A Canon Communications LLC Publication

EDN®

VOICE OF THE ENGINEER

AUG 26
Issue 16/2010
www.edn.com

NEW POWER REGULATIONS BRING POWER-FACTOR CORRECTION TO LOWER-POWER SUPPLIES

Page 30

HARDWARE-CONTROLLED BRUSHLESS DC MOTORS EASE THE BURDEN ON CPUs

Page 24

ARCHITECTURE COMBINES LOW- AND ZERO-IF RECEIVERS

Page 36

find it here
www.digikey.com
Digi-Key Corporation

TAKE CONTROL

From Prototype to Production!

SAME-DAY SHIPPING on orders entered by 8:00 pm CENTRAL NEXT-DAY DELIVERY

1. "Always has available product"
2. "Has an excellent website"
3. "Supports your global distribution needs"
4. "Provides on time delivery"
5. "Is easy to do business with"
6. "Most preferred distributor"

Digi-Key rated #1 in all categories.
Source: *TechInsights*, Distributor Evaluation Study, May 2009.

Digi-Key® CORPORATION

Over 465,000 electronic components in stock from more than 440 supplier partners.*

The industry's broadest product selection available for immediate delivery

www.digikey.com
1.800.344.4539

*Digi-Key is an authorized distributor for all supplier partners. New products added daily. © 2010 Digi-Key Corporation, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA

NEDA Supplier Authorized Distributors


We're giving power a
digital upgrade.
10100011110110111101100011
Find out how our new Digital EXL Core™ technology is redefining Power Factor Correction ICs.
Cirrus Logic's CS1500 and CS1600 are the industry's first Digital Power Factor Correction (PFC) ICs to surpass ordinary analog solutions in performance and price. Enabled by Cirrus Logic's EXL Core technology, these digital solutions intelligently solve traditional power management challenges with newly patented and patent pending designs that dramatically reduce the need for bulky, high-priced components and complex circuitry, lowering overall system cost and simplifying designs. Cirrus Logic now makes it possible for more energy-efficient power supplies in digital televisions, notebook adapters, PC power supplies and lighting ballast applications through advanced digital technology that creates smarter, greener, and more energy-efficient products.
Experience Digital PFC. Register for free samples at www.cirrus.com/ednpfc
EXL CORE
CIRRUS LOGIC®
© 2010 Cirrus Logic, Inc. All rights reserved. Cirrus Logic, Cirrus, the Cirrus Logic logo designs, EXL Core, and the EXL Core logo design are trademarks of Cirrus Logic, Inc. EDN06242010

Over **1.6** Million
Parts Online

IMagine the Possibilities.

Scan with your smart phone or mobile
device's camera/QR-Code reader.
mouser.com/wirless-ad

WARNING: Designing with Hot, New Products
May Cause A Time-to-Market Advantage.

MOUSER
ELECTRONICS®
a tti company

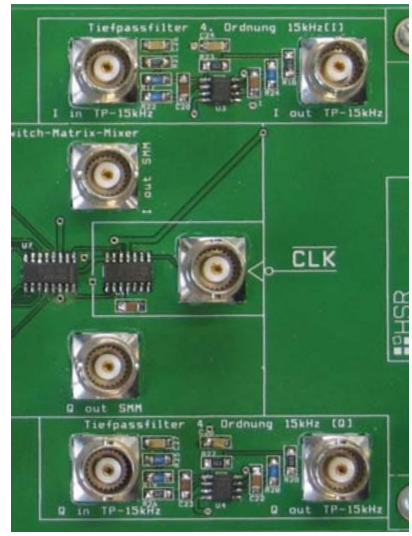
mouser.com (800) 346-6873

Mouser and Mouser Electronics are registered trademarks of Mouser Electronics, Inc. Other products, logos, and company names mentioned herein, may be trademarks of their respective owners.

EDN 8.26.10 contents

New power regulations bring power-factor correction to lower-power supplies

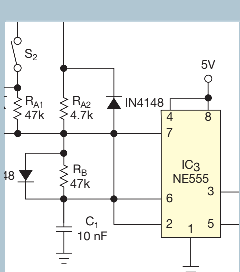
Hardware-controlled brushless dc motors ease the burden on CPUs



