you to design more distance into radios.

By Paul Rako, Technical Editor

A simple calibration for MEMS gyroscopes

21 Inaccuracy in reported data may produce an end-user experience that's worse than not having a MEMS-based system at all.

By Mark Looney, Analog Devices

pulse

Dilbert 14

13 Lighting modules integrate LEDs, drivers, optics, and heat sinks

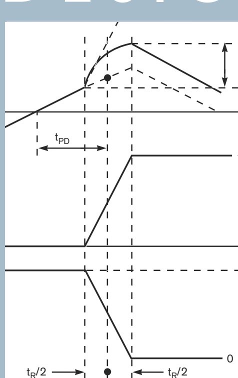
13 VeriWave generator helps support Wi-Fi/radar coexistence

14 InP ICs halve jitter, double true analog bandwidth of real-time digital scopes

16 Quad 8-bit digital potentiometer has internal EEPROM, consumes 5 μA

16 Yet another new idea for FPGAs: relays?

DESIGNIDEAS



43 Pulse generator with precision output-duty cycle operates at a repetition rate beyond 50 MHz

46 Bicolor LED driver uses two leads

46 Supervise and power-sequence an SOC

48 Circuit may save property and life

▶ Send your Design Ideas to edndesignideas@reedbusiness.com.

54 Overall power-supply efficiency depends on sweating the small stuff

By Margery Conner, Technical Editor

56 Design challenges for solar-powered HB-LED lighting

By Heather Robertson, Avnet

60 Digital-power management moves forward as licensing invites innovation

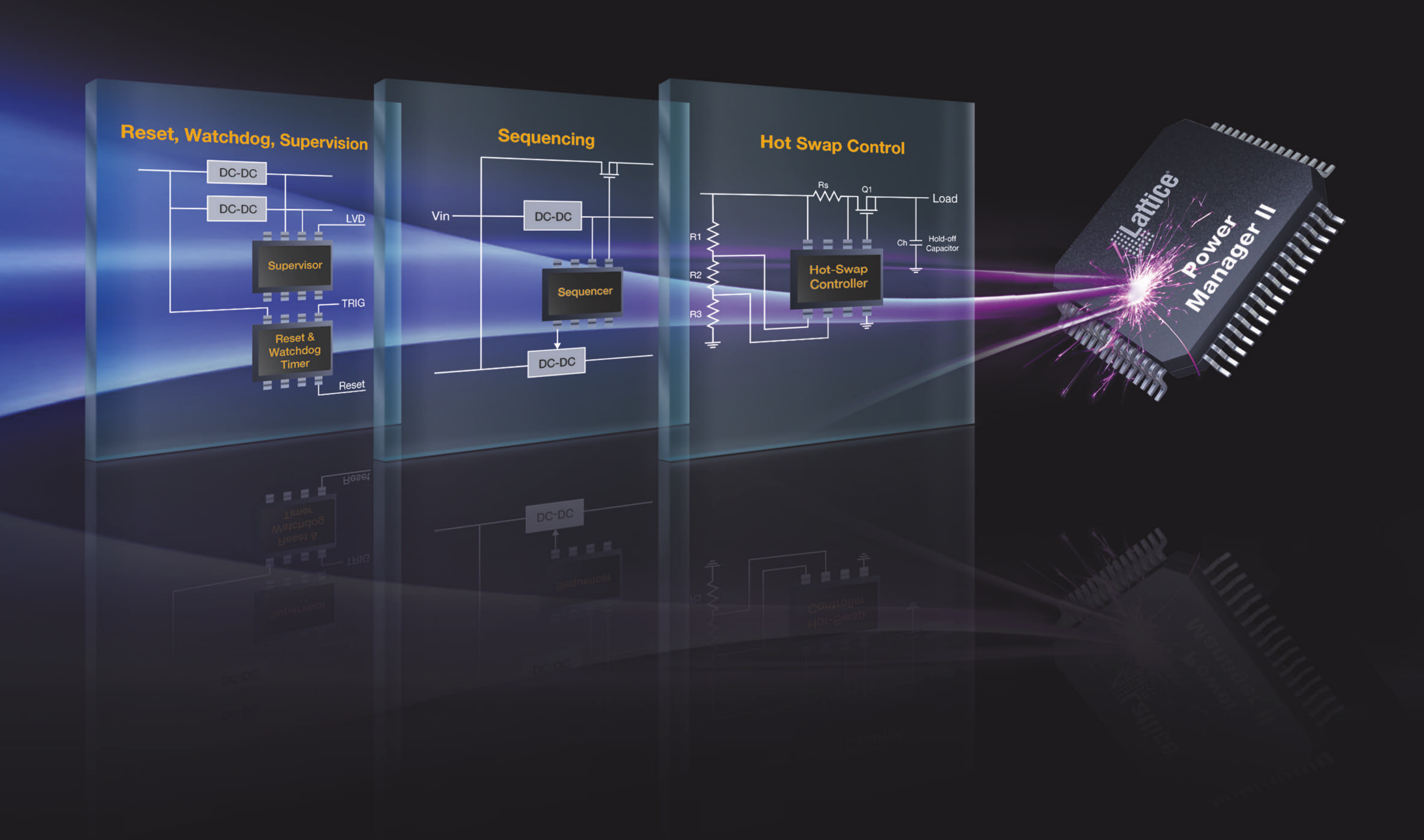
62 Validating and characterizing switch-mode power supplies for maximum efficiency

By Gina Bonini, Tektronix

Power Manager II.
INTEGRATE POWER MANAGEMENT. LOWER COSTS.

Power Manager II features an innovative programmable core and precision analog sensors to reduce component count and increase reliability. Lattice programmability enables your power management design to meet changing requirements without major circuit redesign or a board re-spin.

Learn more about the cost-efficiencies of Power Manager solutions at:
latticesemi.com/powermanager



Features
- Charge pumps for hot swap MOSFET control
- PLD for flexible supply sequencing and reset generation
- 0.2% error (typ.) programmable comparators for fault detection
- Differential sensing for centralized control
- 10-bit ADC with I²C interface for system monitoring
- High volume pricing starts at <$1.00

And more...

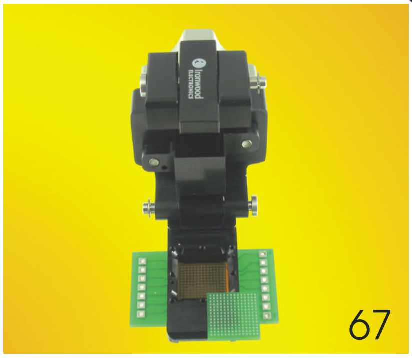
Benefits
- Integrate multiple functions to reduce BOM cost
- Increase fault coverage
- Reduce footprint
- Increase reliability
- Wide application coverage
- Reduce risks through programmability

And more...

Lattice® Semiconductor Corporation

latticesemi.com/powermanager

contents 5.13.10


67


68

DEPARTMENTS & COLUMNS

9 **EDN.comment:** Can the United States continue to innovate?

19 **Signal Integrity:** Stub termination

67 **Product Roundup:** Connectors

68 **Tales from the Cube:** The turn of the screwdriver

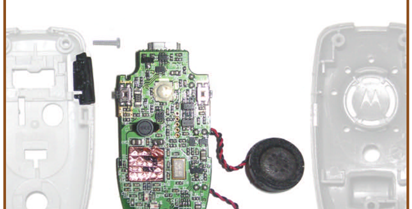
EDN online contents www.edn.com

PRYING EYES

In *EDN*'s Prying Eyes, we peer inside an end-user consumer gadget, a reference design, or any other interesting electronics-enabled thing we can get a good look at. Prying Eyes aims to illuminate the tough design decisions the engineers responsible for the design had to make. Find the entire Prying Eyes archive at www.edn.com/pryingeyes, or sample a couple of installments at the links below:

Taking a hard look at Microsoft's Xbox 360 hard drive
→www.edn.com/article/CA6726488

Inside a cellular femtocell
→www.edn.com/article/CA6711868



FROM *EDN*'s BLOGS

We've got electric cars but no infrastructure to charge them
from Anablog, by Paul Rako

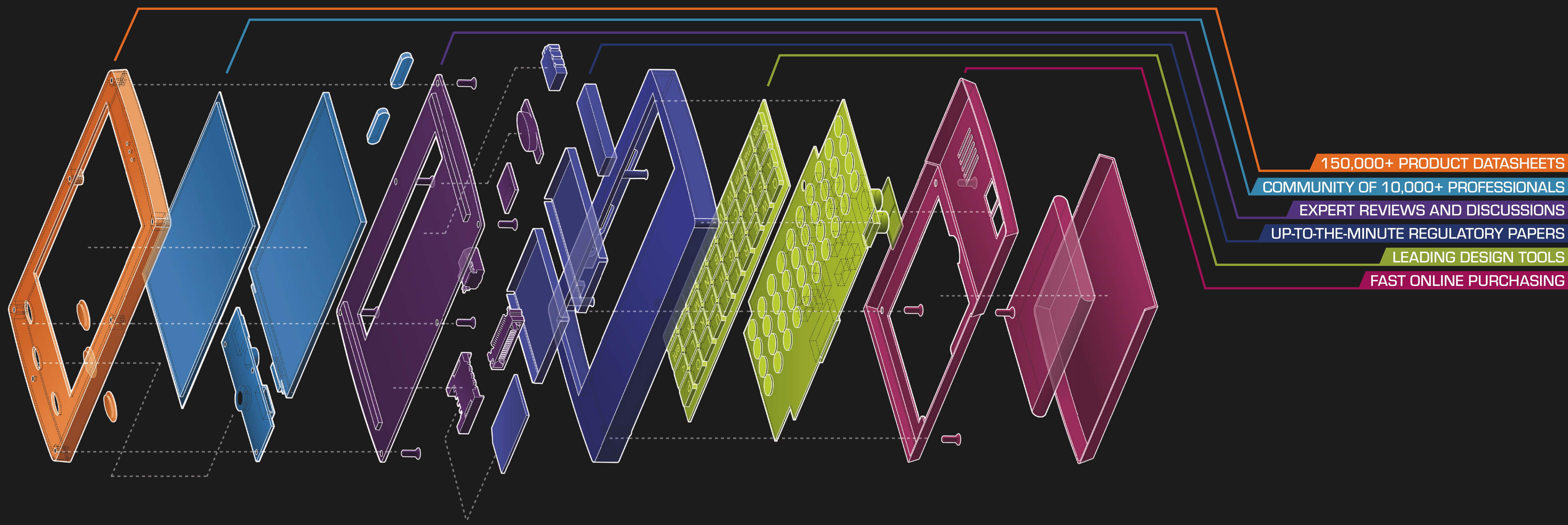
If a bunch of neighbors in a cul-de-sac all bought electric cars, would the excessive load of charging all those cars at night cause the power-line transformer to blow up?
→www.edn.com/100513toc1

Google Sync: a most excellent missing link
from Brian's Brain, by Brian Dipert

I recently downloaded and installed the application on my BlackBerry, pointed it at my Google acccount, and everything worked as advertised, in a relatively trouble-free manner to boot.
→www.edn.com/100513toc2

EDN® (ISSN#0012-7515) is published semimonthly, 24 times per year, by Canon Communications LLC, 11444 W. Olympic Blvd., Los Angeles, CA 90064-1549; 310/445-4200; FAX 310/445-4299. Periodicals postage paid at Los Angeles, California, and at additional mailing offices. SUBSCRIPTIONS—Free to qualified subscribers as defined on the subscription card. Rates for nonqualified subscriptions, including all issues: US, $179.99 one year; Canada, $229.99 one year (includes 7% GST, GST#123397457); Mexico, $229.99 one year; air expedited, $399.99 one year. Except for special issues where price changes are indicated, single copies are available for $10 US and $15 foreign. For telephone inquiries regarding subscriptions, call 763/746-2792. Email: EDN@kmpsgroup.com. CHANGE OF ADDRESS—Notices should be sent promptly to PO Box 47461, Plymouth, MN 55447. Please provide old mailing labels as well as new address. Allow two months for change. NOTICE—Every precaution is taken to ensure accuracy of content; however, the publishers cannot accept responsibility for the correctness of the information supplied or advertised or for any opinion expressed herein. POSTMASTER—Send address changes to EDN, PO Box 47461, Plymouth, MN 55447. Canada Post: Publications Mail Agreement 40685520. Return undeliverable Canadian addresses to RCS International, Box 697 STN A, Windsor, Ontario N9A 6N4.

Volume 55, Number 9 (printed in USA).



FINALLY.
DESIGN INTELLIGENCE TO MATCH YOURS.

Introducing element14: the collaborative online workspace for electronics design engineers. We've converged the best products, a wealth of technical data, and the brightest minds into a singularly powerful community portal. Our mission is simple. To arm engineers with the most useful asset of all—information. And that means you'll be able to research, design and purchase more effectively. Put intelligence to work for you at **element-14.com**

element14™
DESIGN WITH INTELLIGENCE

BY RICK NELSON, EDITOR-IN-CHIEF

INNOVATED IN THE USA

Can the United States continue to innovate?

Innovation has continued aggressively throughout the economic downturn, as *EDN*'s 20th annual Innovation Award winners show. The Numonyx Alverstone phase-change-memory design team, Best Contributed Article author Michael Kultgen of Linear Technology, and 30 products won out over more than 130 finalists in the field of competitive categories. See a complete list of the winners on pg 32.

Conventional wisdom holds that the United States remains an innovation powerhouse even as manufacturing moves offshore. US companies find heavy representation among the *EDN* Innovation Award winners and finalists. Nevertheless, the innovation that the winners represent has a strong international contribution. The team from Synopsys who developed the award-winning DesignWare SuperSpeed USB 3.0 IP (intellectual property), for example, involved engineers in Armenia, Canada, and India, as well as the United States.

There's no doubt that other countries are gaining in innovative capability, but is the United States slowing down when it comes to innovation? A panel recently addressed that question at a conference sponsored by *The Economist*. If so, what can we do about it? An Obama administration official, two Republican and Democratic senators, and Arianna Huffington of *The Huffington Post*, who attended and reported on *The Economist*'s panel discussion, have some suggestions.

As Huffington tells it, the United States has lost its educational edge and isn't investing in innovation (**Reference 1**). The solution, she writes, is to "kick our high-speed-Internet plans into high gear. A robust, broadband-charged, countrywide information superhighway is going to be key to staying ahead of the innovation curve." Huffington adds, "As FCC [Federal Communications Commission] Chairman Julius Genachowski explains, broadband isn't just important for faster e-mail and video games—it's the central nervous system for democracies and economies of the future."

Immigration policy is also ripe for reform in the interest of fostering innovation. But immigration reform is a tough sell when many Americans are out of work. Fortunately, US Democratic Senator John Kerry of Massachusetts and Republican Senator Dick Lugar of Indiana have a solution, which they outline in the *Mercury News* (**Reference 2**): "Job creators want to come to America, hire Americans, and create jobs right here for Americans that won't be outsourced or shipped overseas—and we should be helping them come." The senators propose the Start-Up Visa Act, which would grant a two-year EB-6 visa to an immigrant who can show that a qualified US investor is willing to dedicate at least $250,000 to his or her start-up venture. The immigrant entrepreneur could receive permanent legal-resident status if, after two years, the venture has generated at least five full-time US jobs, attracted $1 million in additional capital, or achieved $1 million in revenue. The bipartisan proposal sounds to me like a win-win for immigrant entrepreneurs and Americans seeking jobs.

At the same *Economist* event, Christina Romer, chairwoman of the President's Council of Economic Advisers, said that the US economy is recovering, " … yet we haven't started to add jobs, and that is truly the gold standard." We can meet the challenges we face, she said, with good, solid innovative growth without speculative excesses. To foster private innovation, government can provide IP protection, make R&D tax credits permanent, support science and math education, and spend federal money on R&D.

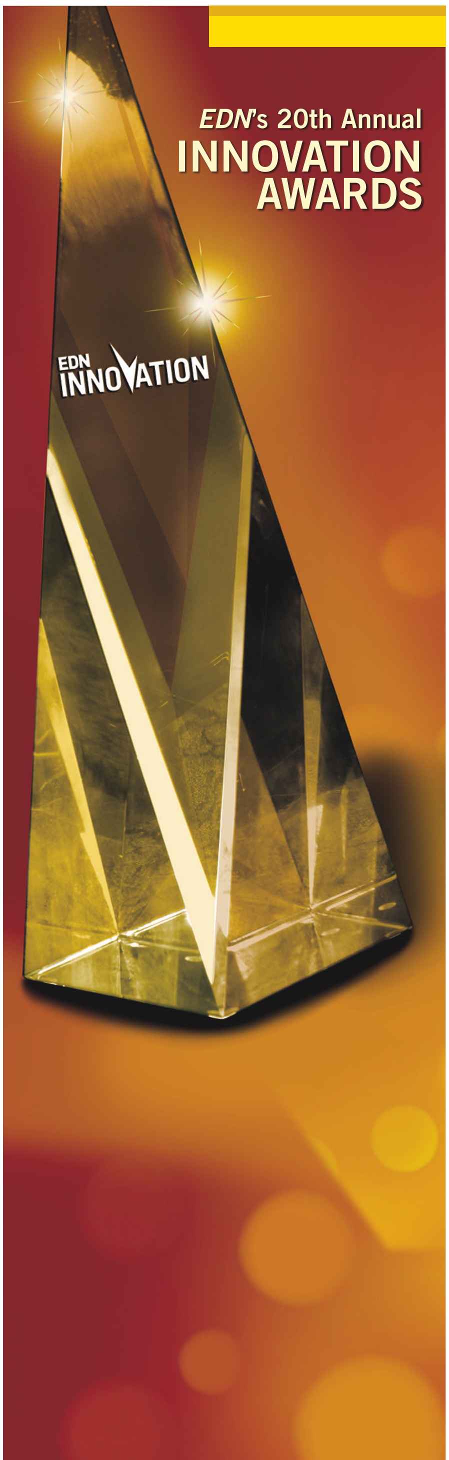
Romer believes that the government could subsidize "green" energy, for example, but it should be up to entrepreneurs to decide which technologies are the most promising areas that could benefit from subsidies. That idea sounds like the right mix of public and private efforts at innovation. **EDN**

REFERENCES

1. Huffington, Arianna, "When It Comes to Innovation, Is America Becoming a Third World Country?" *The Huffington Post*, March 29, 2010, www.huffingtonpost.com/arianna-huffington/when-it-comes-to-innovati_b_512280.html.
2. Kerry, John, and Dick Lugar, "Opinion: Visa for start-ups will keep innovation and jobs in US," *Mercury News*, March 18, 2010, www.mercurynews.com/opinion/ci_14698315?nclick_check=1.

Contact me at rnelson@reedbusiness.com.

2010 Innovation Awards WINNERS



Innovator of the Year	**NUMONYX** » Numonyx Alverstone Phase Change Memory Design Team
Best Contributed Article	**LINEAR TECHNOLOGY** » *"Managing high-voltage lithium-ion batteries in HEVs,"* Michael Kultgen / April 9, 2009
Accelerometers	**HEWLETT-PACKARD** » Digital MEMS Accelerometer
Analog: Converters	**TEXAS INSTRUMENTS** » ADS5400 12-bit, 1G-sample/sec ADC
Analog: Front-End ICs	**ANALOG DEVICES** » ADAS1128 Current-to-Digital Converter
Analog: Signal Path	**FAIRCHILD SEMICONDUCTOR** » FSA800 USB Accessory Switch
Components	**INTERNATIONAL RECTIFIER** » IR1168 SmartRectifier IC
DC and Low-Frequency Test	**AGILENT TECHNOLOGIES** » U2723A USB Source Measure Unit
Design, Debug, and Production Test, Yield Analysis	**MENTOR GRAPHICS** » Tessent YieldInsight Yield-Analysis Tool
Design Frameworks	**ALTERA** » 1080p Video Design Framework
EDA: Back-End Tools	**ALTERA** » Quartus II Version 9.1 FPGA Design Tool
EDA: Front-End Analysis and Synthesis Tools	**SYNOPSYS** » IC Validator In-Design Physical Verification Solution
EDA: Front-End Simulation and Database Tools	**CADENCE DESIGN SYSTEMS** » Virtuoso Accelerated Parallel Simulator
Embedded-System Technologies	**LANTRONIX** » XPort Pro Linux Networking Server
FPGAs	**XILINX** » Spartan-6 LXT
Microcontrollers	**MICROCHIP TECHNOLOGY** » PIC24F16KA nanoWatt XLP PIC Microcontrollers
Microprocessors	**FREESCALE SEMICONDUCTOR** » MPC564xL High-Reliability Processor
Multimedia SOCs	**MARVELL SEMICONDUCTOR** » Armada 1000 HD Media Processor SOC
Multiprocessing	**SOUND DESIGN TECHNOLOGIES** » Wolverine DSP Platform
Networking	**FUJITSU MICROELECTRONICS AMERICA** » MB88395 1394 Automotive Controller IC
Network, Timing, and BER Test	**AGILENT TECHNOLOGIES** » J-BERT N4903B Jitter-Tolerance Tester
Oscilloscopes, Digitizers, and Data Acquisition	**TEKTRONIX** » MSO70000 Series Mixed-Signal Oscilloscopes
PCs and Peripherals	**INTEL** » X25-M Mainstream SSD on 34-nm Flash Memory
Power: Converters	**LINEAR TECHNOLOGY** » LTC3108 Ultralow-Voltage Step-Up dc/dc Converter
Power: Lighting	**IWATT** » iW3610 Dimmable LED Driver
Power: Special	**NATIONAL SEMICONDUCTOR** » WEBENCH Visualizer
Power Supplies/Systems	**NATIONAL SEMICONDUCTOR** » SolarMagic Power Optimizer
RFICs	**SILICON LABS** » Si2170 TV Tuner
RF/Microwave Test	**ANRITSU** » VectorStar Microwave Vector Network Analyzer
Sensors	**AUSTRIAMICROSYSTEMS** » AS5011 Hall-Effect Magnetic Encoder IC
Silicon Intellectual Property	**SYNOPSYS** » DesignWare SuperSpeed USB 3.0 IP
Software/Embedded Tools	**ARM HOLDINGS** » mbed Microcontroller

EDN

EDN. 33 Hayden Avenue, Lexington, MA 02421. **www.edn.com**. **Subscription inquires:** 1-763-746-2792; EDN@kmpsgroup.com. **Address changes:** Send notice promptly to PO Box 47461, Plymouth, MN 55447. Please provide an old mailing label as well as your new address. Allow two months for the change. Canon Communications LLC, 11444 W. Olympic Blvd., Los Angeles, CA 90064-1549; 1-310-445-4200; fax: 1-310-445-4299.

Canon Communications LLC

pulse

INNOVATIONS & INNOVATORS

Lighting modules integrate LEDs, drivers, optics, and heat sinks

Cree recently announced a line of lighting modules that combines the company's TrueWhite LEDs with driver electronics, optics, and primary-thermal-management components. The first product in the new line, the LMR4 LED module, consumes 12W, delivers 700 lumens at a warm-white color temperature of 2700K with a CRI (color-rendering index) of 90, and has a minimum lifetime of 35,000 hours. All a fixture manufacturer needs to do is drop in an optional heat sink to accommodate high-temperature applications, such as down lights for insulated ceilings, and then design the external fixture package. The result is a low-power, long-life solid-state-lighting luminaire. Cree offers an evaluation kit, including two luminaires and two dimmers, for $199.

The LMR4 module consumes 12W, delivers 700 lumens at a warm-white color temperature of 2700K with a CRI of 90, and has a minimum lifetime of 35,000 hours.

How does this product compare with the modular-lighting system that Bridgelux recently announced (see "Modular LED-light system targets new installations," *EDN*, April 22, 2010, pg 14, www.edn.com/article/CA6726495)? First, Bridgelux and Cree LEDs offer different light characteristics. Bridgelux's system focuses on making LED lights interchangeable: The hard-mounted connector makes it easy to swap out the LED module when an end user wants a change in light color or beam pattern. Most important, though, the Bridgelux product lacks power-management electronics, whereas Cree's module does not.

–by Margery Conner

▷**Cree**, www.cree.com.

FEEDBACK LOOP

"Too funny; this is one of those stories where, at the end, you just walk up to a wall and bang your head on it!"

—Engineer "LostInSpace," in *EDN*'s Feedback Loop, at www.edn.com/article/CA6722392. Add your comments.

VeriWave generator helps support Wi-Fi/radar coexistence

VeriWave's new RFI (radio-frequency-interference) and DFS (dynamic-frequency-selection) pulse-generator system lets developers of 802.11n-compliant Wi-Fi chip sets, receivers, access points, and user devices expand test coverage. The generator speeds the development of and reduces the costs associated with ensuring that new products comply with new rules for Wi-Fi devices sharing radio bands with Bluetooth devices, microwave ovens, and civilian radar installations. Rather than requiring multiple signal generators to handle MIMO (multiple-input/multiple-output)-test capabilities, the RFI and DFS pulse-generator system uses a VeriWave 802.11n WaveBlade instrument, which supports three spatial signal streams. Eran Karoly, vice president of marketing at VeriWave, explains that international certification commissions and IEEE specifications for 802.11n require Wi-Fi devices to vacate channels in deference to radar systems. VeriWave's RF system features DFS ability that introduces radar traffic into the mix along with traditional RF-test traffic.

VeriWave's interference generator simplifies the creation of interfering waveforms in popular 802.11 bands to a point-and-click process, allowing testers to configure and modify traffic characteristics, including signal strength, burst lengths, and burst rates; it also automates and repeats tests. Along with the expanded test coverage, the generator simplifies the creation of I/Q (in-phase/quadrature) waveforms for modeling real-world scenarios. The base price for the system is $8995.—**by Rick Nelson**

▷**VeriWave**, www.veriwave.com.

InP ICs halve jitter, double true analog bandwidth of real-time digital scopes

Agilent Technologies has introduced the Infiniium 90000 X-Series of four-channel real-time oscilloscopes, which offer bandwidths as high as 32 GHz when you use two channels. Thanks to a proprietary InP (indium-phosphide)-IC process and advanced packaging techniques for fabricating key mixed-signal components, the real-time bandwidth of the 10 models ranges from 16 to 32 GHz. All models permit bandwidth upgrades to the 32-GHz maximum. Maximum sampling rate is 80G samples/sec/channel, and maximum memory depth is 2G samples/channel.

The new scopes deliver low noise- and jitter-measurement floors, ensuring superior accuracy. By using the same technologies, the accompanying InfiniiMax III probing system, which also works with the company's older ultra-wide-bandwidth sequential-equivalent-time-sampling scopes, offers browsing at bandwidths as high as 30 GHz with a full range of accessories operating at 28 GHz and enables future bandwidth upgrades.

The 90000 X-Series DSA (digital-signal-analyzer) models incorporate more than 40 measurement-specific application packages, including triggering, jitter-measurement and-analysis tools, and full compliance-certification-test suites.

> The InfiniiMax III probing system includes four probe-amplifier models that offer bandwidths from 16 to 30 GHz.

Custom aluminum-nitride packaging technology combines five InP chips in the front-end multichip module, which implements unique noise-shielding and heat-dissipation techniques. This technology gives the scopes true analog-hardware performance at bandwidths as high as 32 GHz. The 90000 X scopes exhibit internal jitter that is approximately half that of competitive products. The improved measurement accuracy manifests itself in a noise floor of 2 mV p-p at 50-mV/division sensitivity and 32-GHz bandwidth and a jitter-measurement floor of approximately 0.18 nsec.

The InfiniiMax III probing system includes four probe-amplifier models that offer bandwidths from 16 to 30 GHz. A wide range of probe heads allows connection via browser, ZIF (zero-insertion-force) tip, 2.92- or 3.5-mm SMA cable, or solder-in tips. To achieve 30-GHz performance, the InfiniiMax III browser uses a novel crisscross blade-grounding system for lower-inductance grounding, wraps coaxial tips in shields cut from a microwave-absorbent PolyIron sheet to reduce standing waves, and uses replaceable resistor tips with low parasitic capacitance and inductance.

Besides providing the highest bandwidth and accepting either single-ended or differential signals, the new probing system works not only with the 90000 X real-time scopes but also with the manufacturer's 86100C DCA-J (digital-communications analyzer/jitter). The system also offers probing-investment protection through upgrades of 16-GHz-bandwidth probe amplifiers to physically identical units that offer bandwidth as high as 30 GHz. Agilent is simultaneously making available both the wider-bandwidth probing system and the wider-bandwidth real-time scopes, avoiding a frustrating period during which the scopes' increased bandwidth is unavailable to those who must use probes.

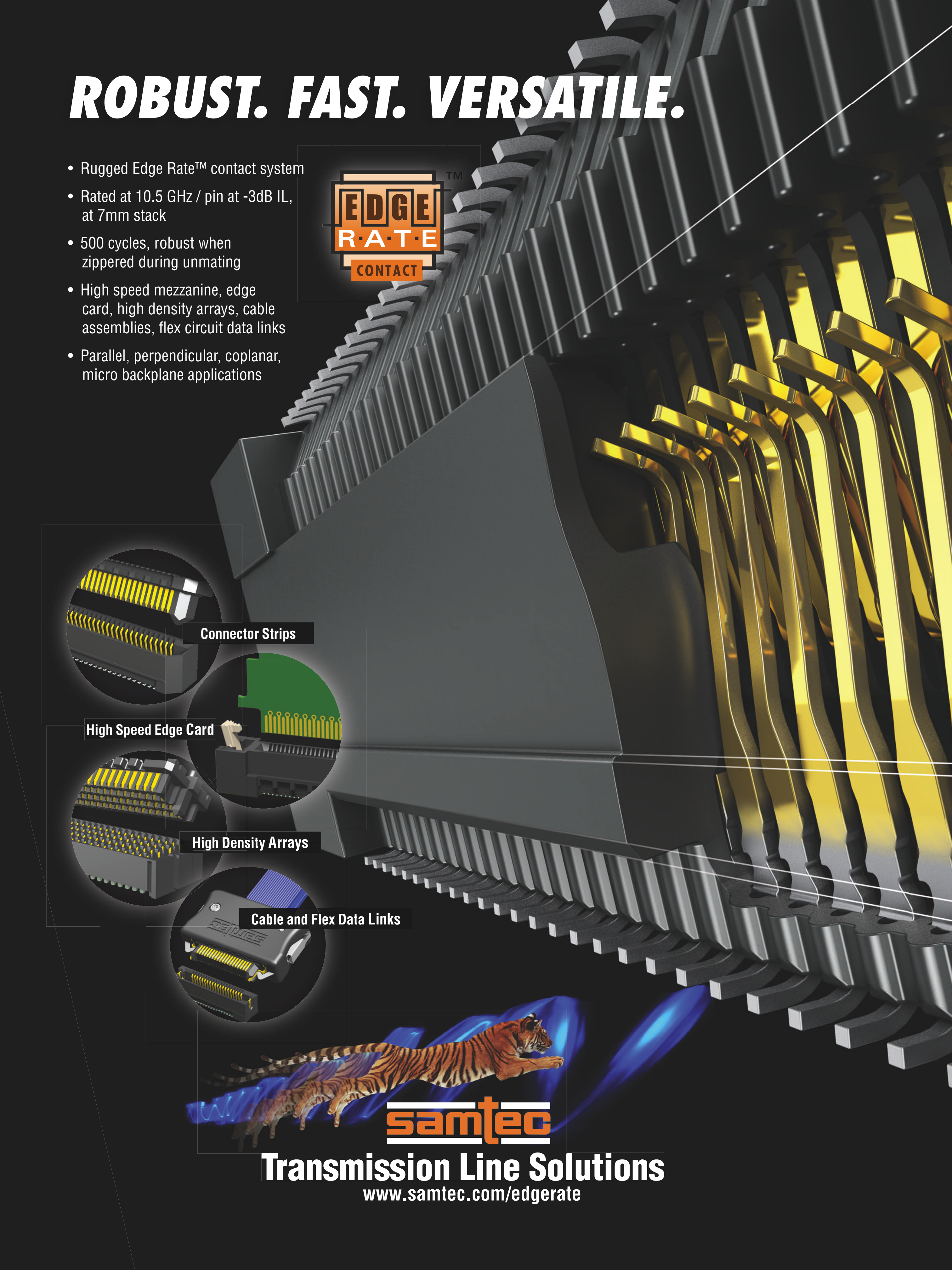
US prices for the 10 models of the Infiniium 90000 X oscilloscope series range from $131,000 for a 16-GHz-bandwidth DSO (digital-storage oscilloscope) model to $286,000 for a 32-GHz DSA unit. The four probe amplifiers in the InfiniiMax III series carry US prices of $14,400 for 16-GHz bandwidth to $29,000 for 30 GHz.

–by Dan Strassberg

▷**Agilent Technologies**, www.agilent.com/find/90000X-Series, www.agilent.com/find/InfiniiMax3.

The 32-GHz members of the Infiniium 90000 X-Series exhibit 10 to 90% rise and fall times of just 13 psec and little noise or jitter.

DILBERT By Scott Adams


ROBUST. FAST. VERSATILE.
• Rugged Edge Rate™ contact system
• Rated at 10.5 GHz / pin at -3dB IL, at 7mm stack
• 500 cycles, robust when zippered during unmating
• High speed mezzanine, edge card, high density arrays, cable assemblies, flex circuit data links
• Parallel, perpendicular, coplanar, micro backplane applications
EDGE RATE CONTACT ™
Connector Strips
High Speed Edge Card
High Density Arrays
Cable and Flex Data Links
samtec
Transmission Line Solutions
www.samtec.com/edgerate

Quad 8-bit digital potentiometer has internal EEPROM, consumes 5 μA

Microchip Technology's new 8-bit, digital MCP4361 quad potentiometer and MCP4362 quad rheostat save their settings in internal EEPROMs. The devices communicate over an SPI (serial-peripheral-interface) bus at 10-MHz rates, function over a 2.7 to 5.5V supply range, and operate at voltages as low as 1.8V. Typical supply current is 2.5 μA, and maximum supply current is 5 μA when the serial bus is inactive and 1 mA maximum during a nonvolatile-write operation.

The devices come in 5-, 10-, 50-, and 100-kΩ variants, with a typical wiper resistance of 75Ω. Maximum INL (integral nonlinearity) is 1 LSB, and maximum DNL (differential nonlinearity) is 0.5 LSB. The absolute temperature coefficient is 50 ppm at 0 and 70°C, and the ratiometric temperature coefficient is 15 ppm.

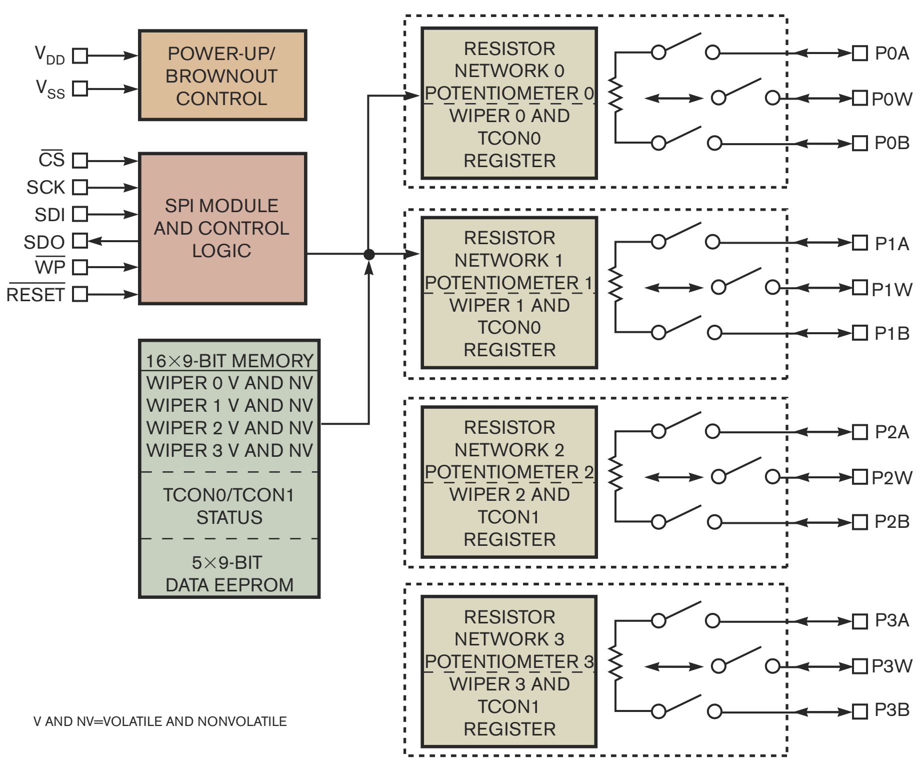
The resistor network of the 5-kΩ part has a 2-MHz bandwidth. By writing to an internal register, you can disconnect the resistor network from the terminals, and you use an input pin to reset the part to its default condition. Weak pullup resistors reside on the serial bus' digital inputs, which tolerate voltages as high as 12.5V and have a Schmitt-trigger-transfer function. The units also operate in split-rail environments.

The devices have applications in consumer and industrial applications, such as power-supply trim and calibration, setpoint and process control, closed-loop servo control, PC peripherals, portable instrumentation, instrumentation-offset adjustment, and signal conditioning. The units' operating-temperature range of −40 to +125°C also makes them suitable for automotive applications. An 80-page data sheet fully characterizes the operation of the units and provides application guidance.

The MCP4361 comes in a 20-pin TTSOP or a 4×4-mm QFN package, and the MCP4362 comes in a 14-pin TTSOP package. They sell for $1.34 (10,000) each.

–by Paul Rako

▷**Microchip Technology**, www.microchip.com.



You control the Microchip MCP4361 quad potentiometer with the SPI bus. The device's nonvolatile memory allows it to power up without microprocessor supervision.

05.13.10

YET ANOTHER NEW IDEA FOR FPGAs: RELAYS?

A relatively unnoticed paper at February's International Symposium on FPGAs described what may be the most radical technology of them all: FPGAs using electromechanical relays. The paper presented work by professors and students at the Stanford University departments of electrical engineering and computer science and researchers at Altera Corp (www.altera.com). It describes a conventional FPGA fabric in which MEMS (micro-electromechanical-system) relays replace the SRAM cells and MOSFET pass gates that control the interconnect routing. The relays would be fabricated in an encapsulated layer between metal 3 and metal 4, according to Stanford professor Subhasish Mitra, so they would neither take up silicon real estate nor interfere with the critical routing on the first two metal layers.

Beside saving space, the MEMS relays have other potentially useful characteristics. By playing with the design, size, and materials, you can change the voltages necessary to open and close the relay, the speed of the relay, and its on-resistance.

For more information on this development, go to www.edn.com/pa.

–by Ron Wilson

▶Stanford University, www.engineering.stanford.edu.

AVAGO TECHNOLOGIES

New Miniature WiMAX Linear Amplifier Modules Solve System Challenges

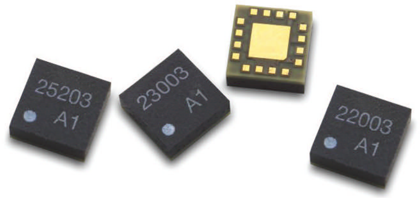
Introduction

Avago has introduced three new linear amplifier modules (LAM) in small 3 x 3 x 1 mm packages: the MGA-22003 (2.3-2.7 GHz, 25 dBm); MGA-23003 (3.3-3.8 GHz, 25 dBm); and MGA-25203 (5.1-5.9 GHz, 23 dBm).

The MGA-22003 and MGA-23003 are optimized for WiMAX systems, and the MGA-25203 is a general purpose amplifier for use when efficient linear power is important. This note focuses on the performance potential of the two WiMAX amplifiers and how system problems can be solved by using them.

WiMAX, Worldwide Interoperability for Microwave Access, is a family of IEEE 802.16 standards designed to address the needs of Wireless Metropolitan Area Networks (WMANs). There are multiple implementations of the standard being developed for fixed and mobile applications.

WIMAX's reach is a significant advantage over Wi-Fi networks. Internet connectivity to local communities and areas can be quickly installed without the infrastructure required by cable or phone technologies. Some forecasts project over 75 million WiMAX subscribers by 2014, with the majority being mobile users. Chipset unit volume may exceed 75 million in the same year.



MGA-22003 and MGA-23003 WiMAX Linear Amplifier Modules

One technical challenge facing designers is how to cover the full band with a dedicated RF Front End solution. After reviewing various deployment scenarios, as well as auctioned frequency bands in certain geographical locations, Avago decided to design a full band solution that provides one set of hardware to cover the WiMAX bands.

The peak-to-average characteristics of a 16QAM OFDMA signal with 10 MHz signal bandwidth over a relatively wide RF band places a special requirement on the TX chain. The requirement to meet a stringent spectrum emission mask in conjunction with system EVM specifications requires special design techniques and sophisticated semiconductor process technologies for the RF power amplifier.

The RF power amplifier must deliver linear power of 23 dBm to the antenna after the post-PA losses. The linearity requirement is met by backing-off the PA at the cost of DC power efficiency. The linearity requirement over a wide frequency band with a high degree of back-off means the RF power amplifier must have a high level of peak power handling capacity. The maximum power from this high 1 dB output power compression point (P1dB) of non-linear power amplification requires a carefully designed output-matching network.

With these constraints in hand the MGA-22003 and MGA-23003 design focused on high gain, full match, low cost, and good efficiency over the WiMAX bands. They meet industry-standard spectral emission mask (SEM) tests. The MGA-22003 meets stringent WiMAX Forum SEM requirements with margin, and the MGA-23003 complies with ETSI SEM requirements. These very small, internally 50 Ω matched amplifiers require only one external capacitor at the supply pin. Standards-compliant performance is achieved in a small space with low supply current. The 50 Ω internal matching reduces development time for both fixed and portable devices. The broad operating frequency range allows designers to use a single power amplifier to cover an entire WiMAX band where previously multiple narrow band parts were necessary to meet performance goals.

WiMAX RF Front end challenges

Equipment designers often experience difficulty locking in the RF front end lineups due to various system architectures and deployment scenarios as well as time-to-market pressure. The lack of historical use model statistics leaves the system architects with RF chain performance assumptions that are iteratively optimized during system integration or network trials. In addition, certain diversity and MIMO expectations in several deployment scenarios require switch + filter combinations with high insertion loss, from 0.5 dB to 4 dB. There are two expectations from these configurations: one is to deliver linear power from 23.5 dBm to 27 dBm from the PA and the second is to maintain the same DC power efficiency across power levels.

The dynamic range requirement of higher than 40 dB can also be handled in the transmit chain by using a gain step. However, once the final RF stage in the transmit chain delivers power levels close to 0 dBm, the PA draws DC current similar to the quiescent current, which is necessary for ultra-linear operation in High Power Mode.

WIMAX OFDMA systems operate using a pulsed signal. The transmit chain is synchronized using a frame structure and the duty cycle of the signal is determined by the application as well as data stream. The MGA-2203 has a bias switch pin (BSW) which eliminates the need for a costly high current switch on the supply line during off-pulse mode. The BSW pin can be controlled by a simple CMOS signal.

How has Avago addressed these challenges?

The choice of semiconductor technology, Avago's proprietary GaAs Enhanced mode pHEMT process, provides a full range of operation from 2.9 V to 5 V with proven reliability. In short, the MGA-22003 and MGA-23003 deliver a linear 25 dBm @3.3 V and over 26 dBm @5 V supply voltage.

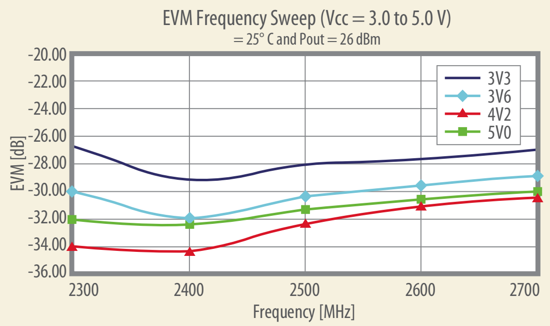


Figure 1. Error Vector Magnitude (EVM) performance at several supply voltages

Both Avago WiMAX LAMs include input and output matching networks and supply/signal pin filtering for ease of use across the full band. Since the LAMs are only 3 x 3 x 1 mm and the number of external components is minimized, the cost of ownership in the final application is kept to a minimum.

Avago has introduced a one-pin external bias control (BCTRL) that is independent of other supply pins. With the BCTRL pin, users can adjust the quiescent current of the three stages for best efficiency and best linearity at various output power levels.

Table1. Bias control settings for high efficiency

VCC = BSPLY = 3.3 V			
Pout	BCTRL	Idd	EVM
25 dBm	1.8 V	418 mA	-27.9 dB
24 dBm	1.7 V	367 mA	-27.6 dB
23 dBm	1.7 V	330 mA	27.0 dB
Idsq	x	94 mA	x

Table 2. Bias control settings for high linearity

VCC = BSPLY = 3.3 V			
Pout	BCTRL	Idd	EVM
25 dBm	2.8 V	501 mA	-32 dB
24 dBm	2.8 V	464 mA	-33 dB
23 dBm	2.8 V	435 mA	-35 dB
Idsq	x	240 mA	x

Avago has introduced two power operating modes: High Power Mode (HPM) and Low Power Mode (LPM). In Low Power Mode, LAM gain is reduced a minimum 10 dB, and the quiescent current is cut to less than 90 mA to make sure that DC power is not wasted. The power mode is selected with the PAMODE pin. No other controls are necessary for quiescent current adjustment. All the adjustments are performed by internal bias circuitry.

In addition, the MGA-22003/MGA-23003's dedicated BSW pin will switch the LAM on/off in nanoseconds. When completely turned off, current is in the microampere range.

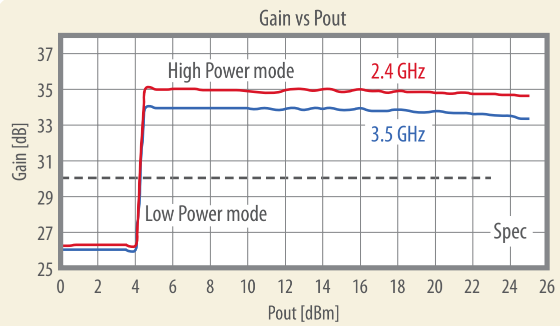


Figure 2. Low power mode current savings

Next steps – Multi-standard Coexistence challenges

As multi-mode portable devices increase in popularity, requirements exist to maintain interoperability when in close proximity to other radios. These coexistence challenges are quickly being addressed by Avago's RF product portfolio. For example, within the transmit path new linear amplifier modules are being developed which utilize aggressive gain-shaping with band-limited noise power characteristics. The next generation of the MGA-22x series covering the 2.5 to 2.7GHz range is scheduled for mid-2010 release and contains an internal filter to suppress out-of-band noise power and attenuate the gain outside the pass-band. Furthermore, the rejection in the PCS and GPS bands from the LAM eases the requirements on the coexistence filter.

Demonstration Boards

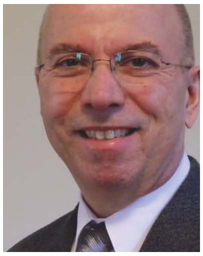
Demonstration boards for product evaluation can be requested from Avago's worldwide sales offices.

References and Resources

1. Avago Web and WiMAX frontend design video : www.avagotech.com/wimaxfrontend

2. WiMAX Forum®: www.wimaxforum.org

Contact us for your design needs at: **www.avagoresponsecenter.com/401**



BY LAMBERT SIMONOVICH

Stub termination

Figure 1 illustrates the channel insertion loss of a 30-in. differential channel with differential vias at each end. Using short vias with no stubs (green, top trace), the response rolls off smoothly to −13 dB at 5 GHz. Thick backplane vias with long stubs (red) create unwanted resonances in the channel insertion loss, whereas vias with short or no stubs do not. If these resonances occur near the Nyquist frequency of the bit rate, they will devastate the eye opening at the receiver.

Stub resonances occur when a portion of the signal traversing the active region of a via diverts down into the stub section, reflects off the open-circuited end, and returns later to recombine with the main signal. At a high frequency—the quarter-wave resonant frequency—the round-trip delay from the active region of the via to the end of the stub and back equals a half-cycle. If this scenario occurs, the main wave and the reflected wave appear 180° out of phase, producing destructive signal cancellation. The longer the stub, the lower the resonant frequency is.

You can shorten your backplane's via stubs by back-drilling the vias as close as possible to the active internal-signal layer. This complex and costly process requires that you specify the necessary back-drilling depth for each via using special design features in your artwork. Occasionally, glitches in the back-drilling process leave some vias with longer-than-expected stubs. It is only after the board has been fully assembled and tested in the system that such a problem can show up in the form of a higher bit-error rate.

Some vias can never be adequately back-drilled. For example, you must maintain a minimum via barrel length to ensure mechanical stability and good electrical contact to a press-fit connector pin. If that pin connects to a signal layer shallower than the minimum required press-fit via length, the protruding portion of the via creates a longer-than-optimum stub.

Because using via stubs seems unavoidable, what is the alternative? Nicholas Biunno, PhD, principal scientist at Sanmina-SCI Corp, suggests terminating them. Sanmina has developed the new MTS (matched-terminated-stub)-via technology, which embeds tiny metal thin-film or polymer thick-film resistors within a PCB (printed-circuit-board) stackup during fabrication. The technology can terminate a differential-via stub, thus preventing reflections. With one resistive layer at the bottom of your PCB stackup, you can terminate all the high-speed via stubs in your design. Experiment with your favorite field solver to find the right value of resistance. As **Figure 1** shows (blue trace), you can eliminate the resonant notches at the cost of additional flat-loss attenuation.

This stub-termination technology looks like a promising alternative to back-drilling, resolving many of its limitations. Combining it with silicon that can accommodate the additional signal loading may extend the life of traditional copper interconnections for the next generation of Ethernet standards beyond 10 Gbps.EDN

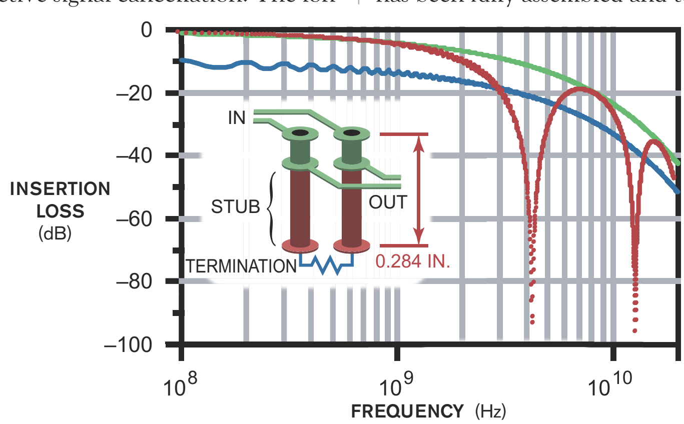


Figure 1 In this simulation, using Agilent's ADS, the channel insertion loss represents two differential vias with 30 in. of PCB etch. This loss deteriorates significantly when you use long via stubs (red), as opposed to short, back-drilled vias (green).

Lambert Simonovich, previously a signal-integrity and backplane architect at Nortel, provides innovative signal-integrity and backplane solutions at Lamsim Enterprises Inc. You can visit his Web site at http://lamsimenterprises.com. Howard Johnson will return next month.


NO MATTER WHAT THE IDEA
YOUR PCB PROTOTYPES SHOULD BE THE EASY PART
QUOTE & ORDER PCBS ONLINE AT WWW.SUNSTONE.COM OR CALL 1-800-228-8198

SILICON-BASED GYROSCOPES AND THEIR ACCELEROMETER SIBLINGS ARE INCREASINGLY PREVALENT IN CONSUMER-ELECTRONICS EQUIPMENT. HOWEVER, INACCURACY IN REPORTED DATA MAY PRODUCE AN END-USER EXPERIENCE THAT'S WORSE THAN NOT HAVING A MEMS-BASED SYSTEM AT ALL.

A SIMPLE CALIBRATION FOR MEMS GYROSCOPES

BY MARK LOONEY • ANALOG DEVICES

Traditionally, gyroscopes were mechanical devices that measured the angular rate of rotation. One common use of gyroscopes has been in navigation systems to provide heading estimation. Installing these types of gyroscopes into systems typically involved a mechanical design mounted to a bulkhead, providing a mechanical setscrew system for frame-alignment calibration. MEMS (microelectromechanical-system)-gyroscope technology now provides this function in a variety of packages that enable integration into PCB (printed-circuit-board)-based systems. MEMS gyroscopes employ tiny micromechanical systems on silicon structures, supporting motion-to-electrical transducer functions.

Although MEMS gyroscopes are simpler to integrate into electronic systems than their mechanical predecessors, many factors still require consideration, including trade-offs among function, performance, and price. For many systems, a key performance metric is accuracy. Although off-the-shelf products may satisfy some design requirements, a gyroscope that appears to suit a system design may end up being too inaccurate. Over a population of parts, for example, you can expect sufficient variation in accuracy to negatively affect critical system goals.

Gyroscope calibration offers an option for bridging this gap, enabling the use of an approach that may be more favorable due to price, package style, power dissipation, or other attributes. The purpose of calibration is to translate transducer behaviors into valuable bits at the system level. A well-designed calibration takes a population of transducer behaviors and produces predictable outputs over the important conditions for the end system. Translating MEMS-gyroscope behaviors into predicable performance at the system level requires you to cultivate an understanding of the transducer's performance and behaviors, establish the impact that the sensor's behaviors will have on critical system-performance criteria, and develop a strategy and process for characterizing and correcting behaviors that can limit the transducer's value in the system.

For system developers in the initial prototype phase, justifying the investment in accurate motor stages, encoders, and stable mechanical structures can be difficult. Although this approach to calibration will not replace the need to invest in proper equipment for production-ready processing, it will speed development cycles and lower up-front investment requirements.

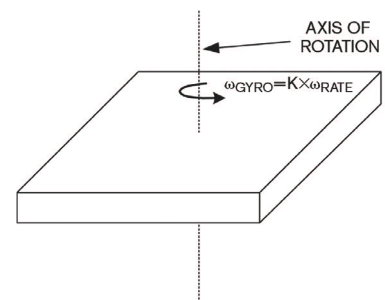


Figure 1 A yaw-rate MEMS gyroscope responds to motion about its predefined axis of rotation.

MEMS-GYROSCOPE BEHAVIOR

An ideal MEMS gyroscope produces a predicable output when you subject it to a known rate of rotation. It has no noise, perfect linearity, and no offset. Perfection is not typically available on economical manufacturing processes, however, creating the need for a deeper understanding of MEMS-gyroscope errors. A yaw-rate MEMS gyroscope responds to motion about its predefined axis of rotation (**Figure 1**). For MEMS gyroscopes, you express the typical unit of measurement for angular rate of rotation in degrees per second. For analog-output products, scale factors are normally in degrees per second per volt or millivolt. For digital products, scale factors are normally in degrees per second per least-significant bit.

The following **equation** provides a simple behavior model for a MEMS gyroscope:

$$\omega_{GYRO}=K\times\omega_{RATE}\times\epsilon+\omega_{BIAS}+\omega_{NOISE}+K_2\times\omega^2_{RATE}+K_3\times\omega^3_{RATE}+\ \ldots$$

Product data sheets typically provide information that enables estimates for each error term in this **equation**. These estimates enable the second step in this process—to determine the system-level impact and establish performance goals.

SYSTEM-LEVEL IMPACT

After establishing an understanding of the MEMS gyroscope's behaviors and error patterns, you then must determine the impact that they will have on system operation. Setting performance goals that support critical system goals is essential to successful sensor integration. Some systems, such as navigation and platform controls, use the gyroscope outputs to determine relative angle displacement through integration. Bias errors add fixed errors to the sensor's output response and can make a device look like it is rotating when it is still. The net result is a constant accumulation of angle-measurement error that is equal to the product of the bias error and time accumulation. The following **equation** shows the mathematical relationship for this drift factor:

$$\varphi_{EBIAS}=\int_0^{t^1}\omega_{BIAS}\times dt=\omega_{BIAS}\times t^1.$$

Scale-factor errors contribute to displacement-measurement errors only when there is motion. The mathematical relationship for the resulting error is as follows:

$$\varphi_{ESCALE}=\int_0^{t^1}\omega_{RATE}\times K\times\epsilon\times dt=\epsilon\times\int_0^{t^1}\omega_{RATE}\times K\times dt.$$

Noise that is inversely proportional to the integration time associated with the measurement contributes random error to the measurement. A common tool for analyzing this impact is the Allan Variance Method, which establishes the variance for a bias estimate with respect to an integration time. For example, the accuracy for a 6-second integration time is approximately 0.004°/sec (**Figure 2**).

Bias, noise, and scale-factor errors, including linearity, have a notable

AT A GLANCE

- The purpose of MEMS (micro-electromechanical-system)-gyroscope calibration is to translate transducer behaviors into valuable bits at the system level.
- You must determine the impact of the MEMS gyroscope's behaviors and error patterns on system operation.
- The Allan Variance Curve helps in analyzing the trade-off between test time and bias accuracy.

impact on systems that use MEMS gyroscopes for angle-displacement measurements (**Figure 3**). These errors directly influence heading estimates in navigation systems, along with the accuracy of a platform-control system that uses them as a feedback-sensing element.

SIMPLE CALIBRATION

A common goal for calibration is to narrow the error distribution of a transducer population and transform that population into sensor systems that provide a predictable output for the measured conditions. This procedure involves characterizing individual transducers under known conditions, thereby providing the necessary data for part-specific correction formulas. The purpose of this process is to offer a simple calibration for getting started. A linear-compensation approach, which addresses first-order bias and scale-factor errors, will suffice for reaching less-than-1% composite errors.

Averaging the MEMS-gyroscope output while holding the device in a constant position is a simple method for estimating bias errors. The Allan Variance Curve for a gyroscope helps in analyzing the trade-off between test time—that is, length of average—and bias accuracy. You typically characterize scale-factor errors using a servo-motor stage, which employs an optical encoder for precise rate control. In this approach, MEMS gyroscopes rotate at known rates while providing output measurements. Although this approach is effective and probably necessary for later stages of development and production, a simpler approach exists. Assuming bias-error correction, the integration of a MEMS gyroscope provides another mechanism for observing scale factor. In this case, the scale-factor error is the ratio of the measured angle to the actual angle displacement.

CALIBRATION EXAMPLE

Practical steps enable using this approach with a gyroscope. This process also works for a system-level board with a surface-mount MEMS gyroscope. Begin the calibration by considering the physical setup:

1. Select a pivot point and secure it with a machine-screw assembly. Experiment with the pivot screw's torque to provide for secure attachment that still allows for smooth rotation on the surface.
2. Install mechanical stops for two angular positions. One idea would be to attach two M2 spacers using M2 machine screws. Set the screws in positions that provide approximately 90° of rotation motion.
3. Pivot the gyroscope assembly between each stop point to make sure that the rotation is clear and smooth motion

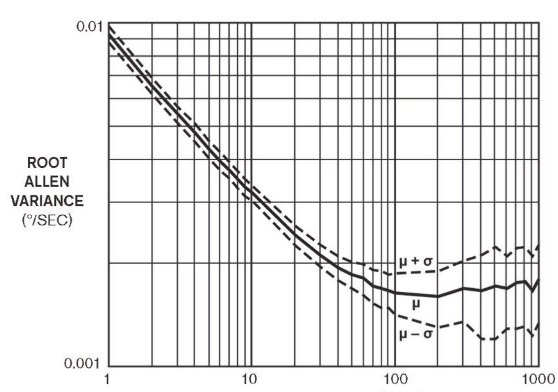


Figure 2 The root Allan Variance graphs noise impact versus integration time of the ADIS16130 MEMS gyroscope.

is possible.

4. Measure the displacement angle using an independent sensor. One option for this step would be an accelerometer-based inclinometer, such as Analog Devices' (www.analog.com) ADIS16209, which you fix to the rotating platform. You then orient the platform vertically and use an inclinometer to measure angular displacement. If the inclinometer's accuracy is 0.25° and the rotation span is 90°, the error will be less than 0.3%.

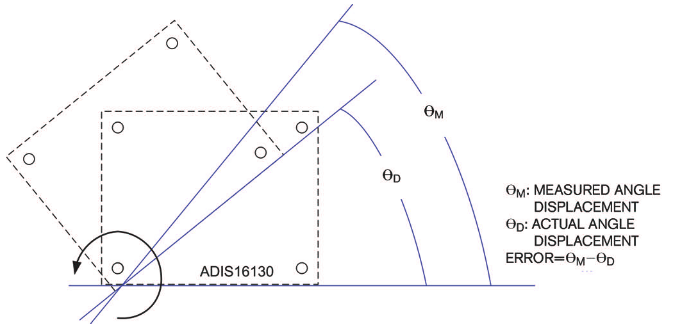


Figure 3 MEMS-gyroscope errors in variables such as bias, noise, and scale factors impact systems that use them for angle-displacement measurements.

Once the setup and angle measurements are complete, use the following procedure to measure the gyroscope's behaviors:

1. Power the gyroscope on and allow it to reach thermal stability. Many MEMS gyroscopes provide a temperature sensor for this purpose.
2. Start measuring the output while holding the gyroscope against the first stop position. Continue sampling the output for the following steps.
3. Wait 5 seconds and then turn the gyroscope toward the second stop. Begin with a smooth motion that takes 3 to 4 seconds to move the 90° span.
4. Wait 5 seconds and then rotate the gyro back to the first stop using a similar motion.
5. Wait 5 seconds and then stop the measurements. Save the data.

Using the obtained time record, use the following steps to calculate correction factors for this MEMS gyroscope (**Figure 4**):

1. Calculate the bias-offset-correction factor by averaging the first 3 seconds of data. The bias correction will be the opposite polarity of this average. In this example, the bias-correction factor is −8.6°/sec. This correction yields an accuracy of greater than 0.1°/sec for the bias estimate.
2. Subtract the bias estimate from the time record. Then integrate output data from the 4-second time stamp to the 9-second time stamp. In this case, the measured angle displacement is 95.1°. The scale factor from this step is 90° divided by 95.1°, or 0.946.
3. Using the bias-corrected response from Step 2, integrate output data from the 12-second time stamp to the 16-second time stamp. In this case, the measured angle displacement is −95.3°. The scale factor from this step is 90° divided by 95.3°, or 0.944.
4. Average the results of steps 2 and 3 to calculate the scale-factor correction, which in this example is 0.945.

Like any other bench-top process, this one requires practice to refine and improve. Experimentation will help refine the speed of rotation, but it is important to make sure that the sensor does not over-range at any point. It is also important to make sure that the surface is smooth, so that the gyro assembly does not jump up and down during the rotation. Another area of sensitivity is in approaching the stop points. If the gyro "bounces" off the stop, it may introduce errors. Using adequate transition times eases the burden of having accurate time stamps. The important thing is to start integrating before the motion begins and to stop integrating after the motion stops.

MEMS gyroscopes are sensitive to acceleration and gravity. Therefore, orientation with respect to gravity is worth consideration. In this example, gravity has the least effect on the gyroscope when you orient it in parallel with its axis of rotation. In some cases, power-supply and thermal influences may also need management In other cases, repeating this process right before taking critical measurements will be sufficient for managing these effects. If not, repeating this process at two power-supply levels and two temperatures will help mitigate the first-order effects.

This MEMS-gyroscope-calibration procedure is relatively simple and requires little investment in equipment. For some systems, this process provides the necessary accuracy. For other applications, the process simplifies the proof-of-concept development phase, helping to justify the investment to subsequently either purchase or calibrate to the necessary accuracy when the final system goes into production. Managing optimal accuracy across a wide range of temperature, power supplies, and other environmental influences will require more investment. EDN

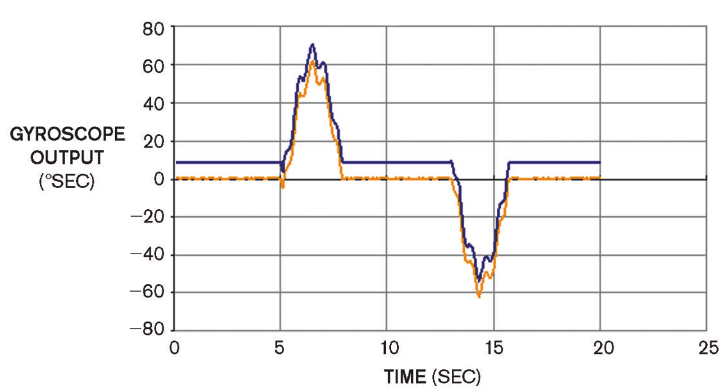


Figure 4 A time record of the MEMS gyroscope's output behaviors enables the calculation of correction factors.

AUTHOR'S BIOGRAPHY

Mark Looney is an applications engineer with Analog Devices, where his responsibilities include developing literature and application information for advanced inertial-sensing products. Looney obtained a master's degree in electrical engineering from the University of Nevada, Reno, in 1995.

PUNCHING THROUGH THE ETHER

with RF-range extenders

BY PAUL RAKO • TECHNICAL EDITOR

RF-FRONT-END CHIPS MAKE IT EASIER FOR YOU TO DESIGN MORE DISTANCE INTO RADIOS.

The RF (radio-frequency) spectrum is crowded, especially in the unlicensed ISM (industrial/scientific/medical) bands. The radios in these bands typically use spread-spectrum frequency modulation to reduce the effects of interference. Although FHSS (frequency-hopping-spread-spectrum) and DSSS (direct-sequence-spread-spectrum) techniques can allow multiple radios to share the same frequency, the interference still exists. It manifests itself as a reduction in range (**Reference 1**). As more radios share a slice of bandwidth, spread-spectrum protocols allow recovery of errors due to occasional interference. Once a sufficient number of radios all share the same frequency band, however, each radio's range decreases as the number of clear channels decreases.

You can increase a radio's range by boosting the signal strength of the transmission and improving the sensitivity of the receiver (see **sidebar** "RF-power units and conversions"). You can accomplish this task using a directional antenna, which concentrates the RF energy over a smaller angle, or you can boost the power of the transmitter and the gain of the receiver. The problem with directional antennas is that many radios are omnidirectional, especially in portable-system applications, leaving you with only one alternative: boosting the signal with a power amp and a low-noise receiver amplifier.

RF design is tricky, and designing power amplifiers is even more demanding than most other undertakings (**Reference 2**). RF engineers solve problems using frequency-domain analysis instead of time-domain techniques. RF design also requires specialized software, such as Agilent's ADS, AWR's Microwave Office, and products from Ansoft. Although such software packages have become easier to use, they still require the user to be knowledgeable about the principles of RF design. PCB (printed-circuit-board) design, including materials and impedances, is also critical in RF designs and their performance. You must pay attention to trace length and width to control the impedances of the connections because circuits interact with each other and reduce performance or cause unacceptable RFI (RF interference).

To maintain the robustness of your design and comply with FCC (Federal Communications Commission) regulations, you may need specialized signal-integrity software (**Reference 3**). This software enables you to predict the performance of the system before you lay out the PCB and then do a post-layout evaluation when you feed the

AT A GLANCE

- Crowded spectrum reduces the range of radios.
- You can extend range by adding directional antennas or more power and sensitivity.
- It is difficult to design power and low-noise amplifiers with discrete components.
- Several levels of integration are available, from power amplifiers to complete transceivers.
- You can add an RF (radio-frequency) front-end chip to a low-power radio to extend its range.
- You can correct for linearity degradation with an analog predistortion chip.

finished layout back into the software. It is also difficult to prototype RF circuits. Using dead-bug and air-ball wiring techniques—so named because of how they look when complete—is strictly verboten (**Reference 4**). You must make a PCB that is a form, fit, and function equivalent to the production board you intend to sell, and you must specify the PCB in a way that will control its dimensions and thickness and that results in predictable trace impedance over the entire manufacturing run.

Once you have built a prototype, you need high-performance test equipment. High-quality frequency generators and spectrum analyzers are expensive, and a good VNA (vector network analyzer) that can measure both the amplitude and phase of an RF-signal path can easily cost as much as your annual salary. RF-system designers also need extensive experience. If a designer encounters a design similar to a previous design, he can often dispense with the expensive design and layout software and get by with minimal test equipment (**Figure 1**). An experienced RF engineer can't debug everything with an antique grid-dip meter but can often get circuits working that inexperienced engineers cannot despite using the best test equipment available. "We have a lot of RF customers that have a digital- and firmware-design background," says Mark Grazier, program manager at Texas Instruments. "Even given a discrete part-reference design and a BOM [bill of materials], they don't get the specified range in their designs." Grazier notes that these customers have more success using TI's integrated ICs, to which they simply add an antenna and a matching network.

For these reasons, you should realize that undertaking an RF design is not trivial. The needs for specialized design software, PCB-layout software, signal-integrity software, prototyping tools, and high-end test equipment all conspire to make it a challenging project.

Figure 1 If you have the experience, you can design your RF circuits with a Boonton Measurements Corp Model 59 Grid-Dip meter, sold in 1947, in lieu of more expensive test equipment (courtesy Ken Blume, K2UPI).

MODULATION PROTOCOLS

When facing an RF-range-extender project, you must keep in mind that RF is always analog. Even if the high-level protocol of the radio is digital, such as in a cell phone, a Wi-Fi hotspot, or ZigBee, the radio waves are still in the analog domain. All that comes from the antenna is a sine wave that might wiggle in frequency, as an analog-FM transmission does; hop around, as an FHSS transmission does; or sweep and smear across a frequency, as a DSSS transmission does. The RF-signal path assumes an understanding of analog-design techniques ranging from the voltage divider to the Fourier transform.

One challenging aspect of new radio standards is that they use sophisticated modulation schemes to allow the transmission of more bits over an analog signal, similar to the way that a 56-kbps modem allows the transmission of more bits across a 3-kHz telephone line. Analog-modulation techniques, such as FM (frequency modulation), require no linear-signal amplifiers because the zero crossing of the waveform encodes all the information. The existence of a distorted sine wave doesn't matter, as long as the distortion doesn't affect the zero crossings. Modern modulation schemes pack 4, 8, or even 16 bits of information into each hertz of frequency bandwidth. Like telephone modems, they accomplish this task by relating the analog value of the RF waveform at any instant to a given digital value (**Reference 5**). Hence, the envelope of the RF signal is important, which implies that the linearity of the transmitter is critical.

ROLL YOUR OWN OR BUY?

If you want to add range to your RF design, you could try to design discrete RF amplifiers from transistors. Bear in mind, however, that you would need to design a power amplifier for transmission and a low-noise amplifier to improve the reception of the radio. Using this approach entails low-cost parts, but you must have a lot of experience and time, as well as expensive software and test equipment, to develop the design. Worse yet, the variations in the PCB may make each of your products behave differently in the field. You must address the process technology of the transistor you use. The technology you use depends on your power and linearity requirements and your ability. A silicon transistor may serve in a low-power, low-frequency application with a simple modulation, but you must use SiGe (silicon-germanium), GaAs (gallium-arsenide), or GaN (gallium-nitride) transistors if your radio operates at bandwidths higher than 3 GHz.

Designing a radio with discrete transistors rarely pays off. "Fully integrated products will be more cost-effective than using discrete parts," notes James Long, an RF consultant. One problem with discrete designs is the physical size of the RF-signal chain. You can reduce the size and complexity of a radio by using an integrated RF power amplifier from Avago, for example (**Figure 2**). This 2.4-GHz device can achieve 38.5 dB of gain and includes three amplifier blocks as well as the gain-switching and amplifier-bias circuitry, all in a 5×5-mm package. Integrated power amplifiers ensure good linearity. The Avago

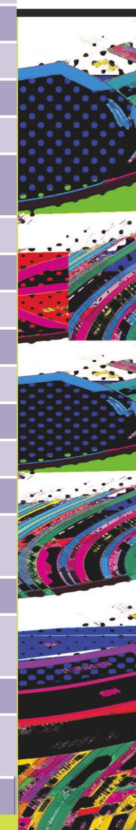
RF-POWER UNITS AND CONVERSIONS

Decibels are popular units of measurement among engineers because the units' logarithmic nature means that you can use them to represent a range of values. Remember, though, that a decibel is a ratio measurement relative to some standard. For instance, dBV (decibel voltage) is the measure of a voltage relative to 1V. The decibel refers to a voltage gain you calculate as 20log(ratio), so a gain of 10 equals a gain of 20 dB. A voltage gain of 1 million is 120 dB. Because power is a multiplication of voltage and current, decibel power terms are 10log(ratio), so a power gain of 10 is 10 dB. You often measure RF (radio-frequency) power relative to 1 mW, yielding the decibels-referred-to-milliwatt scale (Table A). The dBw (decibels-referred-to-watt) scale is power relative to 1W.

TABLE A POWER IN DBM VERSUS POWER IN WATTS

Level (dBm)	Power	Notes
80	100 kW	Typical transmission power of FM-radio station with 50-km range
60	1 kW	Typical combined radiated-RF power of microwave-oven elements
50	100W	Typical thermal radiation emitted by a human body
40	10W	Typical PLC (power-line carrier) transmitting power
36	4W	Typical maximum output power for a Citizens' band radio station (27 MHz) in many countries
33	2W	Maximum output from a UMTS (Universal Mobile Telecom System)/3G (third-generation) mobile phone (Power Class 1 mobiles); maximum output from a GSM (global-system-for-mobile)-communication 850/900 mobile phone
30	1W	Typical RF leakage from a microwave oven; maximum output power for 1800-MHz DCS (digital-cellular-system) mobile phone; maximum output from a GSM 1800/1900 mobile phone
27	500 mW	Typical cellular-phone transmission power; maximum output from a UMTS/3G mobile phone (Power Class 2 mobiles)
26	400 mW	Access point for wireless networking
24	250 mW	Maximum output from a UMTS/3G mobile phone (Power Class 3 mobiles)
21	125 mW	Maximum output from a UMTS/3G mobile phone (Power Class 4 mobiles)
20	100 mW	Bluetooth Class 1 radio, 100m range (maximum output power from an unlicensed FM transmitter); typical wireless-router-transmission power; maximum exterior router protocol allowed by European Telecommunications Standards Institute in Europe
15	32 mW	Typical Wi-Fi transmission power in laptops
10	10 mW	
4	2.5 mW	Bluetooth Class 2 radio, 10m range
0	1 mW	Bluetooth standard Class 3 radio, 1m range
–10	100 µW	Typical maximum received signal power (–10 to –30 dBm) of wireless network
–20	10 µW	
–30	1 µW	
–40	100 nW	
–50	10 nW	
–60	1 nW	The Earth receives 1 nW/m^3 from a magnitude +3.5 star
–70	100 pW	Typical wireless (802.11x) received-signal power
–80	10 pW	Receive threshold for most WLAN devices
–100	0.1 pW	
–111	0.008 pW	Thermal noise floor for commercial GPS (global-positioning-system) single channel signal bandwidth (2 MHz)
–127.5	0.178 fW	Typical received-signal power from a GPS satellite
–174	0.004 aW	Thermal noise floor for 1-Hz bandwidth at room temperature (20°C)
–192.5	0.056 zW	Thermal noise floor for 1-Hz bandwidth in outer space (4K)
– ∞	0W	Zero power is not well expressed in decibels referred to milliwatts; the value is negative infinity.

(courtesy Wikipedia, http://en.wikipedia.org/wiki/DBm)



MGA-43228, for example, can achieve 29.2-dBm (decibels-referred-to-milliwatt) power output and transmit 64-QAM (quadrature-amplitude modulation) or other sophisticated schemes that also require linearity. Other products in Avago's lineup work in the 2.5- to 2.7-GHz frequency band.

Maxim Integrated Products makes both low-noise and power amplifiers that you can combine to make your RF front end (**Reference 6**). Some of these products have 32-, 25-, and 18-dB gain at 800 MHz, 2.4 GHz, and 5.3 GHz, respectively. The company also offers the MAX2642 low-noise amp for 900-MHz cellular- and cordless-phone applications. It uses a SiGe-semiconductor process for better performance than that of discrete silicon transistors or, more surprisingly, GaAs low-noise amps. It has 17-dB gain and sells for 80 cents (1000).

Full-line RF company RFMD provides a wide selection of power amplifiers and low-noise amps. The company combines transmitting and receiving transceivers into one chip, such as the ML5805, targeting 5.85-GHz ISM radios (**Figure 3**). The transceiver integrates a power amp and can attain an output power of 21 dBm with an input sensitivity of −97 dBm. It also includes a fractional-frequency synthesizer and comes in a 6×6-mm package. RFMD recently released the ML2730, an integrated FSK (frequency-shift-keying) transceiver that includes

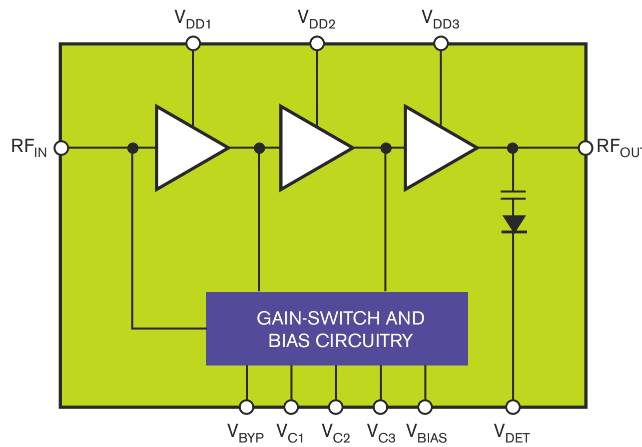


Figure 2 The Avago MGA-43228 RF-power IC integrates three stages of amplification.

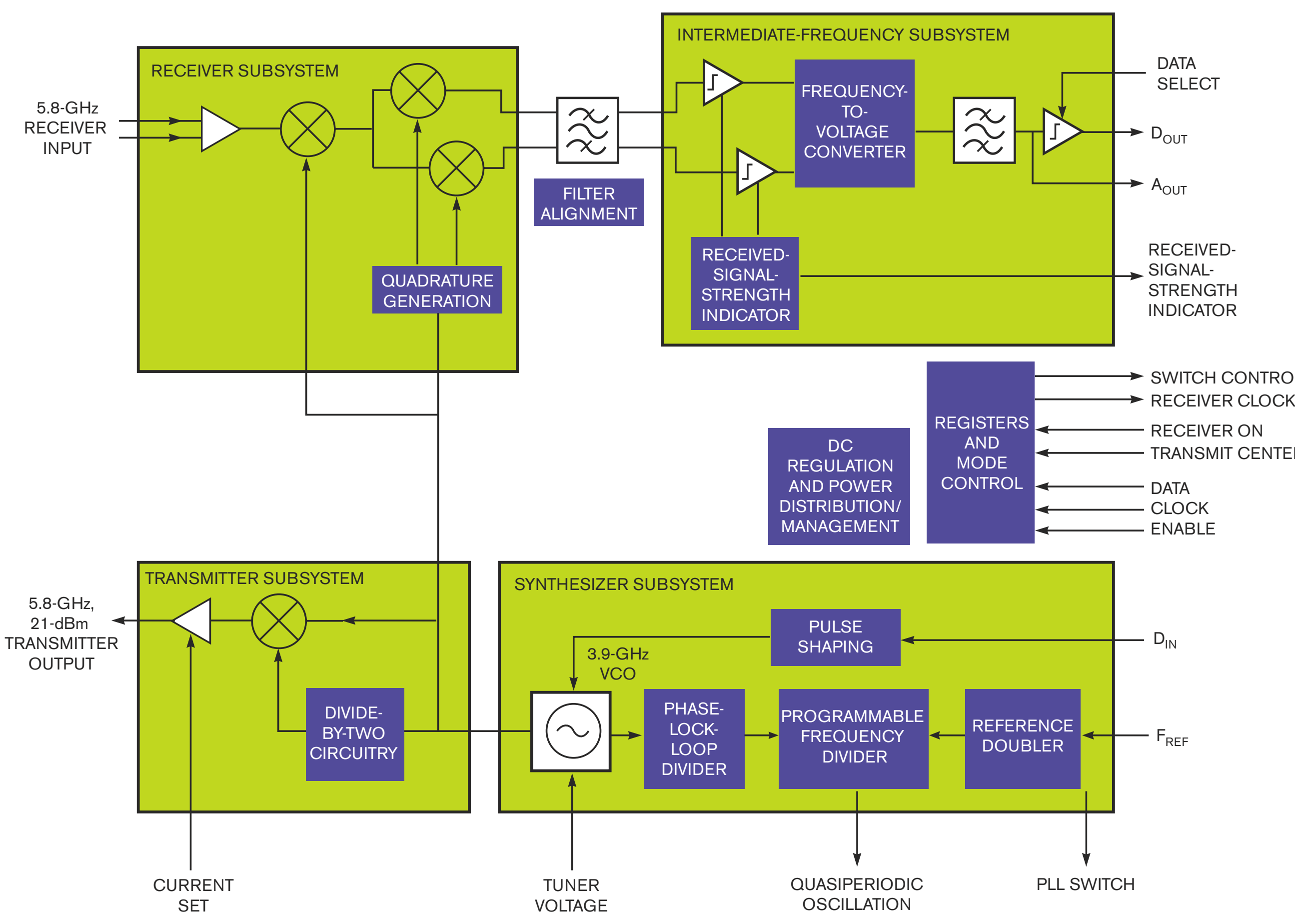


Figure 3 RFMD offers this 5.8-GHz transceiver complete with a frequency synthesizer.

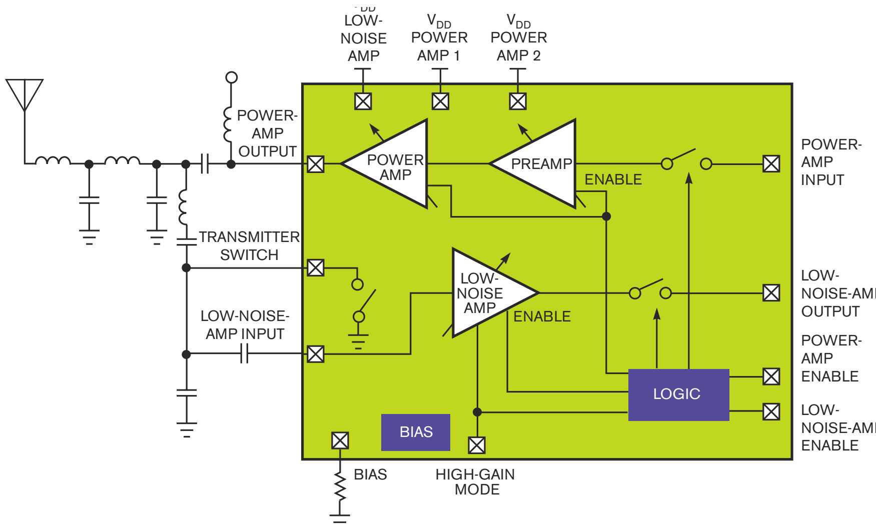


Figure 4 Texas Instruments designed the CC1190 range-extender IC to improve the distance over which a radio will operate.

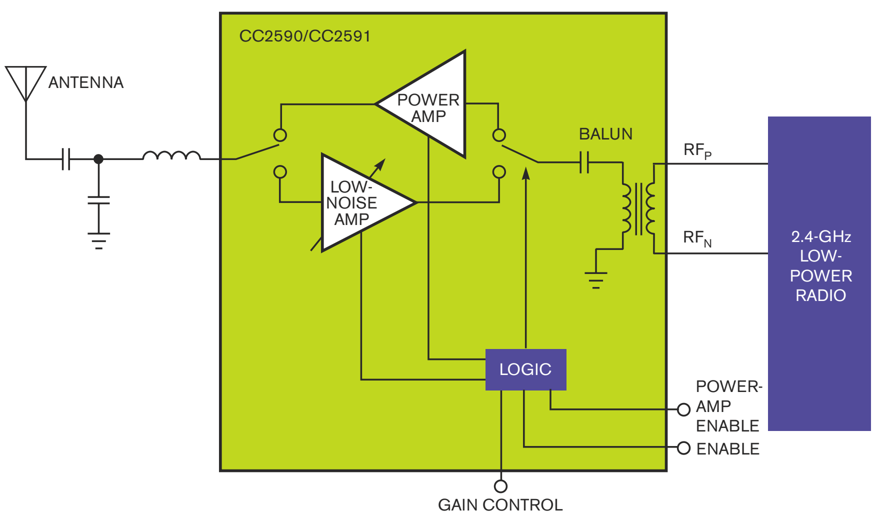


Figure 5 The TI CC2590 provides 12 dBm of power at 2.4 GHz, and the CC2591 provides 22 dBm at the same frequency.

both power and low-noise amplifiers. The device targets use in the 2.4-GHz ISM band and provides 21-dBm gain at its output amplifier. The unit also has a frequency-synthesizer subsystem. The low-noise amp achieves −97-dBm input sensitivity and comes in a 40-pin, 6×6-mm QFN package.

Analog Devices also offers complete transceiver chips, such as the AD9353, but the company incorporates ADCs and DACs into the chips, taking you all the way from RF to digital bits. This device is a complete radio but would be unsuitable if you were just trying to add an RF front end to extend the range of your radio design. Similarly, Semtech makes the XE1205, which can provide 15-dBm output power in the 180- to 1000-MHz range. This part is a complete radio, offering FSK modulation and a digital interface. Silicon Labs also offers a complete ISM transceiver, the Si4421, which can achieve an output power of 7 dBm into 50Ω, which is probably not suitable for a long-range radio. Still, with an input sensitivity of −110 dBm, the device can work with an external power amplifier that you design to get the range you need.

Texas Instruments' RF front-end chips may be ideal for designers who want to extend the range of a design. TI currently makes three transceivers for this purpose. The CC1190 targets use in frequency bands lower than 1 GHz, and the CC2590 and CC2591 work in the 2.4-GHz ISM band. All three parts combine a power amplifier, a low-noise amplifier,

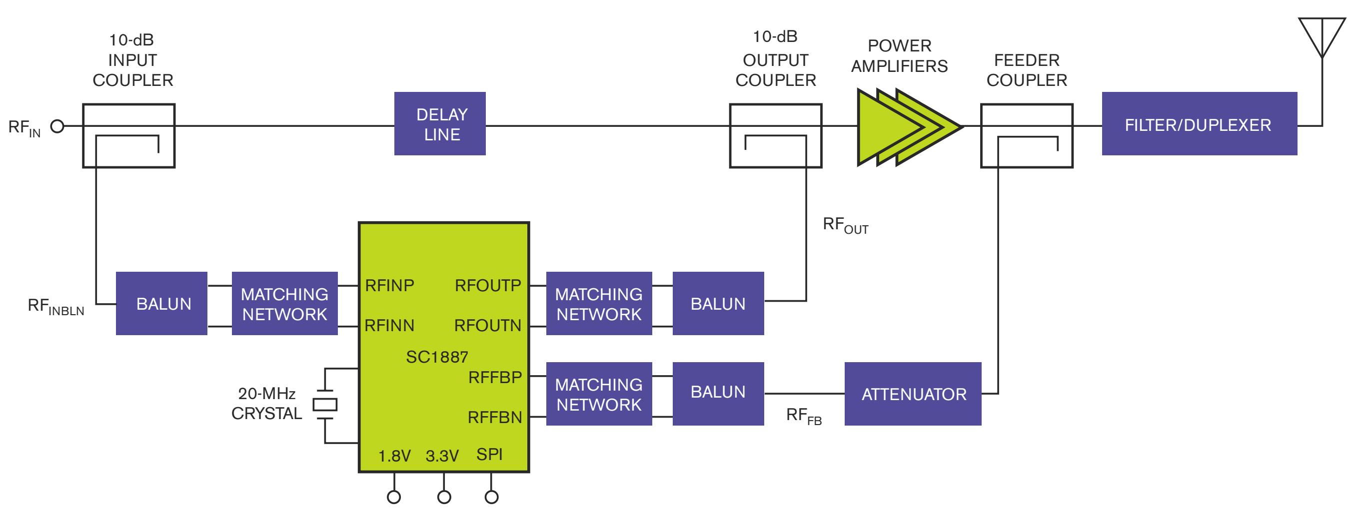
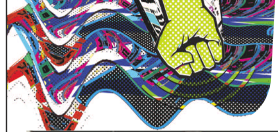


Figure 6 Scintera Networks can correct a power amplifier's nonlinearity using analog predistortion.



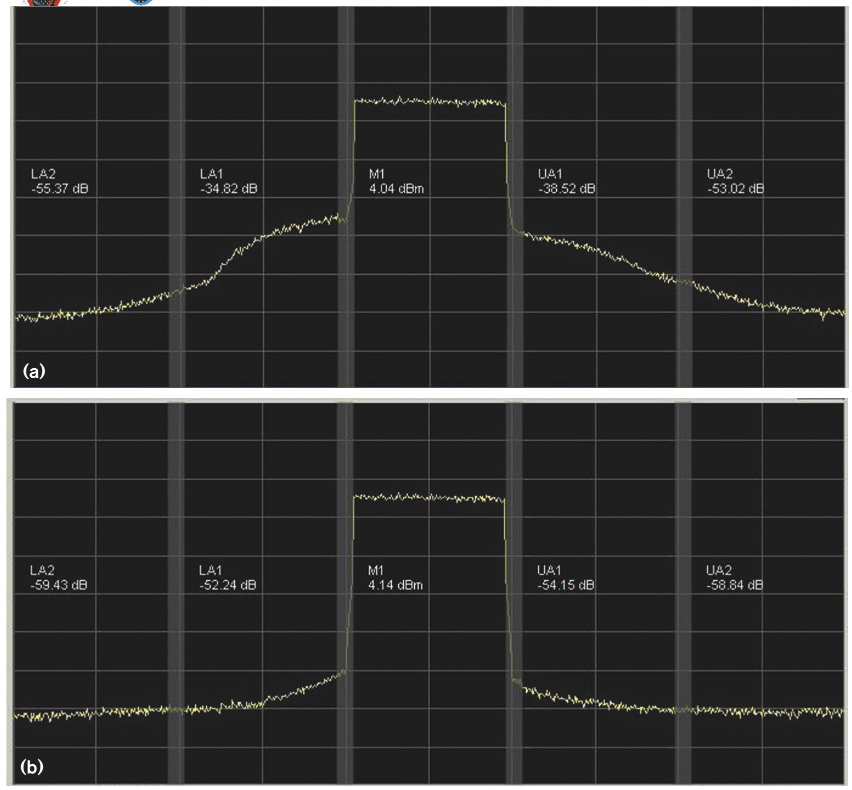


Figure 7 An RF amplifier without the Scintera Networks part operating has skirts at −35 and −38 dB below the nominal output (a). By switching in their analog predistortion, you can reduce the skirts to −52 and −54 dB (b).

a power-amp preamplifier, a transmitting/receiving switch, and the requisite logic to let you switch between transmitting and receiving modes. You need to add only an antenna and a matching network. The CC1190 operates in the 850- to 950-MHz range and can provide 27-dBm output power (**Figure 4**). TI manufactured the device on a cost-effective CMOS process, and it achieves a 2.9-dB noise figure on the low-noise amp. The CC2590 and CC2591 extend the range of 2.4-GHz radios and provide 12- and 22-dBm output power, respectively (**Figure 5**). Both integrate a balun to interface with the differential signal from the low-power radio for which you are extending the range. TI also offers evaluation boards that can speed the development of your system.

Once you boost the output power of your amplifier, you reduce the linearity and deteriorate the EVM (error-vector magnitude) and ACLR (adjacent-channel-leakage ratio) of the communication, especially if your goal is to design an efficient power amplifier. By modulating the RF waveform to levels near the power rails, you compromise the linearity of the output signal. You can look at sophisticated amplifier architectures, such as the Doherty amp, to improve efficiency, but they are also less linear. As a result, you must predistort the RF signal to compensate for the power amplifier's distortion. Normally, you would have to do this task using a complex DSP.

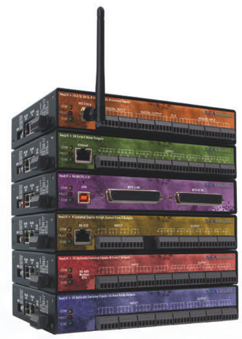
Fortunately, start-up Scintera Networks has come up with a way to perform predistortion purely in the RF-analog domain (**Figure 6**). The company's product automatically and continuously characterizes the linearity of your power amplifier and adaptively updates the coefficients to correct the linearity. The appealing feature, however, is that the RF path of the predistortion correction signal is purely analog. This approach saves both cost and power consumption. Without the need to have a DSP, you can maximize the performance of the radio and deeply modulate the signal for lower operating and capital-equipment cost (**Figure 7**). "Linearization is particularly important to meet EVM for power

Go to www.edn.com/100513cs for the list of references used in this article, as well as information on the companies listed.

amplifiers handling high-order modulation signals, such as LTE [long-term evolution] and WiMax [worldwide interoperability for microwave access]," says Roger Merel, vice president of product strategy at Scintera. This linearization is particularly important when you are using RF-power amplifiers and the adjacent channel is also licensed spectrum with which you must not interfere.

Don't despair if your radio needs more range; many system designers these days face this situation. The need to extend the range of your radio will only increase in the future as the radio spectrum becomes more crowded. Now that you understand the scope and trade-offs involved, you can make a practical plan to design, build, and test your new system. You can start with an RF engineer or consultant with extensive experience who uses that experience to design an RF front end from discrete parts, minimizing the risk and reducing the need for expensive software and test equipment. A quicker and simpler alternative is to let the analog- and RF-semiconductor companies apply their extensive experience and expertise to your problem. By buying a ready-made RF front end or assembling one based on a reference design, you remove the risk from your project and can still meet your schedule. Once you have designed a system with more than enough range, you can then reduce the gain in the RF-signal path to save power or increase gain to improve range at the expense of power consumption. Just remember that you should have a working system fairly early in the project because you will need to do testing to ensure that your radio meets FCC and worldwide regulations. Why reinvent the wheel? Use reference designs to get the head start you need in a demanding RF-design project. EDN

You can reach Technical Editor Paul Rako at 1-408-745-1994 and paul.rako@edn.com.



EDN's 2009 Innovator and Innovations of the Year:

A CELEBRATION *of* EXCELLENCE

For two decades, *EDN*'s annual Innovation Awards program has honored the most innovative technological advances as well as the designers behind those advances. This year was no different. The judges—a team effort that involved *EDN*'s editorial staff and you, the readers of *EDN* and edn.com—faced a serious challenge to decide among closely matched and highly qualified entrants in a record 30 product and technology categories. In addition, we considered nominations for 2009's Best Contributed Article and Innovator of the Year.

Read on to learn who received top honors at this year's ceremony, which took place April 26 in San Jose, CA. For more details on the winners and all of the finalists, as well as information on how you can enter next year, visit www.edn.com/innovation.

INNOVATOR OF THE YEAR

NUMONYX ALVERSTONE PHASE-CHANGE-MEMORY DESIGN TEAM

Current market demands are testing the limitations of flash-memory and DRAM usage in consumer products and enterprises. As increased numbers of computing devices, such as multifunction cell phones and mobile Internet devices, come to market, additional capacity is necessary to store and process increased amounts of information with less power. Additionally, as Internet-server applications offer faster online-search processing and faster response for consumers, servers must be able to handle the extreme increase in "near-memory" storage necessary for maintaining development of these applications.

To address this burgeoning issue, the Numonyx research-and-development team developed Alverstone, the memory industry's first commercially available device using PCM (phase-change-memory) technology—the most significant memory advancement in 40 years. PCM blends the best attributes commonly associated with NOR-type flash memory, NAND-type flash memory, and RAM or EEPROM. The result is a bit-alterable, nonvolatile technology with high read and write speeds and high endurance capabilities. Because physical-state change rather than electron storage powers PCM, shrinking lithographies do not present an issue. In fact, smaller lithographies are better suited for PCM because there is less material to alter between states, which dramatically decreases the power required to change a PCM bit. Consistent reliability and lower power give PCM technology an advantage over today's memory technologies as it scales to smaller-than-45-nm manufacturing nodes, well beyond the point that you can expect NOR and NAND to reach in the future.

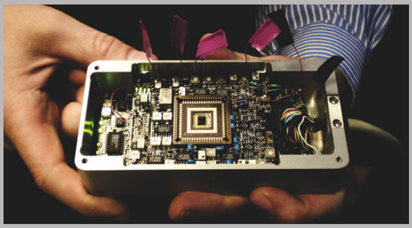
The RAMlike performance and low-power nonvolatility of PCM offer device manufacturers a new approach to storage and higher-performance computing problems, achieving much of the promise of storage-class memory. Its scalability and low-cost structure offer a scaling path beyond NOR and NAND as these electron-storage-based memories encounter limitations. Alverstone represents the first step toward commercialization of the PCM technology and is the result of nine years of extensive research and development to bring this significantly new memory concept and storage physics to production capability.

The Numonyx team includes (from left) Duane Mills, Rich Fackenthal, Greg Atwood, Roberto Gastaldi, Roberto Bez, and Fabio Pellizzer. Not shown: Ferdinando Bedeschi

ACCELEROMETERS

DIGITAL MEMS ACCELEROMETER (HEWLETT-PACKARD)

HP technology enables a new class of ultra-sensitive, low-power digital MEMS (micro-electromechanical-system) accelerometers. As much as 1000 times more sensitive than high-volume, commercial products, the sensors can achieve noise-density performance in the less-than-100 nano-g/$\sqrt{\text{Hz}}$ range to enable dramatic improvements in data quality. HP's large proof-mass and parallel-surface electrodes sense movement over a large dynamic range with a low noise floor. The bulk micromachining processes allow a 1-mg proof mass, resulting in the low noise floor, and the parallel-surface electrodes allow dynamic ranges of greater than 120 dB. In sensor networks, these accelerometers enable real-time data collection, management evaluation, and analysis monitoring. This information finds use in a range of safety, security, and sustainability applications, such as bridge and infrastructure health monitoring,



geophysical mapping, mine exploration, and earthquake monitoring.

ANALOG: CONVERTERS

ADS5400 12-BIT, 1G-SAMPLE/SEC ADC (TEXAS INSTRUMENTS)

The 12-bit, 1G-sample/sec ADS5400 ADC has a buffered input. It improves radar and signal-intelligence capabilities and can double the capture bandwidth of signals with 12-bit resolution in test and measurement. It offers an SNR (signal-to-noise ratio) of 59.1 dBFS (decibels relative to full-scale), SFDR (spurious-free dynamic range) of 75 dBc (decibels referenced to the carrier), and SINAD (signal, noise, and distortion) of 58 dBFS. Its input bandwidth is 200 MHz, and the user-selectable single- or dual-bus DDR LVDS (low-voltage-differential-signaling) outputs provide designers flexibility to choose between I/O speed and trace count. The device's adjustable gain, offset, and phase ease the interleaving of two or more ADCs to create a multigigasample/sec digitizer or to balance two ADCs in an I/Q (in-phase/quadrature) receiver.

ANALOG: FRONT-END ICs

ADAS1128 CURRENT-TO-DIGITAL CONVERTER (ANALOG DEVICES)

High-slice-count CT (computed-tomography) systems can capture real-time moving images, such as a beating heart, with a high degree of accuracy and detail. The 128-channel ADAS1128 current-to-digital converter for CT scanners contains 24-bit converters that change photodiode-array signals into digital signals. The product offers 128 simultaneously sampled data-conversion channels and selectable sample rates as high as 20k samples/sec. The ADAS1128 consumes 4.5 mW/channel at full speed. It has no charge loss, multiple ranges, and charge noise as low as 0.4 fC for low-dose X-ray systems.

ANALOG: SIGNAL PATH

FSA800 USB ACCESSORY SWITCH
(FAIRCHILD SEMICONDUCTOR)

Fairchild's FSA800 3-to-1 USB (Universal Serial Bus)-accessory analog switch enables USB data, audio headsets, and UART (universal-asynchronous-receiver/transmitter) data to all share a connector. The FSA800 also has charger-detection and microphone-connection functions and provides superior audio-signal integrity and overvoltage protection on the bus-voltage line for charging. Cell phones' micro-USB connector allows both charging and data transmission, meaning that users can employ standard USB accessories, including audio headsets, chargers, and cables for USB and UART data transmission, all through one micro-USB connector.

COMPONENTS

IR1168 SMARTRECTIFIER IC
(INTERNATIONAL RECTIFIER)

The 200V IR1168 SmartRectifier secondary-side rectifier-driver IC drives two N-channel power MOSFETs that act as synchronous rectifiers in resonant-half-bridge topologies. The device also has two 200V, high-speed comparators, which differentially sense the drain-to-source voltage of the MOSFET using the device's on-resistance as a shunt resistance to determine the polarity and level of the device currents. The device uses the SmartRectifier control technique, which compares the sensed voltage across the MOSFET with two negative thresholds to determine the turn-on and turn-off transitions for the device. By governing the drive level of the secondary-side MOSFETs according to these three thresholds, the IR1168 ensures accurate performance without the need of a PLL (phase-locked loop) or external timing sources. The IR1168 delivers an efficiency improvement of 1.5% for a standard 240W LCD TV switched-mode power supply, a reduction in rectifier-device temperature of 25°C, and a reduction in board size by two-thirds.

DC AND LOW-FREQUENCY TEST

U2723A USB SOURCE-MEASURE UNIT
(AGILENT TECHNOLOGIES)

Agilent's paperback-sized U2723A USB (Universal Serial Bus) SMU (source-measure unit) supplies ±20V voltage and 120-mA current on three channels and provides accurate current measurements to the nanoamp levels. The channels can connect in series or in parallel to achieve as much as 60V and 360 mA. With a 15-msec rise time, the device improves throughput during mass testing of semiconductor devices. It is useful in consumer electronics, semiconductors, renewable energy, aerospace and defense, and communication. The SMU tests camera modules, CMOS ICs, optical transceivers, and solar cells, and it provides design validation and characterization on semiconductor devices. It also features embedded test scripts that enable high

test throughput through parallel outputs with short rise and fall times. The U2723A supports entry of 200 list modes for each embedded test script, with as many as two embedded test scripts per channel. Its plug-and-play feature simplifies data transfer through the USB interface.

DESIGN, DEBUG, AND PRODUCTION TEST, YIELD ANALYSIS

TESSENT YIELDINSIGHT YIELD-ANALYSIS TOOL (MENTOR GRAPHICS)

The YieldInsight analysis tool enables designers to understand and identify semiconductor yield loss from production-scan-test data, reducing the time to finding the root cause by 75 to 90%. Based on initial analysis, failure-analysis engineers use PFA (physical-failure-analysis) techniques, such as emission microscopes and nanoprobing, to identify the defects in failing devices. They then take corrective action, such as a process, design, or test-program change, to improve yield. YieldInsight mines data with respect to designs, visualizes results consistent with yield-analysis practices, identifies systematic defects, and includes drill-down functions to effectively select die for PFA. It uses layout-aware diagnosis that provides a data set for each failing device. It needs no manufacturing-equipment data, which might be unavailable to fabless-semiconductor manufacturers. YieldInsight also uncovers previously hidden yield limiters representing the last 1 to 2% in high-volume manufacturing.

DESIGN FRAMEWORKS

1080P VIDEO DESIGN FRAMEWORK
(ALTERA)

Targeting broadcast, surveillance, videoconferencing, medical-imaging, and military-vision systems, Altera developed the industry's only FPGA-based 1080p video-design framework, which lets designers rapidly build custom video-processing datapaths with an order-of-magnitude productivity edge. Altera's 1080p video-design framework allows system designers to create a custom image-format-conversion signal chain. The framework comprises a collection of IP (intellectual-property), tools, and building-block video functions and interfaces, including 1080p-quality key video IP; building-block video functions for video input, output, transport, frame-buffer interface, and runtime control; a large collection of hardware-verified reference designs; a standard open-source, low-overhead video interface; and system-level-design tools for integrating processors and memory subsystems. Altera's 1080p video-design framework provides all the key functions that the broadcast-infrastructure systems need to implement image-format conversion.

EDA: BACK-END TOOLS

QUARTUS II VERSION 9.1 FPGA-DESIGN TOOL (ALTERA)

Quartus II Version 9.1 offers 20% faster compilation than Version 9.0 and two- to three-times faster compilation than the nearest competitor for high-density, 65- and 40-nm designs. The release also supports Altera's new Cyclone IV FPGAs and the Stratix-IV E EP4SE820 FPGA. A rapid-recompilation feature permits faster small ECO (engineering-change-order)-type design changes, reducing compilation times by 50% on average for a recompilation versus running another full compilation on the design and preserves critical timing during late design changes. Quartus II performs parallel processing in all synthesis, place-and-route, static-timing-analysis, and assembler design stages. New parallel-synthesis support significantly reduces synthesis time for designs with partitions. Version 9.1 delivers an enhanced timing-driven-synthesis feature, enabling you to improve design performance in 10% less time than the previous versions. Version 9.1's incremental-compilation feature allows you to make changes and compile just the critical blocks until you reach timing closure, reducing compilation times by as much as 70% over a flat compilation.

EDA: FRONT-END ANALYSIS AND SYNTHESIS TOOLS

IC VALIDATOR IN-DESIGN PHYSICAL VERIFICATION TOOL (SYNOPSYS)

IC Validator, Synopsys' new in-design physical-verification tool, working with IC Compiler, allows physical-system designers to efficiently conduct sign-off-quality verification during design. It automatically detects and fixes errors in the full context of area, timing, and power, before the design closes. The end result is a DRC (design-rule-checking)-clean design that easily passes the final sign-off.

IC Compiler integrates and shares a data model with IC Validator. The sign-off-quality accuracy is proven through extensive foundry qualification. The modern implementation uses hybrid polygon/edge-rule processing, is multicore-enabled, and employs a unique programmable language for concise rule creation and execution.

EDA: FRONT-END SIMULATION AND DATABASE TOOLS

VIRTUOSO ACCELERATED PARALLEL SIMULATOR (CADENCE DESIGN SYSTEMS)

The Cadence Virtuoso Accelerated Parallel Simulator addresses the challenges of accuracy degradation of results, excessive runtimes, and huge learning curves for setup and postprocessing. The Accelerated Parallel Simulator delivers the full accuracy of the industry reference Cadence Virtuoso Spectre circuit simulator. It improves convergence and capacity for designs with hundreds of thousands of transistors and parasitic elements, including PLLs (phase-locked loops), data converters, memory IP (intellectual property), power-management circuits, and full-chip designs. The Accelerated Parallel Simulator combines proven Cadence simulation technologies, a breakthrough advanced parallel-circuit solver, and a new multiprocessing engine that runs on computer platforms with as many as 16 cores. The product also addresses performance and capacity challenges. The result is a next-generation-performance circuit simulator with full Spice accuracy; significantly better single-thread and multithread performance; improved dc-, transient-, and RF-analysis convergence; and a larger capacity footprint.

EMBEDDED-SYSTEM TECHNOLOGIES

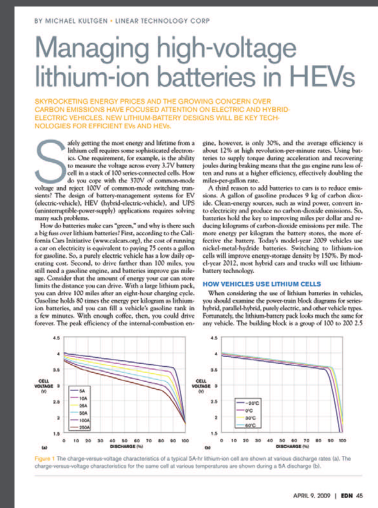
XPORT PRO LINUX NETWORKING SERVER (LANTRONIX)

The powerful, self-contained XPort Pro embedded networking module targets advanced applications on edge devices to enable a new class of device servers for M2M (machine-to-machine) edge computing. The XPort Pro, with 16 Mbytes of flash memory and 8 Mbytes of SDRAM, handles demanding applications with the power of a high-speed, high-performance, advanced-architecture 32-bit processor. XPort Pro offers a variety of robust data-encryption and authentication options. The XPort Pro Linux software-development kit, with built in IPv6 (Internet Protocol Version 6), is an integrated embedded-hardware and -software suite that provides a validated set of Linux-based applications, an extensive software library, a board-support package, and device drivers that allow designers to create custom-tailored products. Employing the stable 2.6 Linux kernel, the software-development kit includes all of the components for building secure network-enabled products using the Linux OS. XPort Pro includes Lantronix's patent-pending VIP (virtual-Internet Protocol) Access technology that allows for seamless integration with the ManageLinx remote-services-enablement platform, allowing access to firewall-protected equipment.

BEST CONTRIBUTED ARTICLE

"MANAGING HIGH-VOLTAGE LITHIUM-ION BATTERIES IN HEVs," MICHAEL KULTGEN, LINEAR TECHNOLOGY CORP, APRIL 9, 2009, WWW.EDN.COM/ARTICLE/CA6648791

Skyrocketing energy prices and the growing concern over carbon emissions have focused attention on EVs (electric vehicles) and HEVs (hybrid-electric vehicles). New lithium-battery designs will be key technologies for efficient EVs and HEVs.



BY MICHAEL KULTGEN • LINEAR TECHNOLOGY CORP

Managing high-voltage lithium-ion batteries in HEVs

SKYROCKETING ENERGY PRICES AND THE GROWING CONCERN OVER CARBON EMISSIONS HAVE FOCUSED ATTENTION ON ELECTRIC AND HYBRID-ELECTRIC VEHICLES. NEW LITHIUM-BATTERY DESIGNS WILL BE KEY TECHNOLOGIES FOR EFFICIENT EVs AND HEVs.

Safely getting the most energy and lifetime from a lithium cell requires some sophisticated electronics. One requirement, for example, is the ability to measure the voltage across every 3.7V battery cell in a stack of 100 series-connected cells. How do you cope with the 370V of common-mode voltage and reject 100V of common-mode switching transients? The design of battery-management systems for EV (electric-vehicle), HEV (hybrid-electric-vehicle), and UPS (uninterruptible-power-supply) applications requires solving many such problems.

How do batteries make cars "green," and why is there such a big fuss over lithium batteries? First, according to the California Cars Initiative (www.calcars.org), the cost of running a car on electricity is equivalent to paying 75 cents a gallon for gasoline. So, a purely electric vehicle has a low daily operating cost. Second, to drive farther than 100 miles, you still need a gasoline engine, and batteries improve gas mileage. Consider that the amount of energy your car can store limits the distance you can drive. With a large lithium pack, you can drive 100 miles after an eight-hour charging cycle. Gasoline holds 80 times the energy per kilogram as lithium-ion batteries, and you can fill a vehicle's gasoline tank in a few minutes. With enough coffee, then, you could drive forever. The peak efficiency of the internal-combustion engine, however, is only 30%, and the average efficiency is about 12% at high revolution-per-minute rates. Using batteries to supply torque during acceleration and recovering joules during braking means that the gas engine runs less often and runs at a higher efficiency, effectively doubling the miles-per-gallon rate.

A third reason to add batteries to cars is to reduce emissions. A gallon of gasoline produces 9 kg of carbon dioxide. Clean-energy sources, such as wind power, convert into electricity and produce no carbon-dioxide emissions. So, batteries hold the key to improving miles per dollar and reducing kilograms of carbon-dioxide emissions per mile. The more energy per kilogram the battery stores, the more effective the battery. Today's model-year 2009 vehicles use nickel-metal-hydride batteries. Switching to lithium-ion cells will improve energy-storage density by 150%. By model-year 2012, most hybrid cars and trucks will use lithium-battery technology.

HOW VEHICLES USE LITHIUM CELLS

When considering the use of lithium batteries in vehicles, you should examine the power-train block diagrams for series-hybrid, parallel-hybrid, purely electric, and other vehicle types. Fortunately, the lithium-battery pack looks much the same for any vehicle. The building block is a group of 100 to 200 2.5

Figure 1 The charge-versus-voltage characteristics of a typical 5A-hr lithium-ion cell are shown at various discharge rates (a). The charge-versus-voltage characteristics for the same cell at various temperatures are shown during a 5A discharge (b).

APRIL 9, 2009 | EDN 45

FPGAs

SPARTAN-6 LXT (XILINX)

Xilinx Spartan-6 LXT FPGAs provide an optimal balance of cost, power, and performance and deliver as many as eight 3.125-Gbps GTP (gigabit transceivers/low-power) and an integrated PCIe (Peripheral Component Interconnect Express)-compatible core. Xilinx Spartan-6 LXT FPGAs are the first low-cost FPGAs fabricated on a 45-nm process. Spartan-6 FPGAs include as many as 140,000 logic cells in a new six-input LUT (look-up-table)-logic fabric, as much as 4800 kbits of RAM, and as many as 180 DSP48A1 slices; 3.125-Gbps GTPs, typically consuming less than 150 mW; integrated PCIe-endpoint blocks, providing PCI SIG (special-interest-group)-verified Revision 1.1, Generation 1 compliance; an integrated memory-controller block that simplifies the implementation of 800-Mbps DDR2 and DDR3 memory interfaces; and additional power saving with hibernation power-down mode.

MICROCONTROLLERS

PIC24F16KA NANOWATT XLP PIC MICROCONTROLLERS (MICROCHIP TECHNOLOGY)

The PIC24F16KA family of 16-bit microcontrollers features nanoWatt XLP (extreme-low-power) technology, including sleep currents as low as 20 nA, which enables battery life as long as 20 years. The devices also integrate peripherals such as capacitive touch sensing. The PIC24F16KA family includes a watchdog-timer mode consuming power as low as 370 nA, a real-time clock and calendar mode consuming as little as 510 nA, a low-power active mode consuming as little as 8 μA, 1.8 to 3.6V operating voltage for all on-chip analog and digital peripherals, and a 32-MHz maximum speed at a battery-friendly 3V. The PIC24F16KA family achieves maximum battery life from 3V batteries. They can also run all on-chip analog and digital peripherals at a minimum voltage of 1.8V. The PIC24F16KA executes 90% of its instructions in one cycle to achieve more efficient software execution, faster task completion, and lower overall power consumption across the life of an application. The PIC24F16KA features two-speed start-up, which is a battery-friendly method of waking up from sleep and performing a task in a timely manner. It achieves this goal without creating large current drains on the battery.

MICROPROCESSORS

MPC564XL HIGH-RELIABILITY PROCESSOR (FREESCALE SEMICONDUCTOR)

The MPC564xL family implements a new strategy for detecting critical faults in safety-relevant blocks and provides major test capabilities in hardware to reduce the software overhead and typical board component count. The cores, memories, crossbars, communica-

tion blocks, and peripherals all feature BIST (built-in self-test) mechanisms. The device prevents common-cause failures due to clock or voltage-supply issues. The MPC564xL family provides hardware blocks for detecting clock deviations as well as hardware monitors for main voltages. The processor's selectable modes of operation, which both support SIL3 (Safety Integrity Level 3) and ASILD (Automotive SIL Level D) requirements, are lock-step operation, which provides a software environment for redundant processing and calculations, and independent-core, or dual-parallel-mode, operation, which provides a software environment for diverse processing and calculations to increase performance or to cross-check for reliable operation. The MPC564xL features core, crossbar, memory-protection-unit, interrupt-controller, DRAM, and software-watchdog-timer "sphere of replication." The main benefit is the ability to detect single-point failures, which are typically higher-rate soft errors not only in the cores but also in key submodules of the microcontroller.

MULTIMEDIA SOCs

ARMADA 1000 HD MEDIA PROCESSOR SOC (MARVELL SEMICONDUCTOR)

Marvell's Armada 1000 SOC (system on chip), also known as the 88DE3010, targets network-connected consumer-electronics applications, such as Blu-ray players, digital media adapters, set-top boxes, and Ethernet-augmented digital televisions. At its nexus are dual Sheeva PJ1 CPU cores, each operating as fast as 1.2 GHz and derived from the ARM Version 5 instruction set. The device includes a dual-channel decoder, which decodes H.264, VC-1 (Video Codec 1), MPEG-2 (Motion Pictures Experts Group 2), DIVX (Digital Video Express), and other formats. It also has a Qdeo postprocessing engine, which reduces per-pixel 3-D noise and provides 3-D deinterlacing, scaling, natural depth expansion, intelligent color remapping, and adaptive contrast enhancement. It also handles video at high-resolution frame sizes and bit rates. Graphics- and audio-processing engines and security- and system-management CPUs round out the multimedia-processing mix. Other integrated peripherals include dual SATA (serial-advanced-technology-attachment) and dual USB (Universal Serial Bus) transceivers, SDIO (secure digital input/output), SPI (serial-peripheral interface), PCIe (Peripheral Component Interconnect Express), Fast Ethernet, HDMI (high-definition multimedia interface) Version 1.3, and six video DACs.

MULTIPROCESSING

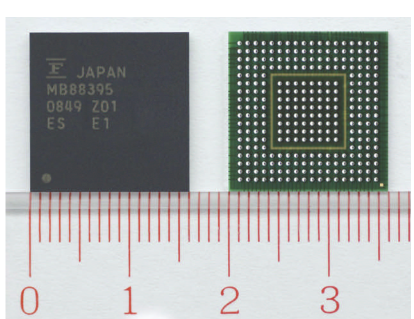
WOLVERINE DSP PLATFORM (SOUND DESIGN TECHNOLOGIES)

The 90-nm, multicore, open-platform Wolverine targets use in hearing aids. It combines four DSPs, 11 hardware accelerators, a nonvolatile memory, and several analog functions in less than 11 mm². The chip includes filtering and FFT (fast-Fourier-transform) functions and a patented cross-point architecture. This multicore approach delivers as much as 50 MIPS of processing power at a 2-MHz system-clock rate and draws only 1 mA. By adjusting the onboard programmable clock multiplier to 12 MHz, the processing capability increases to 95 MIPS. Wolverine includes 266 kbits of program memory, 369 kbits of data memory, and 256 kbits of OTP (one-time-programmable) memory. To round out the digital functions, the chip includes several interfaces such as GPIOs (general-purpose inputs/outputs), I²S (inter-IC sound), I²C (inter-integrated circuit), SPI (serial-peripheral interface), and debugging. The analog portion of Wolverine includes two audio-rate ADCs and one audio DAC for speech processing. A third multichannel, low-speed, 9-bit ADC monitors battery voltage, temperature, and analog GPIOs. Wolverine also integrates a voltage regulator for the digital circuitry as a means of reducing digital-power consumption. The analog functions consume less than 300 μA of current. The platform comes in a compact hybrid using Sound Design's thin-Stax technology.

NETWORKING

MB88395 1394 AUTOMOTIVE-CONTROLLER IC (FUJITSU MICROELECTRONICS AMERICA)

Fujitsu's MB88395 automotive-controller IC transmits audio and high-definition video over an IEEE 1394 FireWire in-vehicle multimedia network. The MB88395 simultaneously transmits multiple streams around the vehicle,



such as images from Blu-ray DVDs, digital television, blind-spot cameras, and navigation systems. It uses an 800-Mbps physical layer and link layer. The MB88395 incorporates the DTCP (digital-transmission-content-protection) encryption protocol, which prevents unauthorized duplication, downloading, or alteration of any audio or visual media. Fujitsu's proprietary SmartCodec compresses high-resolution video to one-quarter its original size in 2 to 3 msec. The subsequent lack of perceptible time lag means that viewers can watch the same content on front and rear monitors. Using SmartCodec compression, a 1280-pixel×720-line video stream from a Blu-Ray disc compresses to a rate of 249 Mbps, such that the 800-Mbps network bandwidth can transmit two channels' worth of information.

NETWORK, TIMING, AND BER TEST

J-BERT N4903B JITTER-TOLERANCE TESTER (AGILENT TECHNOLOGIES)

Agilent's new J-BERT (jitter/bit-error-rate-tester) N4903B offers complete jitter tolerance test for characterizing emerging serial-bus interfaces, supporting both embedded and forwarded-clock devices at data rates as high as 14.2 Gbps. It allows accurate and efficient characterization of forwarded-clock devices, such as QPI (QuickPath Interconnect), HyperTransport, and memory buses. J-BERT also allows accurate receiver characterization with its unique capabilities, such as variable duty-cycle distortion on half-rate clocks, delayable jitter on clock and data signals, variable de-emphasis, and the new clock doubler accessory. J-BERT N4903B considerably reduces test-setup time and complexity, significantly increasing efficiency. Integrated and calibrated jitter sources allow generation of stress conditions for multiple serial-bus interfaces, variable output levels and rates on data and clock signals, a powerful pattern sequencer for simplified setup of training sequences, automated jitter-tolerance-test routines, and fast total-jitter and eye-measurement routines.

OSCILLOSCOPES, DIGITIZERS, AND DATA ACQUISITION

MSO70000 SERIES MIXED-SIGNAL OSCILLOSCOPES (TEKTRONIX)

Tektronix's MSO70000 series of high-performance mixed-signal oscilloscopes combines high-performance analog and digital acquisition capability to address emerging classes of mixed-signal applications from embedded-computing and high-speed serial interfaces to wideband RF. The MSO70000's 16 logic channels can accommodate low-speed serial interfaces in high-performance ASICs and

Need a 470 to 510MHz FSK Transceiver for your Wireless Meter Network?

Micrel has you Covered.

Low-Power, Low-Cost 470 to 510MHz +10dBm FSK Transceiver

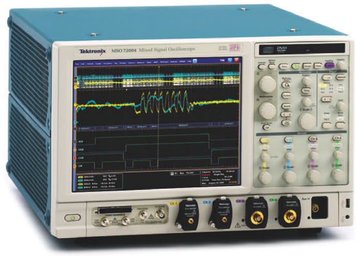
The MICRF507 is the latest addition to Micrel's family of low-cost, low-power, 410 to 950MHz, +10dBm FSK Transceivers and is optimized for the China Short Range Device (SRD) band of 470 to 510MHz. The transceivers combination of excellent 59dB receiver blocking performance, for a low 12mA of receiver supply current, makes it an ideal solution for mesh-based metering applications which require the ability to sense a distant transmitter in the presence of a high blocker. In transmit mode, the transmitter only consumes 21.5mA of supply current from a 2.5V supply, providing excellent efficiency for +10dBm output power. The devices complements and is pin for pin compatible with the MICRF506 (410 to 450MHz) and the MICRF505 and MICRF505L (850 to 950MHz).

For more information, contact your local Micrel sales representative or visit Micrel at: www.micrel.com/micrf507.

Features

- Data Rates up to 200kbps
- -113dBm Receiver Sensitivity at 2.4kbps
- 59dB Receiver Blocking at 1MHz Offset
- 12mA Receiver Supply Current
- +10dBm Transmitter Output Power at 21.5mA from 2.5V
- 0.2µA Power Down Current
- FSK Digital Demodulator and Clock Recovery
- Frequency Error Estimator
- 5mm x 5mm 32-Pin MLF® Package

MICREL®
Innovation Through Technology®
www.micrel.com



systems, leaving its four high-bandwidth analog channels available for critical timing analysis. The logic channels also provide the signal visibility necessary for state-specific triggering in complex systems, such as DDR3 and electronic-warfare systems requiring transient group-delay measurements. Precise, deep-record logic-signal acquisition; a 2.5-GHz differential-logic probe with solder-in accessories; and time-aligned digital and analog trigger paths for real time fault detection set this family apart.

PCs AND PERIPHERALS

X25-M MAINSTREAM SOLID-STATE DRIVE ON 34-nm FLASH MEMORY

(INTEL)

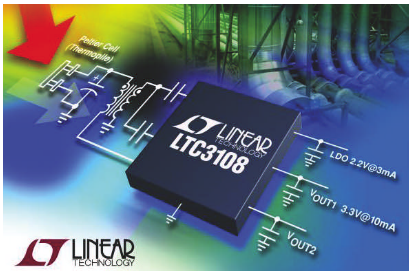
New variants of Intel's X25-M solid-state drives employing 34-nm-fabricated NAND-flash memories deliver equivalent or better performance than their 50-nm-lithography-based predecessors at a fraction of the cost. Retail-channel prices for the 80-Gbyte X25-M variant are $225 (1000), a 60% reduction from the original $595 introduction price of one year ago. Similarly, the 160-Gbyte version sells for $440 (1000), down from $945 at introduction. Intel's drives achieve a 25% reduction in latency and two-times-faster random-write I/O operations/sec versus 50-nm solid-state-drive precursors. They also deliver 56% better system performance versus a 5400-rpm hard-disk drive per the PC Mark Vantage benchmark utility. By delivering as many as 6600 4-kbyte write-I/O operations/sec and as many as 35,000 read-I/O operations/sec, the X25-M leapfrogs hard-disk drives, thereby providing for markedly faster system and application responsiveness.

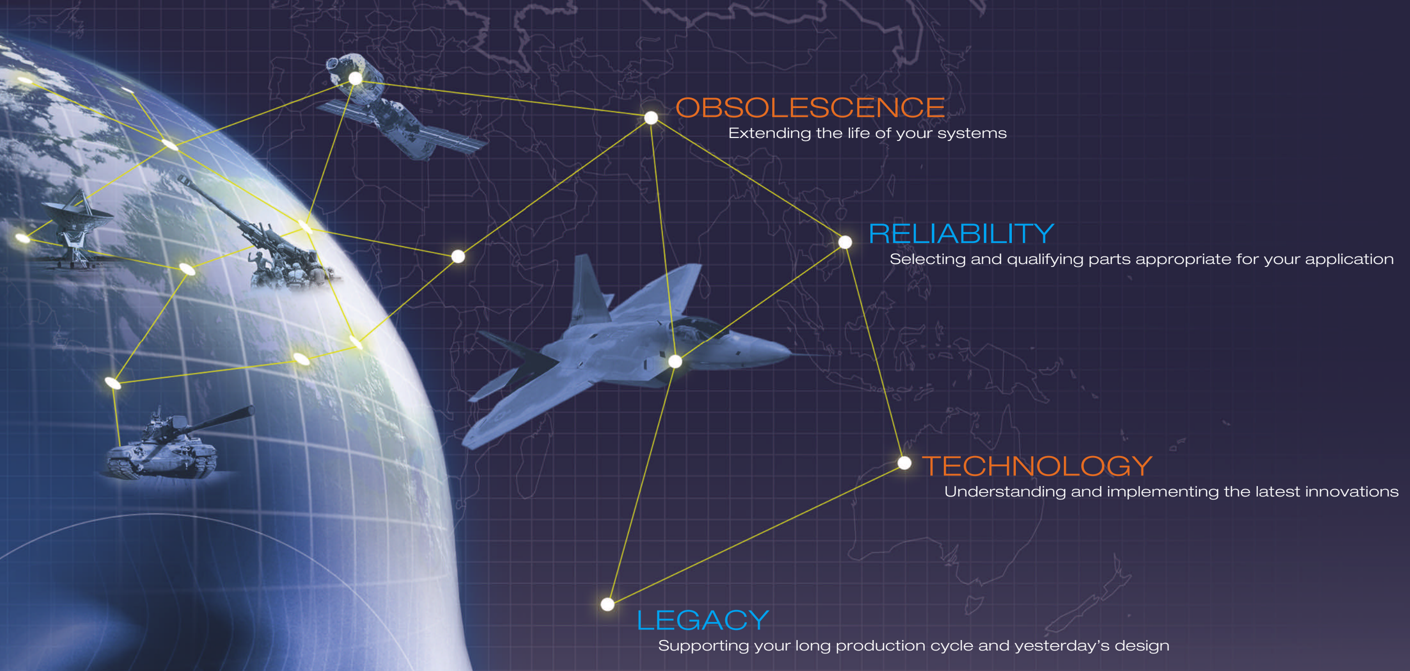
POWER: CONVERTERS

LTC3108 ULTRA-LOW-VOLTAGE STEP-UP DC/DC CONVERTER

(LINEAR TECHNOLOGY)

The LTC3108 step-up dc/dc converter starts up and operates from 20-mV voltage sources, such as thermoelectric generators, thermopiles, and small solar cells. The part has selectable output voltages of 2.35, 3.3, 4.1, and 5V. It has an auxiliary low-dropout regulator output of 2.2V at 3 mA. Using a small step-up transformer, the LTC3108 provides power management for wireless-sensing and data-acquisition applications. The 2.2V low-dropout regulator powers an external microprocessor, and you can program the main power output to one of four fixed voltages to power a wireless transmitter or sensors. A second output can act as the host, and a storage capacitor provides power when the input voltage is unavailable. The LTC3108's 3×4-mm DFN package or SSOP-16 and small external components provide a compact approach to energy-harvesting applications.





DESIGN FOR TIME

It's about *more* than technology,

it's about sustaining technology over time

What part do you play?

Selecting the latest technology is only part of the answer. As the electronics industry's premier distributor, Avnet Electronics Marketing helps you bridge the gap between legacy and leading edge – mil-spec and COTS – obsolescence and sustainability. Our defense/aero team of experts work to protect your design investment, flex your creativity and stretch your product's life expectancy. Avnet provides comprehensive supply-chain and integration services, strategic product intelligence and design support for all your mission-critical projects and applications. Delivering reliable, sustainable solutions from the strength and scale of a trusted industry veteran – *that's our part.*

How will you DESIGN FOR TIME?
Download our white paper, "The Best Defense Is a Good Offense," at:
www.em.avnet.com/DesignForTime

AVNET® electronics marketing

Accelerating Your Success™

POWER: LIGHTING

iW3610 DIMMABLE LED DRIVER (iWATT)

You can use the iWatt iW3610 as a primary-side regulated PWM (pulse-width-modulator) controller for 5 to 25W dimmable LED lamps or in a 15W dimmable-LED-driver PCB (printed-circuit board) with a footprint smaller than 30×75 mm in an Edison-base socket. The part achieves greater-than-80% efficiency and supports a maximum switching frequency of 200 kHz. It allows automatic reduction of LED current at high temperature. This approach also prevents overheating and increases the life of the electrolytic capacitors. The iW3610 eliminates the need for a feedback optocoupler. An intelligent algorithm ensures that the iW3610 automatically detects the presence or absence of a wall dimmer and allows 2 to 100% flicker-free dimming range.

POWER: SPECIAL

WEBENCH VISUALIZER (NATIONAL SEMICONDUCTOR)

The Webench Visualizer Web software allows engineers to see the results of multiple power-supply-design configurations. It builds on the foundation of the Webench Designer online power-supply, filter, sensor, and signal-path-development tool. Rather than analyze just one design, the Visualizer extends the analysis to every possible option. It can show design results for 25 dc/dc-power-supply architectures and more than 21,000 components from 110 manufacturers. Roughly 48 billion alternative input values are available for a single power supply to cover the possible values for input voltage, output voltage, and output current. The software highlights the design that best meets the desired dialed-in weighting and shows alternative designs. Each design includes a BOM (bill-of-materials) cost for components for each socket to meet the user's dialed-in preference.

POWER SUPPLIES/SYSTEMS

SOLARMAGIC POWER OPTIMIZER (NATIONAL SEMICONDUCTOR)

In the traditional PV (photovoltaic)-system architecture, panel mismatches from real-world conditions negatively affect power output. Traditional PV systems rely on a centralized inverter; as each string of solar panels in series connects either directly or in parallel with other series strings to the inverter, the inverter can "see" this module array only as one electrical equivalent. Consequently, small amounts of mismatch can cause disproportional energy losses. To overcome the panel-mismatch problem, National Semiconductor's researchers and engineers used proprietary algorithms to enable the SolarMagic power optimizers to extract the maximum energy available by applying a localized MPP (maximum power point) and translate input voltage and current to the best output voltage and current, maximizing energy transport. The devices sense their voltages and currents and jointly adjust for them until they reach an optimum value for the string.

RFICs

Si2170 TV TUNER (SILICON LABS)

The Si2170 globally compliant analog/digital-TV tuner has an analog-TV demodulator in a CMOS IC. The Si2170 eliminates the need for more than 100 discrete components and integrates a low-noise amplifier and a high-Q tracking filter that provides gain only around the desired channel frequency. The Si2170's patented digital low-IF architecture addresses the problems of analog and digital reception and the existence of multiple regional standards.

RF/MICROWAVE TEST

VECTORSTAR MICROWAVE VECTOR-NETWORK ANALYZER (ANRITSU)

The VectorStar microwave VNAs (vector-network analyzers) deliver best-in-class frequency coverage of 70 kHz to 70 GHz, dynamic range of 103 dB at 67 GHz, and measurement speed of 20 μsec/point. The 70-kHz, low-end device provides seven octaves of additional information below the traditional 10-MHz cutoff point of conventional microwave VNAs. For applications requiring 70-kHz to 2.5-GHz bandwidths, VectorStar uses a mixer-based receiver with bridges for directional devices. At frequencies greater than 2.5 GHz, it uses a harmonic-sampling receiver with couplers for directional devices. A VNA that operates in the frequency domain can supply time-domain information using IFFTs (inverse fast-Fourier transforms) to convert frequency-domain data to the time domain.

SENSORS

AS5011 HALL-EFFECT MAGNETIC-ENCODER IC (AUSTRIAMICROSYSTEMS)

The one-chip, 2-D AS5011 Hall-effect magnetic-encoder IC from austriamicrosystems monitors a magnet's displacement relative to its center position and provides position information through its I^2C (inter-integrated-circuit) outputs. It integrates five Hall sensing elements for detecting lateral displacement as great as ±2 mm, a high-resolution 12-bit ADC, an XY-coordinate and motion-detection engine, and a smart power-management controller. The on-chip processing engine frees system designers from integrating complex software algorithms on their host processors and reduces development time. The EasyPoint joystick module provides a mechanical stack incorporating a navigation knob with a magnet and the AS5011 IC.

SILICON INTELLECTUAL PROPERTY

DESIGNWARE SUPERSPEED USB 3.0 IP (SYNOPSYS)

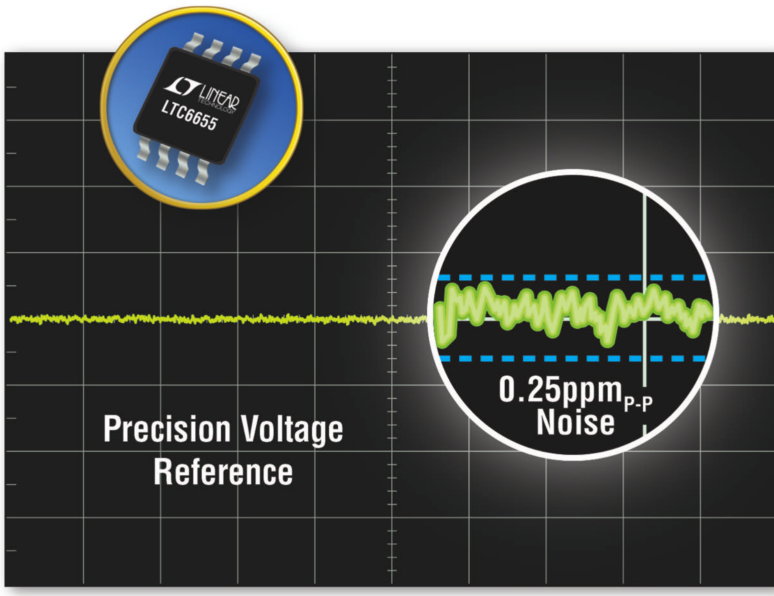
The silicon-proven Synopsys DesignWare SuperSpeed USB (Universal Serial Bus) 3.0 IP (intellectual property) offers on-chip instantiation of the IP through certification and production test, saving cost and lowering the risk of separately acquiring and integrating the IP. The product comprises digital controllers, PHY (physical-layer) IP, verification IP, virtual-platform software, and production-test and debugging software. Innovations include support for a range of cost-effective reference clocks, asynchronous operation during at-speed loop-back testing, the ability to test receiver eye compliance after the receiver equalizer during production test on any digital tester, an on-chip receiver sampling scope to help debug signal-integrity issues, and a virtual platform for early software development.

SOFTWARE/EMBEDDED TOOLS

mBED MICROCONTROLLER (ARM HOLDINGS)

The ARM mbed microcontroller rapid-prototyping tools and developer platform enable designers to prototype with modern microcontrollers. Features of the mbed platform include a microcontroller hardware form factor suitable for prototyping, an integrated programmer that works as a USB (Universal Serial Bus) flash drive, online compiler tools that require no installation, software libraries that allow interaction with microcontroller peripherals without implementation expertise, and online developer resources that enable reuse and collaboration. EDN

Pure DC



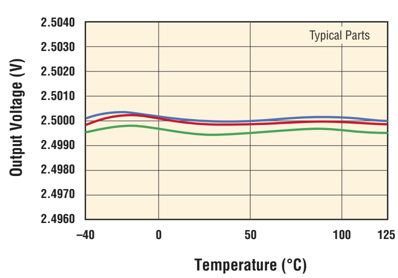
Announcing the Industry's Lowest Noise, Complete Voltage Reference Family

A lot of noise is made about precision voltage references. At Linear Technology, we're taking the quiet approach—introducing the LTC®6655 precision reference, with less than ***0.25ppm*** of low frequency noise. And if that is not enough, the LTC6655 exhibits less than 2ppm/°C of drift and an initial accuracy within ±0.025%. Such rock solid, pure DC performance ensures that the LTC6655 will be the new standard for high performance instrumentation and test equipment.

Features

- Low Noise: 0.25ppm$_{P-P}$ (0.1Hz to 10Hz)
- ±0.025% Accuracy, 2ppm/°C Drift
- Fully Specified from –40°C to 125°C, & 100% Tested at –40°C, 25°C and 125°C
- Sinks and Sources Current: ±5mA
- V_S: 500mV Dropout to 13.2V
- Load Regulation: 3ppm/mA
- Low Power Shutdown: <20µA
- 1.25V, 2.048V, 2.5V, 3V, 3.3V, 4.096V, 5V
- 8-Lead MSOP Package

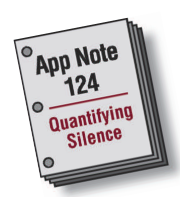
Temperature Drift



Info & Free Samples

www.linear.com/6655

1-800-4-LINEAR



www.linear.com/an124

LINEAR TECHNOLOGY

Pulse generator with precision output-duty cycle operates at a repetition rate beyond 50 MHz

Marián Štofka, Slovak University of Technology, Bratislava, Slovakia

A previous Design Idea describes an astable multivibrator that gets hysteresis from the positive-feedback stage using a technique you can characterize as positive-capacitive feedback (**Reference 1**). It creates hysteresis by a charge transfer to its main timing-capacitor. The circuit uses two logic inverters to generate complementary logic outputs. In contrast, the circuit in **Figure 1** uses a single fast analog comparator that has complementary outputs, thus eliminating the need for an additional inverter.

Comparators such as Analog Devices' (www.analog.com) ADCMP603, IC_1, have symmetry that results in a very low time skew of the transitions at its Q and $\overline{Q}$ outputs that are fractions of a nanosecond. Thus, the charge transfer to the main capacitor, C, theoretically starts immediately at the start of the level transition at the Q output, from which C is charged through a resistor, R. No additional propagation delay occurs at any stage besides Q, resulting in a further increase in operating frequency.

The output frequency of the pulse generator in **Figure 1** is less sensitive to supply voltage variations than a generator with the ADCMP603, which uses the IC's internal hysteresis. The charging current of C and the charge-transfer-based hysteresis of the pulse generator rise almost linearly with the rising supply voltage, which results in an output signal's insensitivity.

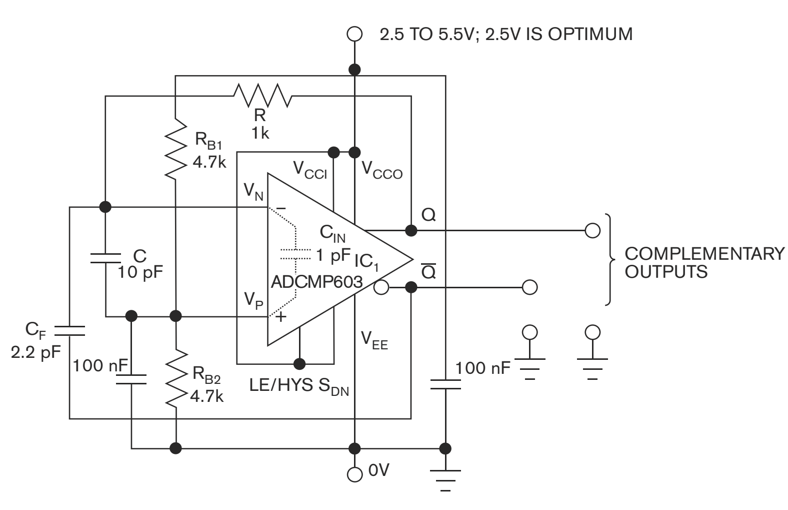


Figure 1 This pulse generator produces time-aligned complementary logic waveforms. The duty cycle holds at 50%.

DIs Inside

46 Bicolor LED driver uses two leads

46 Supervise and power-sequence an SOC

48 Circuit may save property and life

▶To see all of *EDN*'s Design Ideas, visit www.edn.com/design ideas.

Contrarily, the internal hysteresis, which an external resistor sets at the comparator's LE/HYS pin, varies nonlinearly with the supply voltage. If, for example, the external resistor's value is 225 kΩ, the hysteresis has the same value of about 36 mV for supply voltages of 2.5 and 5.5V.

At frequencies close to the upper frequency limit of operation, the charge injection through capacitor C_F is gradual rather than steplike because the rise and fall times of waveforms at the Q and $\overline{Q}$ outputs are still of finite value. **Figure 2** shows an idealized operation for the positive peak of voltage at capacitor C. Although the real voltages, V_Q and $V_{\overline{Q}}$, have somewhat rounder "corners," they resemble those in the **figure**.

If you assume that the voltage swing at capacitor C is considerably lower than that at Q and $\overline{Q}$, then a rectangular current pulse, $I_{CF}(t)$, charges capacitor C during a positive-voltage transition at output $\overline{Q}$. The current through resistor R, $I_{RF}(t)$, which also flows to capacitor C, changes its polarity at the midtransition at Q and $\overline{Q}$ outputs. The final current, which charges capacitor C, is a sum of $I_{RF}(t)$ and $I_{CF}(t)$. Although the waveshape of the voltage at capacitor C depends on the final charging current, it gains in peak solely due to $I_{CF}(t)$.

The following **equation** calculates the added peak:

$$\Delta V_C \approx \frac{I_{CF} \times t_R}{C_1} \approx \frac{C_F}{C_1} \Delta V_{OUT},$$

where ΔV_C is the added peak, $C_1 = C + C_{IN}$, and $C_1 \approx 1$ pF. The added peak is independent of $I_{RF}(t)$ due to the zero mean value of this current within the level transition at the Q and $\overline{Q}$ outputs.

For C=10 pF, C_1=11 pF, C_F=2.2 pF, and $\Delta V_{OUT} \approx 2.4V$, a voltage you derive from the **equation** $\Delta V_C \approx 0.48V$.

The following **equation** calculates the nearly constant part of $I_{RF}(t)$ current:

$$I_{RF} \approx \frac{1}{2} \times \frac{\Delta V_{OUT}}{R}.$$

I_{RF} determines the slope, S, of the $V_C(t)$ waveform in **Figure 2**, which excludes the time interval of level transitions at the comparator's Q and $\overline{Q}$ outputs. You calculate the slope with the following **equation**:

$$S = \frac{I_{RF}}{C} \approx \frac{1}{2RC} \times \Delta V_{OUT}.$$

The following **equation** determines the absolute value of peak voltage of $V_C(t)$, referred to supply midvoltage:

$$V_{CPEAK} = S\left(t_{PD} - \frac{t_R}{2}\right) + \Delta V_C.$$

Voltage $V_C(t)$ decreases from its peak value with a slope of −S. You calculate the time interval, T_{DESC}, when it reaches the reference level as:

$$T_{DESC} = \frac{V_{CPEAK}}{S} = t_{PD} - \frac{t_R}{2} + \frac{\Delta V_C}{S} = t_{PD} - \frac{t_R}{2} + 2C_F R.$$

By evaluating this **equation** for a t_{PD} of approximately 3.5 nsec and R with a value of 1 kΩ, the time interval is approximately 6.8 nsec.

The following **equation** calculates the total time, when $V_C(t)$ is higher than the reference voltage, $V_{CC}/2$:

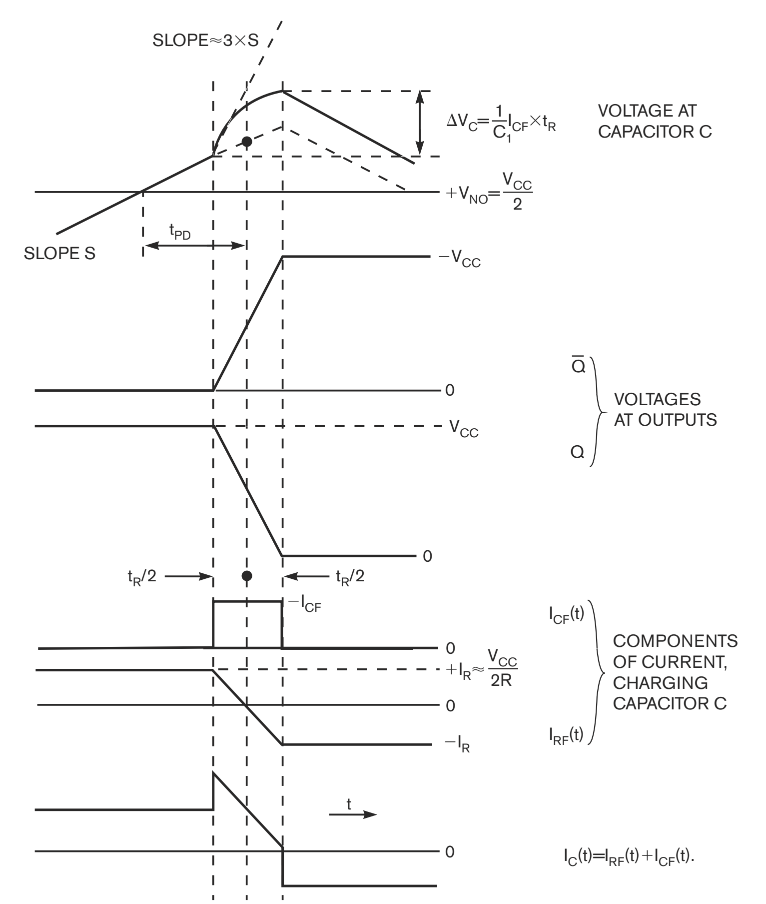


Figure 2 An idealized but still close-to-reality modeling of the operation of the generator gives you a formula for determining the output frequency.

$$T_H = t_{PD} + \frac{t_R}{2} + T_{DESC} = 2(t_{PD} + C_F R).$$

The symmetry of the ADCMP603's internal circuit architecture, T_H, is the right half-period of logic waveforms at the Q and $\overline{Q}$ outputs. In other words, the duty cycle of the output pulse is 50%. By evaluating the **equation** for T_H, you get 11.4 nsec. Thus,

$$f_Q = \frac{1}{2T_H} = 43.86 \text{ MHz}.$$

The circuit's output frequency is 56.75 MHz with a power-supply voltage of 2.052V. With a supply voltage of 3.51V, the frequency changes to 56.12 MHz. Thus, the relative sensitivity of the output frequency to the supply-voltage variation is approximately 8×10^{-3}/V. You can attribute an increase of experimental frequency as compared with a theoretical value to the fact that, during the estimated signal-propagation delay, t_{PD}, the comparator's input overdrive rises gradually to about 330 mV, which is more than triple the value at which you define the propagation delay. You can therefore assume a lower propagation delay and a higher frequency. **EDN**

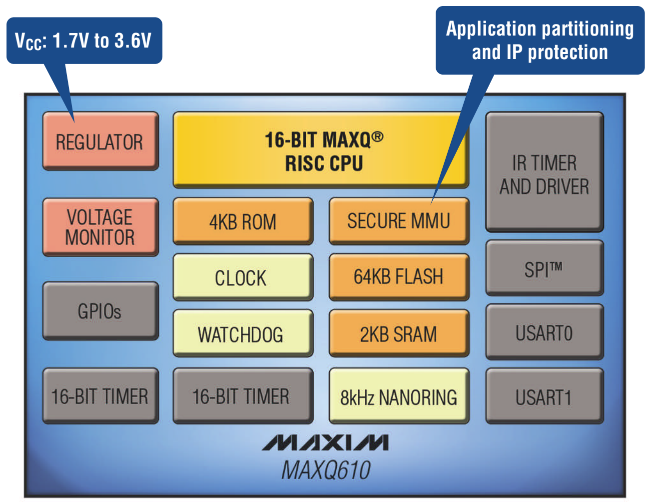
REFERENCE

1. Larson, Robert, "Astable multivibrator gets hysteresis from positive-feedback stage," *EDN*, Oct. 22, 2009, pg 43, www.edn.com/article/CA6702271.

Extend battery life with the MAXQ610 16-bit microcontroller

Up to 12 MIPS in under 4mA—industry's highest MIPS/mA!

The MAXQ610 microcontroller is designed for low-cost, high-performance, battery-powered applications. This 16-bit, RISC-based microcontroller has a wide operating range (down to 1.7V) for long battery life and ultra-low power consumption. Its anticloning features and secure MMU enable you to protect your IP.



Microcontroller

- 16-bit MAXQ RISC core
- 64KB flash memory, 2KB SRAM
- Ultra-low supply current
  - Active mode: 3.75mA at 12MHz
  - Stop mode: 200nA (typ), 2.0μA (max)
- Wide, 1.7V to 3.6V operating voltage range
- IP protection
  - Secure MMU supports multiple privilege levels, helps protect code from copying and reverse engineering

Peripherals

- Two USARTs and one SPI master/slave communication port
- Two 16-bit timers/counters
- 8kHz nanoring functions as programmable wakeup timer
- IR timer simplifies support for low-speed infrared communication
- IR driver capable of 25mA sink current

Part	Temp Range (°C)	Program Memory	Data Memory	Operating Voltage (V)	Package	Price† ($)
MAXQ610B	0 to 70	64KB flash	2KB SRAM	1.7 to 3.6	40-TQFN	1.45

MAXQ is a registered trademark of Maxim Integrated Products, Inc.
SPI is a trademark of Motorola, Inc.
†1000-up recommended resale. Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates. Not all packages are offered in 1k increments, and some may require minimum order quantities.

www.maxim-ic.com/MAXQ610-info

MAXIM DIRECT
www.maxim-ic.com/shop

AVNET electronics marketing
www.em.avnet.com/maxim

MAXIM
INNOVATION DELIVERED™

For free samples or technical support, visit our website.

Bicolor LED driver uses two leads

Mario Marcoccia, United Circuits, Fort Lauderdale, FL

You can use the circuit in **Figure 1** to drive a bicolor LED with only two leads. This circuit detects the correct closed condition of the left and right side bags in a motorcycle companion. The bag has two locks that you must close for protection. When you push the two momentary SPDT (single-pole/double-throw) switches, they sense the correct closed bag. One bicolor red-and-green LED indicates the bag's status, with the red color showing the open-bag condition. To illuminate the LEDs, you must reverse the polarity of the applied voltage to the LED to change the color (**Table 1**).

Diodes D_1 and D_2 and resistor R_1 form a discrete OR gate. When either pushbutton switch connects to 12V, the voltage at Point A is positive with respect to Point B. Transistor Q_1 conducts, letting current illuminate the red LED. When neither switch connects to 12V, neither diode conducts. The base of Q_1 pulls low through R_1 and R_4, indicating that the bags are closed. Thus, the green LED illuminates as current passes through it and through R_1 and R_2.

The diode, transistor, and resistor values are not critical, and you can adjust them according to your needs. You can also replace the bicolor LED with two discrete LEDs of different colors placed back to back. **EDN**

TABLE 1 LOGIC CONDITIONS FOR THE CIRCUIT

	Switches		Bicolor LED	
Bag condition	**S_1**	**S_2**	**Red**	**Green**
Open	1	1	On	Off
Open	0	1	On	Off
Open	1	1	On	Off
Closed	0	0	Off	On

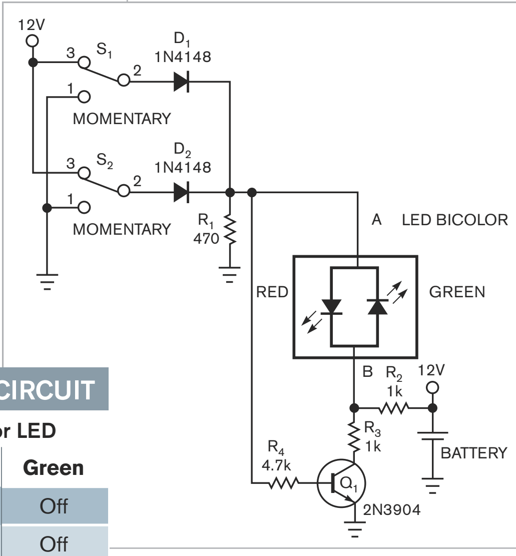


Figure 1 This circuit detects the correct closed condition of the left and right side bags in a motorcycle companion.

Supervise and power-sequence an SOC

Eric Schlaepfer, Maxim Integrated Products, Sunnyvale, CA

Microprocessors, microcontrollers, and SOCs (systems on chips) often need a reset pulse to initialize properly. Many of these devices also use separate I/O- and core-voltage supplies. When you use multiple supplies, you must turn them on in a specific sequence to prevent the circuits from ending up in an unknown state or burning out due to unexpected current paths. You should also monitor the voltages to ensure that the device does not come out of reset until both voltages settle to levels within the operating-voltage range.

A previous Design Idea presents a circuit performing the reset function (**Reference 1**). Unfortunately, this circuit suffers from a number of limitations. For example, it does not monitor the voltage on the 3.3V rail. The 3.3V rail acts as a reference, so the 1.8V rail suffers from poor monitoring accuracy. Further, the reset delay may not be present if you sequence the power rails in the reverse order, and the reset pulse has a glitch that could cause problems with the SOC. Finally, the reset-delay capacitor may reset incorrectly if you rapidly cycle power.

The circuit in **Figure 1** uses a reset IC to provide a glitch-free reset pulse with a well-defined pulse width. It accurately monitors both the 3.3 and the 1.8V rails. You adjust resistors R_1 and R_2 to set the monitoring threshold for dif-

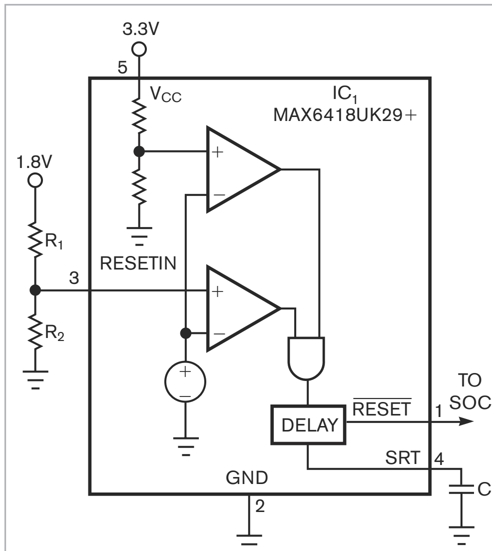


Figure 1 This circuit provides a microprocessor or an SOC with a clean reset pulse.

ferent core voltages using the **equation** $V_{TH}=1.263\times(1+R_1/R_2)$, where V_{TH} is the threshold voltage. You adjust C_1 for different pulse widths. You calculate C_1 using the following formula: $C_1=(t-275\times10^{-6})/(2.73\times10^{6})$, where t is the desired delay in seconds and C_1 is in farads.

Two other previous Design Ideas present circuits for sequencing the two power-supply rails (**references 2** and **3**). One circuit requires many components to achieve a simple function, and the other circuit requires a microcontroller-firmware-development tool set. A simpler alternative implements a sequencing circuit using two ICs acting as voltage detectors (**Figure 2**). This circuit is useful when performing experiments to determine the proper sequencing order. You adjust R_1 and R_2 to set the sequence delay for each power rail. Each IC monitors the voltage on the RC circuit and asserts its output when the capacitor voltage crosses the threshold.

Once you determine a sequence order, you can implement the power sequencing with a single IC (**Figure 3**). This approach monitors the output voltage of the previously sequenced power supply before enabling the next power supply. It also monitors the 5V rail. For cost-sensitive applications, you can devise a passive circuit (**Figure 4**). It works, although the sequence delay is not well-controlled and the voltages are not monitored. In this case, the open-drain output from the first supply holds the node low until power is good. When the open-drain output releases the node, C_1 charges through R_1, asserting the active-high enable of the second supply. You choose R_1 and C_1 to determine the sequence delay. **EDN**

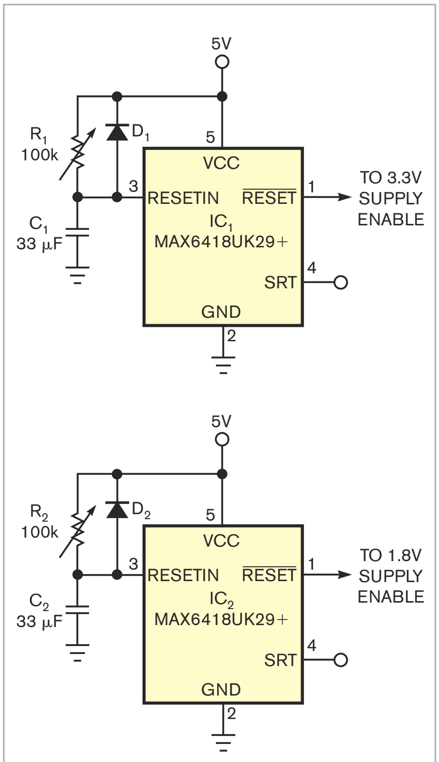


Figure 2 Sequence two power supplies using R_1 and C_1 to set the delay.

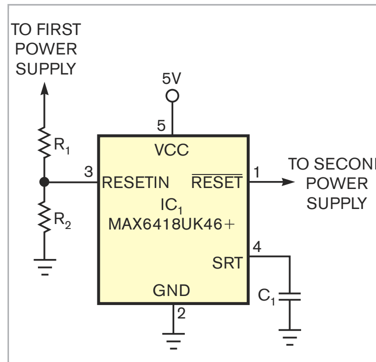


Figure 3 C_1 sets a delay to sequence two power supplies.

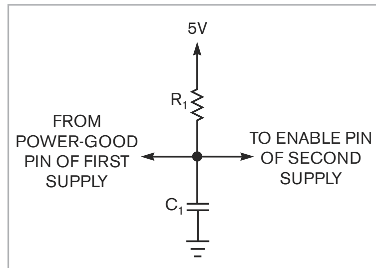


Figure 4 Use this circuit to try different sequencing delays and adjust the sequencing order.

REFERENCES

1. Ban Hok, Goh, "Reset an SOC only when power is ready," *EDN*, Dec 3, 2009, pg 40, www.edn.com/article/CA6709555.
2. Karmann, Dan, "Circuit provides simpler power-supply-sequence testing," *EDN*, Dec 3, 2009, pg 44, www.edn.com/article/CA6709556.
3. Ban Hok, Goh, "Circuit eases power-sequence testing," *EDN*, July 9, 2009, pg 50, www.edn.com/article/CA6668618.

Circuit may save property and life

Vladimir Oleynik, Moscow, Russia

The circuit in **Figure 1** sounds an alarm whenever the perimeter-protection line—a thin copper wire of appropriate length—breaks. You can get the thin wire from a used relay coil. Place the wire around a tent, a camping area, or another area. The wire is thin and invisible in the dark, especially when you place it in grass as high as 0.5m. Because the wire's resistance is small relative to the 200-kΩ resistor, the two form a voltage divider that keeps the MOS transistor off. When a human or an animal intruder breaks the protection wire, a transistor switches on and a buzzer sounds. Because the blinking LED controls the transistor, the buzzer sounds at the LED's switching frequency. The protection wire's resistance can be as great as 33 kΩ.

The circuit operates at a battery voltage as low as 4.8V. In standby mode, it consumes less than 50 μA. When the buzzer sounds, the circuit consumes about 30 mA using a 9.6V battery; this value decreases while the battery drains. The circuit uses a 9V-dc Varta Longlife Extra alkaline battery and operates in standby mode 24 hours a day, with a test alarm switching on for 10 seconds daily. Under those conditions, the daily battery voltage drain is 0.02V, so you can estimate battery life at about eight months while the battery voltage

declines from 9.6V when the battery is new to 4.8V when it is exhausted. If there were no alarm switching, the battery would operate for several years.

The circuit in **Figure 2** reduces current consumption to less than 0.5 μA and lets you use longer protection wire, thus enlarging the protected area. The protection wire can have resistance as great as 3.3 MΩ, and the circuit still works. Thus, you can calculate a possible perimeter-protection-wire length according to the appropriate wire diameter and copper resistance (**Reference 1**). Both circuits can stay in standby mode for years.**EDN**

REFERENCE

1. "Reference & Information, AWG Cable Description," American Wire Gauge, www.interfacebus.com/Copper_Wire_AWG_SIze.html.

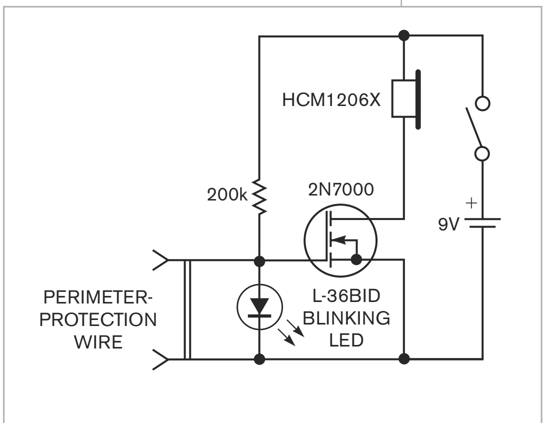


Figure 1 When the perimeter wire breaks, an LED lights and an alarm sounds.

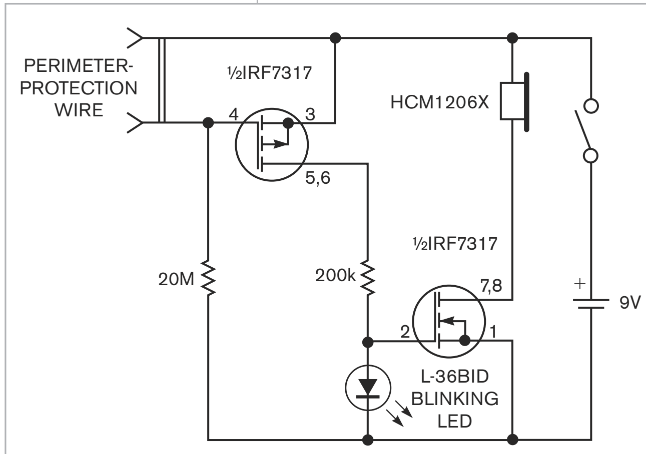


Figure 2 Adding a P-channel MOSFET cuts current consumption.

DESIGN NOTES

Dual Output Step-Down Controller Produces Accurate, Efficient and Reliable High Current Rails – Design Note 478

Mike Shriver and Theo Phillips

Introduction

The LTC®3855 makes it possible to generate high current rails with the accuracy and efficiency to satisfy the most demanding requirements of today's leading edge network, telecommunications and server applications. This 2-phase, dual output synchronous buck controller includes strong gate drivers that support operation with per-phase currents above 20A. The accurate 0.6V ±0.75% reference and its integrated differential amplifier (diff amp) allow remote sensing of the output of critical rails. This controller has an output voltage range from 0.6V to 12.5V when used without the diff amp and from 0.6V to 3.3V with the diff amp.

The LTC3855 uses the reliable peak current mode architecture to achieve a fast and accurate current limit and real time current sharing. Its current sense comparators are designed to sense the inductor current with either a sense resistor or with inductor DCR sensing. DCR sensing offers the advantage of reduced conducted power losses, since the current is measured using the voltage drop across the already-present inductor DC resistance—eliminating the losses incurred by adding a sense resistor. The trade-off is that DCR sensing is less accurate than a dedicated sense resistor because the DCR varies from part to part and over temperature. The LTC3855 uses an innovative scheme to improve the accuracy of DCR sensing by compensating for the DCR's variation with temperature.

1.5V/20A and 1.2V/20A Buck Converter with Remote Sensing and NTC Compensated DCR Sensing

Figure 1 shows a 1.5V/20A and 1.2V/20A dual phase converter with DCR sensing, operating at 325kHz. High efficiency is achieved with the strong gate drivers,

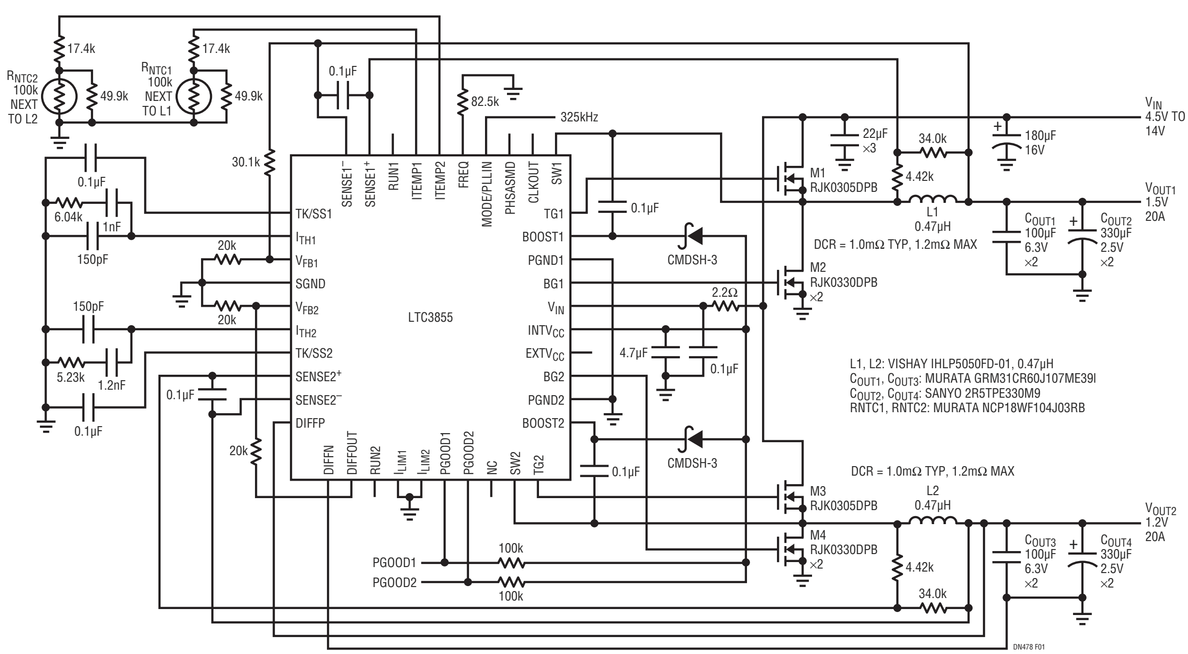


Figure 1. Dual 1.5V/20A and 1.2V/20A Converter Operating at f_{SW} = 325kHz. The Entire Circuit Fits within 1.7in² with Both Sides of the Board Populated

optimized dead-time and DCR sensing. The typical full load efficiency for the 1.5V and 1.2V rails is 89.5% and 87.8%, respectively (see Figure 2). The 1.2V output is remotely sensed with the diff amp. As a result, the 1.2V rail's output accuracy is unaffected by the voltage drops across the V_{OUT} and GND planes. The load step response for the 1.2V rail is shown in Figure 3.

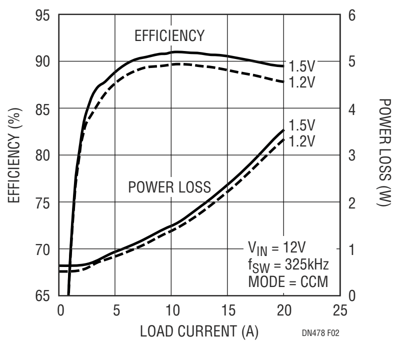


Figure 2. Efficiency and Power Loss of the 1.5V/20A and 1.2V/20A Converter

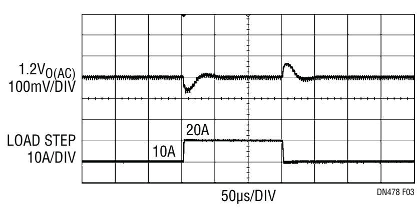


Figure 3. 50% to 100% Load Step Response for the 1.2V Rail at V_{IN} = 12V

The LTC3855 features precise current limit thresholds of 30mV, 50mV and 75mV, selected via the I_{LIM} pins. The current limit threshold can be raised by biasing the ITEMP pins below 500mV. Since the ITEMP pins source 10µA of current, the peak current sense voltage can be increased by inserting a resistance of less than 50k from the ITEMP pin to ground. By placing an inexpensive NTC thermistor next to the inductor and connecting this thermistor to a linearization network from the ITEMP pin to ground, the current limit temperature coefficient can be greatly reduced. As Figure 4 illustrates, the compensated current limit is 20% higher than the uncompensated current limit at 110°C. Another use for the ITEMP pins is to increase the current limit for conventional DCR sense and R_{SENSE} applications.

PolyPhase® Operation

The LTC3855 provides inherently fast cycle-by-cycle current sharing due to its peak current mode architecture,

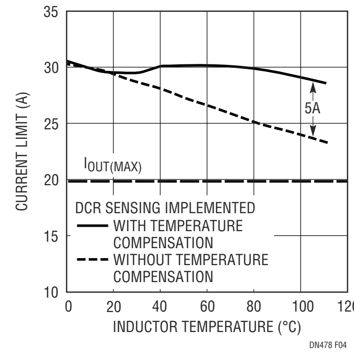


Figure 4. Measured Current Limit of the 1.2V Rail Over Temperature with and without Temperature Compensation

plus very tight DC current sharing for single output PolyPhase applications. Up to 12-phase operation can be achieved by daisy chaining the CLKOUT and MODE/PLLIN pins and by programming the phase separation with the PHASMD pins. A major advantage of PolyPhase operation is the reduction of the required input and output capacitance due to ripple current cancellation. Also, single output PolyPhase applications have a faster load step response due to a smaller clock delay.

Other Important Features

The switching frequency of the LTC3855 can be programmed between 250kHz and 770kHz with a resistor placed from the FREQ pin to ground or synchronized to an external clock in this frequency range using its internally compensated phase lock loop. High efficiency at light load is achieved by selecting either Burst Mode® operation or discontinuous mode operation, as opposed to continuous conduction mode. The LTC3855 can be used for inputs up to 38V, and its 100ns typical minimum on-time allows for high step-down ratios. The LTC3855 has a TK/SS pin for programmable soft-start or rail tracking, and dedicated RUN and PGOOD pins for each channel. The LTC3855 comes in either a 6mm × 6mm QFN or a thermally enhanced 38-lead TSSOP package.

Conclusion

The LTC3855 is a high performance dual output buck converter intended for low output voltage, high output current supplies. It provides the user with the benefits of a precise 0.6V 0.75% reference, an accurate current limit and high efficiency.

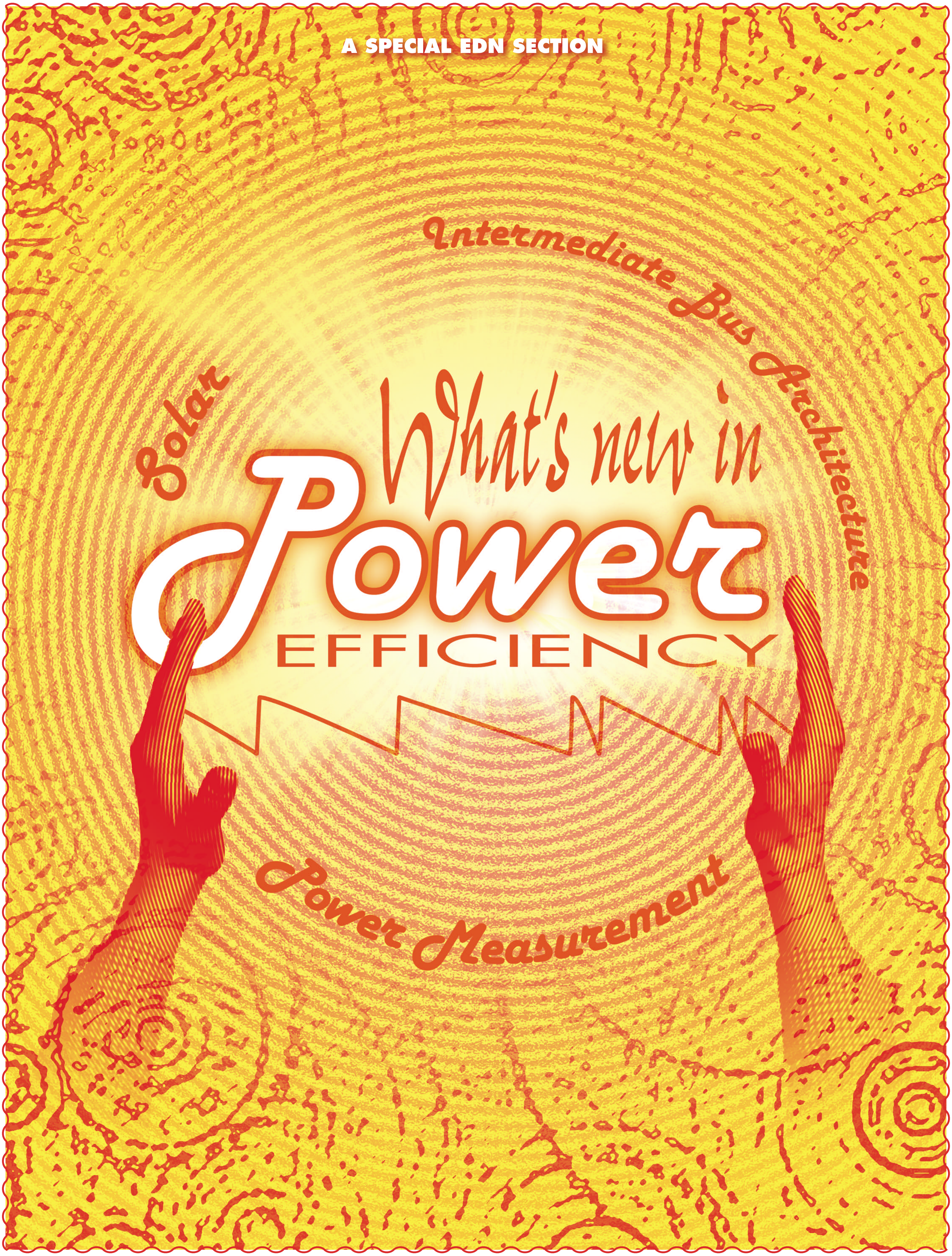
Data Sheet Download

www.linear.com

For applications help,
call (408) 432-1900, Ext. 3720

dn478f LT/TP 0510 116K • PRINTED IN THE USA

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com


A SPECIAL EDN SECTION
Intermediate Bus Architecture
Solar
What's new in
Power
EFFICIENCY
Power Measurement

By Margery Conner, Technical Editor

Overall power-supply efficiency depends on **sweating the small stuff**

Sweating the small stuff adds up to significant system-level gains in efficiency—especially important in applications that rely on solar and battery power.

An industrywide move toward increasing power-supply efficiency is now afoot. There are two reasons for the efficiency push: One is coming from government regulations that aim to raise the overall efficiency level of all power supplies on the market to meet minimum standards. Many customer companies have requirements that the products that they purchase meet Energy Star standards at a minimum. Energy Star compliance is now necessary but not sufficient for consideration in the market. The second reason is that, for some hardware, such as datacom servers, the cost of the energy the hardware consumes within four years exceeds the cost of the hardware itself. Containing power costs represents a significant cost saving for many businesses.

According to David Norton, vice president of marketing at TDK-Lambda, the companies that are the best in power supplies significantly improve overall efficiency by sweating the small stuff. For example, efficiency improves when manufacturers select the lowest practical on-resistance for every load switch in an ac/dc power supply. These tiny MOSFETs are not power switchers; they turn on or off the whole power section. Another example is a capacitor-discharge switch, such as Power Integrations' new CapZero X. The smart switch automatically switches out the discharge resistors at the input of many ac/dc power supplies, which can otherwise cause a small but significant power loss.

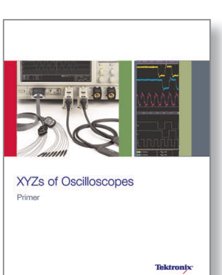
As Norton says, sweating the small stuff adds up to significant system-level gains in efficiency, and the articles in this power section will help you accomplish that task. Efficiency is especially important in applications that rely on solar and battery power; be sure to read Heather Robertson's article "Design challenges for solar-powered HB-LED lighting." "Digital-power management moves forward as licensing invites innovation," an interview with Matt McKenzie, president of power-supply-vendor CUI, points to how the increasing use of digital-power management in power supplies will further increase efficiency. How do we know just how efficient our supply design really is? Gina Bonini's article "Validating and characterizing switch-mode power supplies for maximum efficiency" explains how the right measurements help. I hope these articles will help take some of the sweat out of your design challenges.

The World's Standard.

Oscilloscopes from Basic to Bench and Beyond.

Whatever your need, there is a Tektronix oscilloscope to fill it. Tektronix offers the world's broadest portfolio of oscilloscopes to debug and test tomorrow's designs, today. Start with Tektronix Basic oscilloscopes: fast, familiar and affordable; they're what you know and trust. Our Bench oscilloscopes provide next-level productivity, with the feature-rich tools you need to debug today's complex mixed signal designs. And for those who demand fast, flexible, in-depth PHY layer analysis, our Performance oscilloscopes offer the industry's best signal fidelity, verification and characterization capabilities to help you shorten your design cycles.

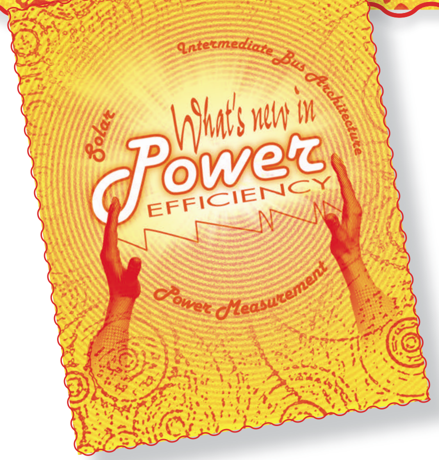
No wonder **8 of 10 engineers worldwide trust Tektronix** to help them bring advanced designs to market on time and on budget. Wherever you're going, we'll get you there.

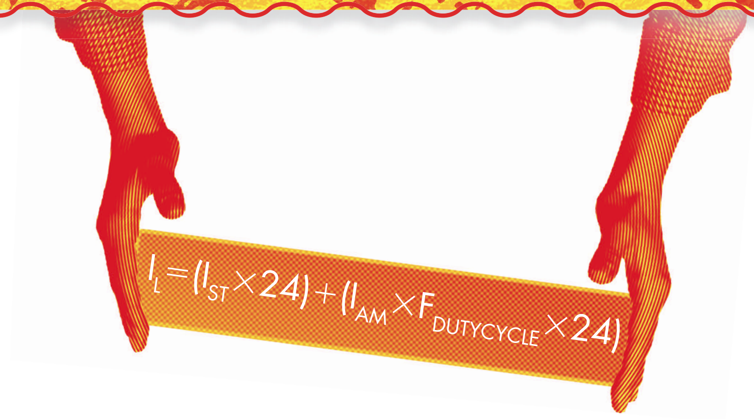


See why Tektronix is the World's Standard in Oscilloscopes and download your free Oscilloscope Primer.

www.tektronix.com/worldstandard

Tektronix®





Design challenges for solar-powered HB-LED lighting

By Heather Robertson, Avnet

SOLAR-POWERED HB-LED LIGHTING SYSTEMS COMBINE A CLEAN ENERGY SOURCE WITH THE ADVANTAGE OF AN EFFICIENT FORM OF LIGHTING. DESIGNING SUCH SYSTEMS REQUIRES UNDERSTANDING THE MAJOR COMPONENTS OF A SOLAR-POWERED HB-LED LIGHTING SYSTEM, AS WELL AS THE DESIGN CHALLENGES IN IMPLEMENTING SUCH A SYSTEM.

EFFICIENT POWER CONVERSION is an important factor in typical HB-LED (high-brightness-light-emitting-diode) lighting applications—and especially in solar-powered applications. Designers of systems for these applications must not only maximize power from the solar panel but also condition it for maximum energy storage in the battery array and convert it for use in powering the HB LEDs (**Figure 1**).

FUNDAMENTALS OF DRIVING HB LEDs

As diodes, LEDs exhibit a steep VI (voltage/current) curve, which means that even a small change in voltage results in a large change in current and brightness. It follows, then, that the most convenient method of regulating their output is to control current and not voltage. When you use multiple HB LEDs in a current-controlled configuration, you often must wire them in series to ensure uniform brightness.

Depending on the application, many highly efficient, highly integrated HB-LED drivers are available. Common power-conversion topologies for constant-current HB-LED drivers are boost, buck, SEPIC (single-ended primary-inductance converter), and flyback. LEDs are not capacitive loads, and most integrated HB-LED-driver circuits have soft-start-up protection, so HB-LED drivers typically appear as well-behaved loads on the battery.

When designing a system, you must establish the size of batteries and solar panels by estimating current consumption, usually in ampere-hours. A design's current consumption includes standby and active power. "Standby power" refers to the times when the HB LEDs are off, such as in the daytime. In standby mode, the design minimizes current use, and only a small amount of sense/control circuitry is active; only leakage currents remain. "Active power" refers to power consumption when the system is operating—in this case, when the HB LEDs are on. Designs can have one or multiple active and standby modes. Active modes usually have a well-understood duty cycle—a percentage of time in a day during which the system is active, as the following **equation** describes: $I_L=(I_{ST}\times 24)+(I_{AM}\times F_{DUTYCYCLE}\times 24)$, where I_L is the current load in ampere-hours, I_{ST} is the standby current in amps, I_{AM} is the active-mode current in amps, and $F_{DUTYCYCLE}$ is the duty-cycle factor in percentage points.

SIZING AND CHOOSING SOLAR PANELS

A number of technologies are available for solar panels, and each has its own characteristics. **Table 1** provides an overview of technologies and their notable features. Most solar lighting applications use crystalline-silicon panels because of their general availability and high efficiencies. Most HB-LED lighting systems require panels with less than 100W of power. Crystalline-silicon panels are available in the form factors and sizes for industrial applications requiring power of 5 to 100W. In an interesting fit for a different technology, flexible amorphous silicon wraps a light pole with solar materials, forming the solar panel around the light pole itself (**Reference 1**).

You must consider a number of factors when sizing the solar panels. Assuming no active tracking, you achieve optimum performance for solar panels when the panels point south, with a tilt angle approximately equal to the latitude of the installation plus 20°. You can achieve further optimization by adjusting the tilt angle of the panels two or four times per year to track seasonal changes in the path of the sun. If you cannot place the solar panels with the optimum tilt angle, or facing south, they cannot generate maximum power. For example, some systems require you to place panels parallel to the ground, with no tilt angle. Alternatively, you must place them in locations in which they will be subject to a significant amount of shading. You must figure an orientation/shading-multiplication factor for these situations into the panel-sizing equation. It is also prudent to factor degradation into the size of the panels because solar panels may lose as much as 20% of their rated output over a 20-year period.

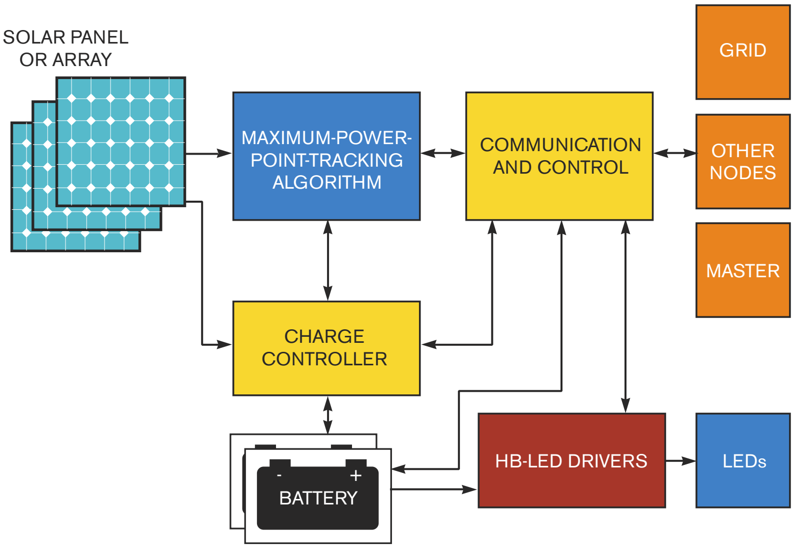


Figure 1 Designers of systems for solar-powered HB-LED lighting applications must not only maximize power from the solar panel but also condition it for maximum energy storage in the battery array and convert it for use in powering the HB LEDs.

It is important to understand the amount and power of sunlight that any geographic location receives to plan a solar-powered lighting system. "Insolation" describes the amount of solar irradiation a given surface area receives in a given time, usually in kilowatt-hours per square meter per day. The NREL (National Renewable Energy Lab, www.nrel.gov) provides a variety of solar-insolation data (**Reference 2**). When sizing solar panels for a system, you must also consider the "solar-autonomy" days—those days during which the system must be able to run without any sun. **Figure 2** shows estimates for general and conservative systems. These estimates use worst-case winter solar insolation for the regions in which the system will find use. You can use the following **equation** for making these estimates: $W_{PANEL}=(I_{LOAD}/\text{WINTER PEAK ISOLATION})\times V_{BATTERY}\times F_{ORIENTATION}$, where W_{PANEL} is the panel size; I_{LOAD} is the current load; $F_{ORIENTATION}$ is the orientation, shading factor, and degradation; $V_{BATTERY}$ is the nominal battery voltage; and WINTER PEAK INSOLATION is the number of winter-sun hours, which typically uses NREL data.

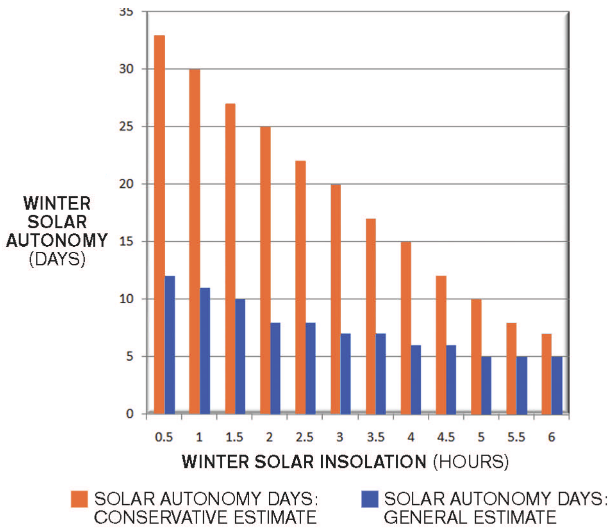


Figure 2 When sizing solar panels, you must consider solar-autonomy days–the number of days that the system can run without sun.

SIZING AND CHOOSING BATTERIES

Another aspect of a system is energy storage. Although SLA (sealed lead-acid) batteries are the most common in off-grid solar-powered HB-LED lighting, other options may be feasible (**Table 2**). You can charge SLA batteries at below-freezing temperatures, which is desirable in solar-powered applications. Although other types of batteries can operate at below-freezing temperatures, they may not be able to charge.

Temperature, the depth of discharge, and the rate of discharge significantly affect SLA-battery performance. Manufacturers label not only these batteries' capacity but also their rate of discharge. The rate of discharge affects the capacity of a battery; the faster the rate of discharge, the lower the capacity. The converse is also true: The slower the rate of discharge, the higher the capacity of the battery.

The depth of discharge is the amount of energy as a percentage of total capacity that the battery discharges. The greater the depth of discharge, the fewer cycles the battery can support. There is a direct relationship between depth of discharge and battery life; manufacturers typically recommend a 50% of

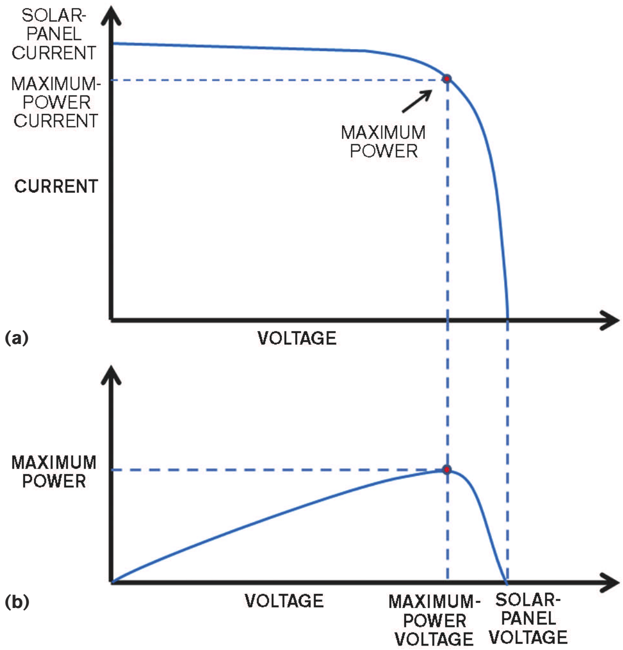


Figure 3 Solar panels have a characteristic IV curve depending on irradiance and temperature. On one point on that curve, the panel generates maximum power current (a) and power (b).

capacity limit for deep-cycle SLA batteries. Lower depth-of-discharge rates extend battery life.

In choosing the capacity of a battery, especially SLA batteries, it is important to include a design factor to account for the impact of ambient temperature because SLA-battery capacity decreases in cold environments. **Table 3** shows design factors for SLA batteries.

The following **equation** calculates battery capacity: $C_{BATTERY} = (I_L \times T_{SOLAR} \times 24 \times F_{TEMPERATURE})/F_{DOD}$, where $C_{BATTERY}$ is the battery capacity, I_L is the current load, T_{SOLAR} is the number of solar-autonomy days, $F_{TEMPERATURE}$ is the temperature-design factor, and F_{DOD} is the maximum battery-depth-of-discharge percentage. This **equation** is a good estimate for SLA batteries when the rated discharge rate is similar to the expected discharge rate. If the discharge rate is higher or lower than the specified discharge rate of the battery, you must adjust

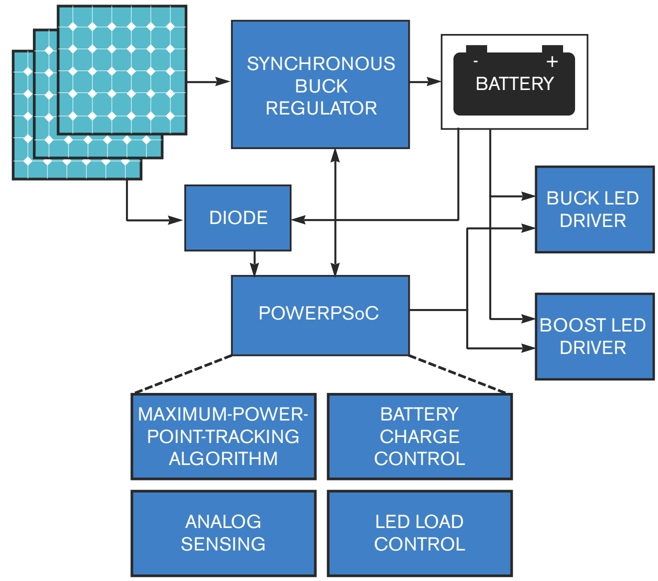


Figure 4 Cypress' PowerPSoC reference design includes an MPPT function, a battery charger, and both buck and boost HB-LED-driver circuits.

this estimate accordingly. You can use Peukert's Law, which expresses the capacity of an SLA battery in terms of the rate at which it discharges. As the rate increases, the battery's available capacity decreases. Lithium-ion batteries generally do not have a significant sensitivity to discharge rate.

MAXIMUM-POWER-POINT TRACKING

Solar panels have a characteristic IV curve, which varies depending upon irradiance and temperature. The panel generates maximum power at a point on the IV curve (**Figure 3**). In many solar applications, the system operates the panel at this point, generating maximum power. Many algorithms exist for this phenomenon, MPPT (maximum-power-point tracking), but the goal of all of them is the same: to operate the panel as close as possible to the characteristic peak-power point of the power curve.

Implementations of MPPT can be fully analog or mixed signal and often include a microcontroller or a state machine. In designing a system, you should perform a cost-benefit analysis to determine whether adding an MPPT function will increase energy capture enough to offset the cost of implementation.

CHARGE CONTROL

You use charge controllers to safely and efficiently charge batteries. You can buy these controllers off the shelf, or designed for your application—often by combining the MPPT and charge-controller circuits. As noted, SLA batteries are among the most common for HB-LED solar-powered lighting

TABLE 1 SOLAR-PANEL TECHNOLOGY

Technology	Module-conversion efficiency (%)	Temperature coefficient	Diffused/low light	Degradation due to light	Flexible	Cost
Crystalline silicon	14 to 18	Highest	Poor	No	No	High
Amorphous silicon	8	Lowest	Good	In intense light	Yes	Low
Copper-indium-gallium selenide	11	High	Good	No	Yes	Low
Cadmium telluride	10	Low	Fair	No	No	Lowest

applications. Efficient charging of these batteries requires a variety of charging modes, including bulk charge, absorption, floating, and equalizing. Each state requires charging with different current and voltage characteristics, making sensing/feedback and control important elements in the controller. A common architecture for an off-grid MPPT-charge-controller implementation is the use of a boost, buck, or buck/boost switching regulator; a microcontroller with analog inputs for sensing current and voltages from both the solar panel and the batteries; and PWM (pulse-width-modulated) outputs to control switches in the regulator.

TABLE 2 BATTERY TECHNOLOGY

Battery type	Relative-cost factor	Relative-weight factor	Relative-size factor	Approximate watt-hours/kilogram	Temperature (°C)	Approximate no. of cycles
Sealed lead acid	1	4	3.5	40	−15 to +50	300
Lithium ion	4	1	1	130	−10 to +60	500 or more
Nickel-metal hydride	2.5	1.3	1.3	70	−10 to +60	500 or more

CONTROL AND COMMUNICATION

You can use HB-LED lighting in either networked or standalone lighting. Networked lighting enables energy-saving control and dimming; communication of environmental activity, such as movement and traffic; and battery and fault status. Both wired and wireless networks are common, and these networks commonly use standards-based wireless protocols, such as ZigBee, and proprietary wireless protocols operating over the ISM (industrial/scientific/medical) bands of 902 to 928 MHz and 2.4 GHz. For wired networking, power-line modems can communicate over the grid.

Although it may seem contradictory to have a grid-connected, solar-powered HB-LED luminaire, the grid would primarily perform networked communication and provide an optional power source for battery charging. A potential application using both wired and wireless communication would be a wireless link connecting a subnet of lights. A node that connects to the main controller through a power-line modem would control these subnets.

SYSTEM EXAMPLES

Electronics for solar lighting applications lend themselves well to integration. You can now buy integrated products for solar lighting, and other products are currently in development. Cypress Semiconductor (www.cypress.com) has a complete solar-charger HB-LED reference board employing the company's PowerPSoC (programmable-system-on-chip) processor. A 12V solar panel charges the board, which charges 12V SLA batteries and includes an MPPT function, a battery charger, and both buck and boost HB-LED-driver circuits.

TABLE 3 SLA-BATTERY TEMPERATURE AND DESIGN FACTOR

Temperature (°F)	Battery-design factor
80+	1
70	1.04
60	1.11
50	1.19
40	1.3
30	1.4
20	1.5

The Cypress architecture uses a current-controlled buck regulator for MPPT and battery charging (**Figure 4**). The MPPT and battery-charging algorithm in the PowerPSoC uses voltage and current feedback from the panel and operates the panel at its peak power by controlling the switches in the buck regulator. The switches in the synchronous buck-regulator circuit also operate in a way that ensures that the current arriving at the battery meets the requirements of the charge state of the battery.

The design features two LED drivers: a floating-load buck driver for LED loads as high as 8V and 2A in which the forward voltage is less than the battery voltage, and a boost driver for LED loads as high as 40V and 2A in which the forward voltage is more than the battery voltage (**Figure 5**). For additional information, see **references** 3 and **4**. EDN

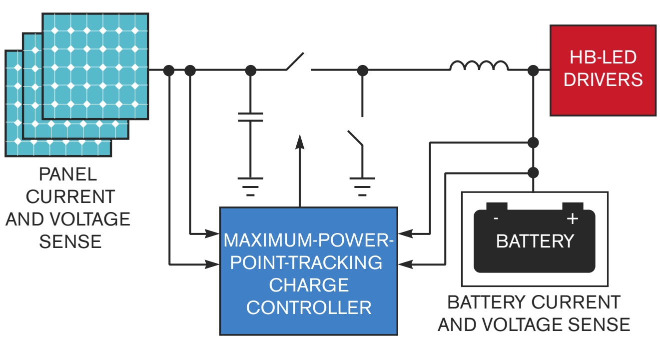


Figure 5 Microcontroller-based MPPT and battery charging are implemented in a current-controlled buck regulator with voltage and current feedback from the solar panel and battery.

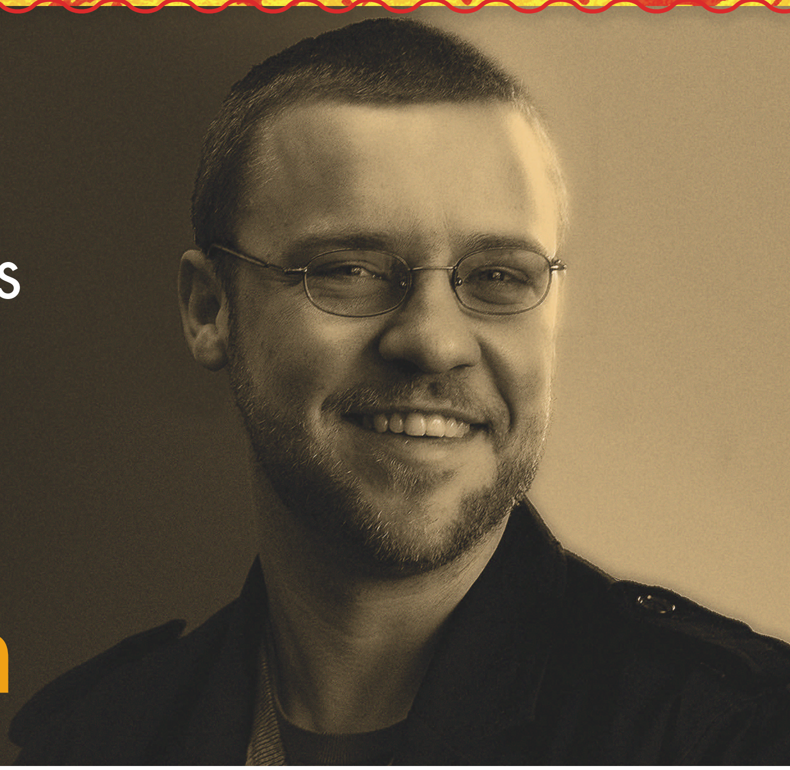
AUTHOR'S BIOGRAPHY

Heather Robertson is solar technology director for Avnet Electronics Marketing.

REFERENCES

1. Conner, Margery, "Visionaire's Solar Lighting Pole: shedding light on off-grid lampposts," *EDN*, Nov 26, 2009, pg 16, www.edn.com/article/CA6707787.
2. National Renewable Energy Lab, www.nrel.gov/gis/solar.html.
3. Solar-industry-related articles, www.em.avnet.com/solar.
4. HB-LED-related articles, www.em.avnet.com/Lightspeed.

Digital-power management moves forward as **licensing invites innovation**



What role will digital-power management play in power subsystems with intermediate power buses? Matt McKenzie, president of CUI, claims that digital power's role will be significant, not just in the larger telecom/datacom centers but down through the smaller OEM systems, resulting in efficiency increases that would otherwise be unreachable. *EDN* recently interviewed McKenzie on the role of digital power.

What technology do you see affecting the future of power-conversion systems?

A I think digital communications and monitoring is going to be the big thing in power. We at CUI have been waiting like everybody else to see what would happen after the Power-One lawsuit [over its patent on the digital-communications bus for dc/dc POL (point-of-load) converters], which was not good for anybody.

We were very glad when Power-One started licensing and opening up the market to competition. The innovation is about to start, and we're seeing customers start to understand the benefits of digital. Our analogy is that digital is "removing the veil" from all the data that can be collected from any electronics power stage. The ability to understand what's happening in the system and to monitor over time is a big benefit.

Was the uncertainty caused by the Power-One lawsuit a hindrance to potential customers?

A Yes. When Power-One started going after its competitors and winning, customers were not apt to go with the technology; they backed out and started figuring out different solutions. Now, we don't have that issue. Power-One has licensed to just about every gorilla in the market: Linear Tech, TI, Intersil, and Powervation. I think we're going to start seeing products that are smart, functional, and competitive. Digital power is in its infancy, and the industry is still on the beginning of the learning curve.

Are all your customers–or just the early adopters–already familiar with digital power's benefits?

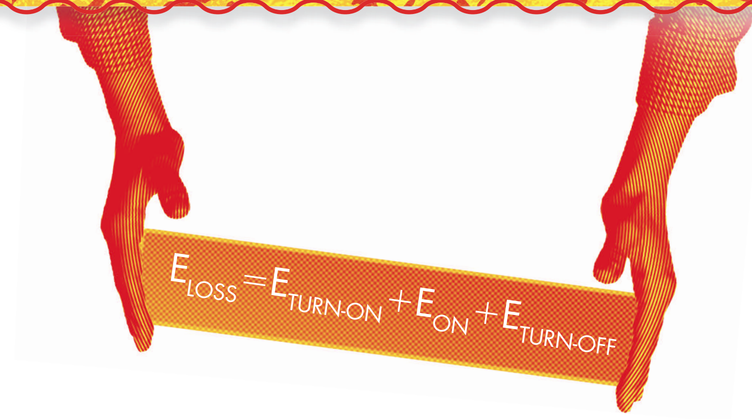
A At this point, it's still mostly early adopters. Our slogan is "simple digital." We're not just targeting the leading-edge telecom vendors; we want to put it into the hands of the smaller OEMs as well, so our push is to make digital power easy to use. Customers in the smaller tier may just need some kind of exposure but don't need to understand all of the intricacies that go into digital. A lot of the innovation comes from this level as well.

You've said that efficiency is a major concern for your customers. How do digital power's advantages in data logging, system monitoring, and the like make a power subsystem more efficient?

A With digital power, you're able to see at what point the power is actually needed and where it's not. In a big network-server system where you're running, say, eight rails, you may not know exactly how much power is needed and where. Engineers will usually overdesign so that their system is prepared for whatever may hit it.

With digital power, you're able to monitor on a microsecond level what's happening in the system and optimize each subsystem for what it needs to do, including the ability to go into standby modes and shutoff modes. These gains may be small, but, over a system or over many systems, you start getting massive efficiency gains.

–interview conducted and edited by Margery Conner



Validating and characterizing switch-mode power supplies for maximum efficiency

By Gina Bonini, Tektronix

TO ENSURE OPTIMAL EFFICIENCY WITH ACCEPTABLE TRADE-OFFS, IT'S IMPORTANT TO VALIDATE AND CHARACTERIZE SMPS DESIGNS BY MEASURING SWITCHING AND MAGNETIC POWER LOSS TO DETERMINE POWER-SUPPLY EFFICIENCY, AS WELL AS MEASURING POWER QUALITY AND HARMONICS TO UNDERSTAND THE EFFECT OF THE SMPS ON THE POWER LINE.

THE GREATEST ENERGY LOSS in electronic systems usually occurs during power conversion by ac/dc and dc/dc power supplies. With energy conservation a top priority in nearly every design, SMPSs (switch-mode power supplies) featuring conversion efficiencies of 80 to 90% have emerged as the prevailing architecture. In a perfect world, every power supply would behave like its mathematical model. In the real world, however, components are imperfect, loads vary, line power may be distorted, and the environment changes frequently. To ensure optimal efficiency with acceptable trade-offs, it is critical to validate and characterize SMPS designs. These tasks typically require measuring switching and magnet-power loss to determine the efficiency of the SMPS as well as measuring power quality and harmonics to understand the impact of the SMPS on the power line.

MEASURING SWITCHING LOSS

Switching transistors in an SMPS have fast switching times to minimize energy loss. The largest source of energy loss for an SMPS occurs during switching since these transistors dissipate little power in either the on or the off states. They lose energy during transitions due to the discharge of diode-stored charge and the discharge of energy stored in parasitic inductance and capacitance. "Turn-off loss" describes the loss when the device moves from on to off. Similarly, "turn-on loss" describes the energy loss when the switching device changes from off to on. The following **equation** calculates energy loss during transitions:

$$E_{TRANSITION} = \int_{t_0}^{t_1} v_A(t) i_A(t) dt,$$

where $E_{TRANSITION}$ is the energy loss in the switch during the transition, $v_A(t)$ is the instantaneous voltage across the switch, $i_A(t)$ is the instantaneous current through the switch, t_1 is when the transition is complete, and t_0 is when the transition begins.

The total energy loss for an entire switching cycle includes the turn-on and turn-off switching losses and conduction losses. The following **equation** yields the total loss: $E_{LOSS} = E_{TURN\text{-}ON} + E_{ON} + E_{TURN\text{-}OFF}$, where E_{LOSS} is the energy loss in the transistor for a switching cycle, $E_{TURN\text{-}ON}$ and $E_{TURN\text{-}OFF}$ are the switching losses, and E_{ON} is the conduction loss.

Analysis of these losses is essential for characterizing the supply and gauging its efficiency. You can measure switching loss with an oscilloscope (**Figure 1**). By using an oscilloscope with specialized power-analysis software, you can measure switching and conduction losses across multiple switching cycles to determine device behavior over time. Measurement statistics show how the measurement results are changing.

Accurately measuring turn-on and turn-off losses can be a

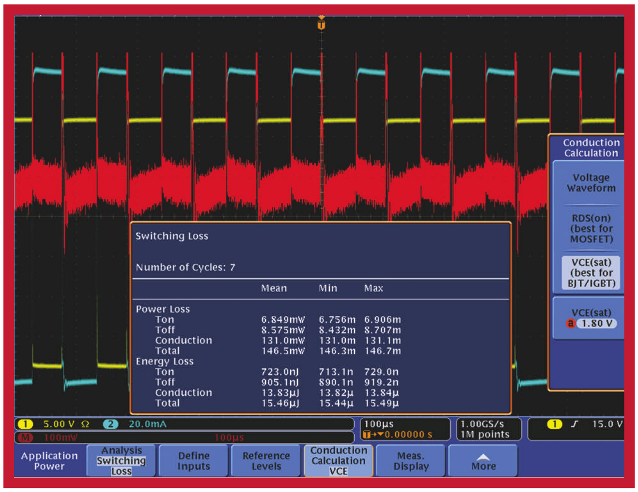


Figure 1 An oscilloscope with specialized power-analysis software can show switching and conduction losses across multiple switching cycles to determine device behavior over time.

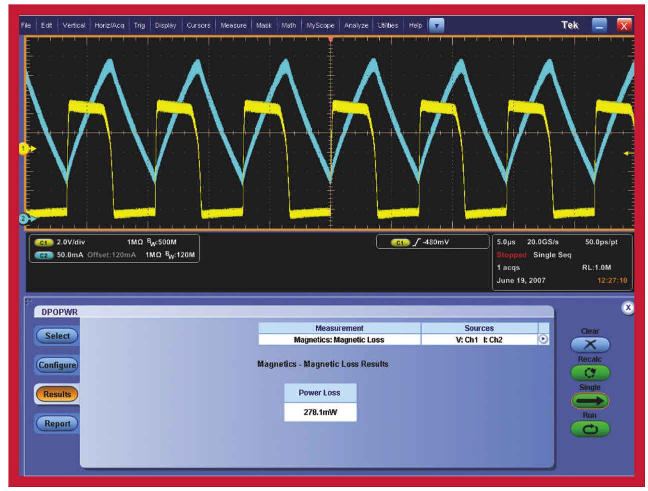


Figure 2 You can measure the power loss of a single-winding inductor using an oscilloscope with power-analysis software. Channel 1 (yellow trace) is the voltage across the inductor, and Channel 2 (blue trace) is the current, measured with a nonintrusive current probe, through the inductor. The power-measurement software automatically computes and displays the power-loss figure, 278.1 mW.

challenge because the losses occur over short time periods, whereas the losses during the remainder of the switching cycle are minimal. This measurement requires precise timing between the voltage and the current waveforms and minimal measurement-system offsets.

MEASURING MAGNETIC POWER LOSS

SMPSs usually employ inductors for filtering and transformers for changing voltage levels because these elements as a rule have low power loss. Inductors exhibit increasing impedance with frequency, impeding higher frequencies more than lower frequencies. This feature makes them useful for filtering at the power supply's input and output.

Transformers couple ac voltage and current from a primary winding to a secondary winding, increasing or decreasing signal levels for either voltage or current but not both. Thus, a transformer might accept 120V at its primary and step this voltage down to 12V on the secondary with a proportional increase in current on the secondary. Because the transformer's primary and secondary do not electrically connect, they also provide isolation between circuit elements.

Magnetic power loss affects the efficiency, reliability, and thermal performance of the power supply. Two types of power losses are associated with magnetic elements: core loss in the ferrous core and copper loss in the copper windings. Magnetic loss is equal to core loss plus copper loss, where core loss comprises hysteresis loss and eddy-current loss, and copper loss is due to the resistance of the copper winding wire.

You can derive the total power loss and the core loss using information from the core vendor's data sheet and results from an oscilloscope running power-measurement software. You can then calculate copper loss from these two values. Knowing the power-loss components enables you to identify the cause for power loss at the magnetic component.

Magnetic power loss affects the efficiency, reliability, and thermal performance of the power supply.

The method for calculating the magnetic component's total power loss depends in part on the type of component you are measuring. The device under test may be a single-winding inductor, a multiple-winding inductor, or a transformer. **Figure 2** shows the measurement result for a single-winding inductor. Channel 1 (yellow trace) is the voltage across the inductor, and Channel 2 (blue trace) is the current, measured with a nonintrusive current probe, through the inductor. The power-measurement software automatically computes and displays the power-loss figure, 278.1 mW.

For optimum performance, designers generally specify magnetic components using hysteresis curves from the manufacturer. These curves define the performance envelope of the magnetic component's core material. To ensure that operating voltage and current remain within the linear region of the hysteresis curve during operation, it is essential to characterize the magnetic component operating within the SMPS.

Dedicated power-measurement software can greatly simplify magnetic-property measurements with an oscilloscope. In many instances, you need to measure only the voltage and the magnetizing current. The software then performs the mag-

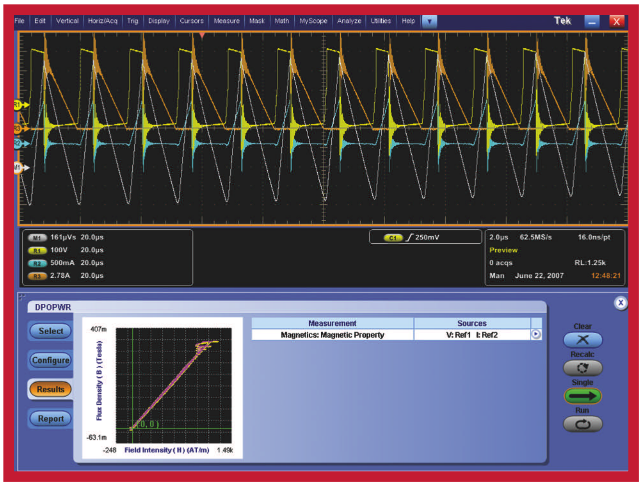


Figure 3 In this hysteresis plot for the transformer, Channel 1 (yellow trace) is the voltage across the transformer, Channel 2 (blue trace) is the current through the primary, and Channel 3 (golden trace) is the current through the secondary. Using data from channels 2 and 3, the software determines the magnetizing current.

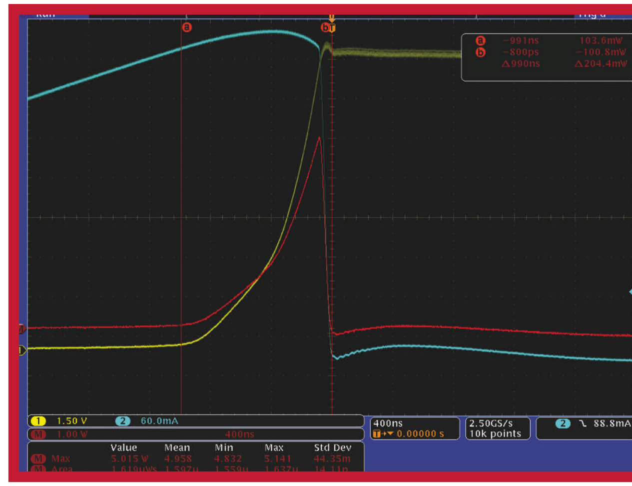


Figure 4 This scope display shows the result, 5.141W, of a measurement without deskewing of the two probes.

netic-property-measurement calculations. You can perform magnetic-property measurements on a single-winding inductor as well as on a transformer with both primary and secondary current sources.

In **Figure 3**, Channel 1 (yellow trace) is the voltage across the transformer, Channel 2 (blue trace) is the current through the primary, and Channel 3 (golden trace) is the current through the secondary. Using data from channels 2 and 3, the software determines the magnetizing current. Some power-measurement software can also create an exact hysteresis plot for the magnetic component and characterize its performance. You must first enter the number of turns, the magnetic length, and the cross-sectional area of the core before the software can compute a hysteresis plot.

PROBING CONSIDERATIONS

To make power measurements with an oscilloscope, you must measure voltage across and current through the drain-to-source node of the MOSFET switching device or the collector-to-emitter node of an IGBT (insulated-gate bipolar transistor). This task requires a high-voltage differential probe and a current probe. Each of these probes has its own characteristic propagation delay. The difference in these two delays, or skew, causes inaccurate power measurements and distorted timing measurements.

It is important to understand the impact of the probes' propagation delays on maximum-peak-power and area measurements. After all, power is the product of voltage and current. If the two multiplied variables are not perfectly time-aligned, then the result will be incorrect. The accuracy of measurements such as switching loss suffers when you do not correctly deskew the probes. For example, **Figure 4** displays the result, 5.141W, of a measurement an engineer took without first deskewing the two probes. The measurement results in **Figure 5** illustrate the importance of proper deskewing. As the example indicates, skew introduces a measurement error of 5.3%. Accurate deskewing reduces error in peak-to-peak power-loss measurements.

The accuracy of measurements suffers when you do not correctly deskew the probes.

Some power-measurement software automatically deskews the chosen probe combination. The software adjusts the delay between the voltage and the current channels using live signals to remove the difference in propagation delay between the probes. A static deskew function, when available, relies on the fact that certain voltage and current probes have constant and repeatable propagation delays. The static deskew function automatically adjusts the delay between selected voltage and current channels based on an embedded table of propagation times for selected probes.

In addition, differential and current probes may have slight amplitude offset. Because this offset can affect accuracy, you should remove it before taking measurements. Some probes have a built-in automated method for removing the offset. These probes work with the oscilloscope to remove any dc offset errors in the signal path. Degaussing removes any residual dc flux in the core of the current probe's transformer, which a large amount of input current may cause.

POWER LINES

Power-line measurements, such as power quality and line harmonics, are important for ac/dc power supplies to characterize

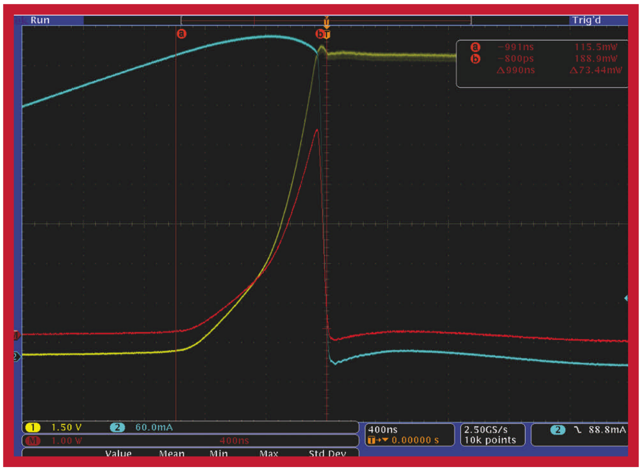


Figure 5 Peak amplitude has risen to 5.415W, or 5.3% higher, after deskewing the signal in Figure 4.

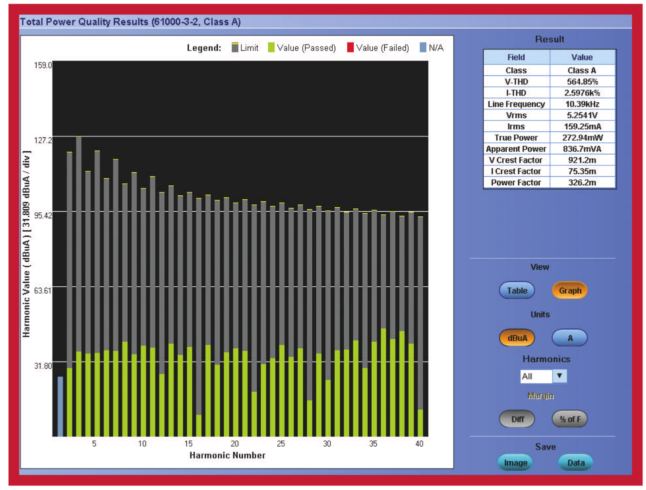


Figure 6 This display shows the result of a harmonic analysis on a power supply's load current. The software automatically calculates the current harmonics and determines THD relative to the fundamental and root-mean-square values.

the interaction of the SMPS and its service environment. Real-world electrical-power lines never supply ideal sine waves because there is always some distortion and impurity on the line. A switching power supply also presents a nonlinear load to the source. As a result, the voltage and current waveforms are not identical. The SMPS draws current for some portion of the input cycle, causing the generation of harmonics on the input-current waveform. Determining the effects of these distortions is an important part of power engineering.

To determine the power consumption and distortion on the power line, you measure power quality at the input stage. Digital oscilloscopes running power-measurement software provide good alternatives to the power meters and harmonic analyzers engineers traditionally use for power-quality measurements.

The oscilloscope offers a number of advantages. The test instrument must be able to capture harmonic components up to the 50th harmonic of the fundamental. Power-line frequency is usually 50 or 60 Hz, according to applicable local standards. In some military and avionics applications, the line frequency may be 400 Hz. Signal aberrations may contain even-higher frequencies. Modern oscilloscopes with high sampling rates capture fast-changing events with great resolution. In contrast, conventional power meters can overlook signal details due to their relatively slow response. An oscilloscope's record length is also typically sufficient for acquiring an integral number of cycles, even at high sampling resolutions.

CURRENT HARMONICS

Switching power supplies tend to generate predominantly odd-order harmonics, which can find their way back into the power grid. The effect is cumulative, and as more and more switching supplies connect to the grid—for example, as an office adds more desktop computers—the total percentage of harmonic distortion returning to the grid can rise. Because this distortion causes heat buildup in the cabling and transformers of the power grid, it is important to minimize harmonics. Regulatory standards such as EN/IEC61000-3-2 specify power quality for a particular nonlinear load.

Performing harmonics analysis is as easy as taking an ordinary waveform measurement with an oscilloscope that has power-measurement software. **Figure 6** shows the result of a harmonic analysis on a power supply's load current. In this case, the software automatically calculates the current harmonics and determines important values, such as THD (total harmonic distortion) relative to the fundamental and rms (root-mean-square) values. These measurements are useful in analyzing compliance with standards such as EN/IEC61000-3-2 and Military Standard 1399. Some software automatically compares the measurement results with the standard for a quick check of device compliance.

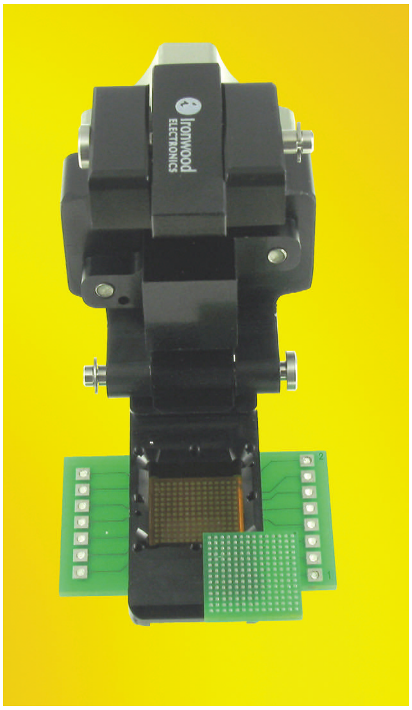
The power supply is integral to virtually every type of electronic product, and the SMPS has become the dominant architecture, thanks to its conversion efficiency of as much as 90%. Measuring switching and magnetic power loss along with power quality and harmonics is often necessary for validating and characterizing SMPS designs to ensure that they will function properly in real-world environments. Although power-supply measurements can be complex, an oscilloscope with appropriate probing tools and automated measurement software can simplify these tasks. **EDN**

AUTHOR'S BIOGRAPHY

Gina Bonini is the worldwide embedded-systems technical-marketing manager for Tektronix. She has worked extensively in various test-and-measurement positions for more than 15 years. Bonini holds a bachelor's degree in chemical engineering from the University of California—Berkeley and a master's degree in electrical engineering from Stanford University (Palo Alto, CA).

productroundup

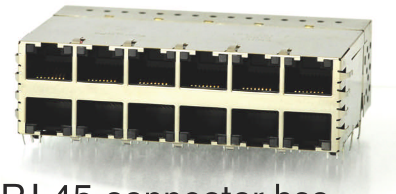
CONNECTORS



Socket features clamshell lid

The CG-BGA-4010 socket targets use with 194-pin, 0.8-mm-pitch BGA ICs. The device measures 12×12 mm and operates at bandwidths as high as 6.5 GHz with less than 1 dB of insertion loss. The socket has an easy-open clamshell lid and integrates a heat-sinking mechanism. Contact resistance is typically 20 mΩ per pin. The socket connects all pins with 6.5-GHz bandwidth on all connections. The CG-BGA-4010 sockets have a high-performance, low-inductance elastomer-contactor construction and operate at temperatures of −35 to +100°C. The pins' self-inductance is 0.11 nH, and mutual inductance is 0.028 nH. The capacitance to ground is 0.028 pF, and current capacity is 2A per pin. The CG-BGA-4010 sells for $544; volume pricing is available.

Ironwood Electronics, www.ironwoodelectronics.com



RJ-45 connector has built-in POE technology

This RJ-45 connector embeds enhanced POE (power-over-Ethernet) technology, reducing the cost, footprint, and design-cycle time associated with integrating POE into Ethernet switches. Targeting next-generation Ethernet switches with IEEE 802.3af- or IEEE802.3at-compliant POE functions, it delivers IEEE802.3 at power with built-in dynamic, emergency, backplane, and resilient power management. Prices for complete systems, including a 2×6-connector array, start at approximately $5/port.

Tyco Electronics, www.tycoelectronics.com

PCB connector eliminates the need for board-to-board connectors

The plastic APD direct-PCB connector connects to a PCB internally, rather than with a standard crimped-cable connection, eliminating the need to use board-to-board connectors. The connector requires no harnessing and is sealed to IP67 and IP69K specifications, providing protection against the effects of dust and temporary immersion. Available in six-, seven-, 19-, 37-, or 51-way versions, the APD direct-PCB connector also has a four-way configuration for sensor applications. Maximum operating voltage is 48V. Typical prices for the APD direct-PCB connector range from $5 to $25 per mated pair.

ITT Interconnect Solutions, www.itt.com

EDN product mart

This advertising is for new and current products.

MARKUS METTENLEITER • ZOLLER+FRÖHLICH GMBH

The turn of the screwdriver

DANIEL VASCONCELLOS

In 1992, as a student in electronics engineering and robotics, I had been working in a robotics lab, developing electronics. The major research project was an autonomous robot the size of a small table, with a three-wheel drive; a VAX workstation; and several sensors, including ultrasonic transducers, a 70-GHz scanning radar, a laser-radar scanner, odometers, and gyroscopes.

The older parts of the robot, such as the motor and steering-wheel control, generally worked well and hardly ever failed, but the steering wheel one day began to flicker and tremble randomly. I was assigned to find and fix the problem after the entire robot had been dismantled. Unfortunately, the motion control resided in the lowest rack, between the front and rear wheels.

Starting at the steering-wheel motor and working backward, I quickly found that the fault must lie within the TTL (transistor-to-transistor-logic) electronics of the interface to the VAX workstation, which was on a TTL-stuffed board in the 19-in. rack. I had to use a bus extender to access the pins and traces on the board.

Checking all the signals, first with a scope and finally with a logic analyzer, I quickly found two issues. First, the designer of this interface truly loved asynchronous logic and had developed a masterpiece of logic gates, flip-flops, and one-shots, triggering each other. With one-shots, such as the 74LS123, whenever a rising or a falling edge triggers the input, the output goes high and remains high for a certain time, which an external resistor/capacitor combination sets. By connecting several one-shots, logic gates, and flip-flops, you can build an asynchronous, mostly delay-driven state machine.

The second issue was that many of the one-shot's time constants had considerably changed over the years, so one or another time margin for proper operation of the state machine had decreased significantly. In the end, though, everything still worked fine—as long as this board was sitting on the bus extender. After I reinserted the board in the 19-in. rack, the flicker and tremble problem reappeared.

I soldered wires to several signal lines and logic outputs on the board so that I could measure the signals while the board was in the rack. It then became clear that the output of one one-shot was causing the trouble, although all input signals were perfectly clean. Even the supply voltage didn't suffer from too much electric noise or dirt. The IC was just damaged.

Surprisingly, the problem persisted after I replaced the part. I then thought that the input signals or the power supply was perhaps not clean or that I had overlooked some fast ground bounce. The several centimeters of probe wires, which I had soldered to the board for accessing the signals, were perhaps acting as an inductor, just "filtering out" the very fast distortions I was looking for. None of these wires were impedance-controlled, shielded, or even debounced. So I went through some more probing and testing with more sophisticated shielded probe wires with a series-debouncing resistor. In the end, though, I got the same result.

In desperation, I grabbed a big screwdriver from the toolbox and placed its blade over the erratic one-shot—and the problem went away! It turned out that a small piece of copper foil, glued onto the one-shot housing and soldered to ground, had the same effect. Some electromagnetic signals had been radiating right into the chip or the bonding wires, causing random distortions of the output. Some power-converter and motor-driver stages on the adjacent board, near the one-shot, had been radiating these strong fields, causing the flickering and trembling. **EDN**

Markus Mettenleiter is team leader for laser-scanner development at Zoller+Fröhlich GmbH (Wangen, Germany).


THE EMBEDDED
DEVELOPER
Microsoft®
Windows® Embedded
BUILT WITH
WINDOWS 7
TECHNOLOGIES
Vol. 5
A MALFUNCTION IN THE SYSTEM
COULD COST THE PLANT MILLIONS...
THE DEVICE HAS TO...
WORK PERFECTLY, TO THE MICROSECOND, AND HAVE THE CONNECTIVITY TO TRACK PERFORMANCE IN REAL TIME.
THEY'RE COUNTING ON ME TO DELIVER.
WINDOWS® EMBEDDED OFFERS A HIGHLY RELIABLE PLATFORM, WITH THE LEVEL OF PERFORMANCE YOU NEED TO HELP DELIVER CONNECTED DEVICES THAT STAND OUT.
WHICH WINDOWS® EMBEDDED-PLATFORM CAN HELP YOU DELIVER STANDOUT DEVICES?
FIND OUT AT WINDOWSEMBEDDED.COM/DEVICESTORIES