Architecture combines low- and zero-IF receivers

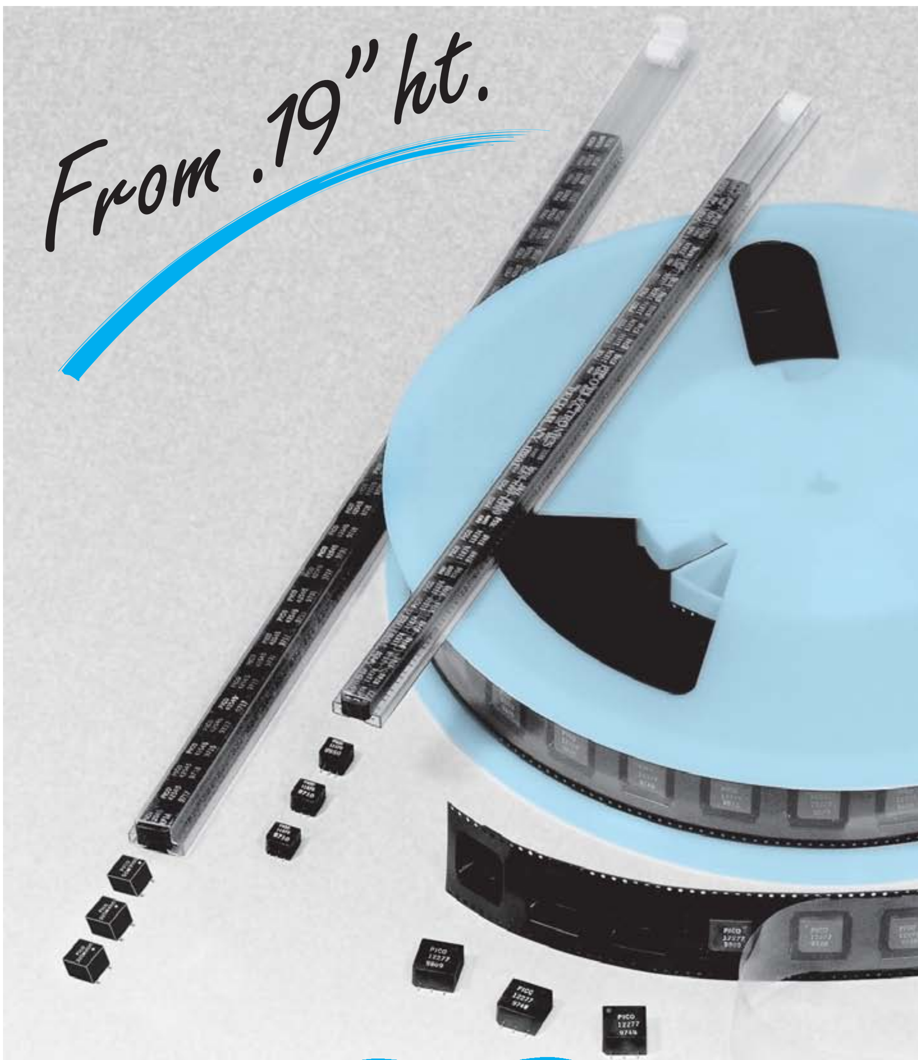
pulse

DESIGNIDEAS



Over 5000 Standard

PICO Transformers and Inductors



Surface Mount
(and Plug-In)

Audio Transformers
Impedance Levels 10 ohms to 250k ohms, Power Levels to 3 Watts, Frequency Response ±3db 20Hz to 250kHz. All units manufactured and tested to MIL-PRF-27. QPL Units available.

Power & EMI Inductors
Ideal for noise, spike and Power Filtering Applications in Power Supplies, DC-DC Converters and Switching Regulators

Pulse Transformers
10 Nanoseconds to 100 Microseconds. ET Rating to 150 Volt Microsecond, Manufactured and tested to MIL-PRF-21038.

Multiplex Data Bus Pulse Transformers
Plug-In units meet the requirements of QPL-MIL-PRF 21038/27
Surface units are electrical equivilents of QPL-MIL-PRF 21038/27.

DC-DC Converter Transformers
Input voltages of 5V, 12V, 24V And 48V. Standard Output Voltages to 300V (Special voltages can be supplied). Can be used as self saturating or linear switching applications. All units manufactured and tested to MIL-PRF-27.

400Hz/800Hz PowerTransformers
0.4 Watts to 150 Watts. Secondary Voltages 5V to 300V. Units manufactured to MIL-PRF-27 Grade 5, Class S (Class V, 155°C available).

DELIVERY-stock to one week for sample quantities

PICO Electronics, Inc.

143 Sparks Ave. Pelham, NY 10803 • ***Call Toll Free*** 800-431-1064 • fax: 914-738-8225

Send for free 180 pg PICO Catalog

See PICO's full Catalog Immediately on the internet

www.picoelectronics.com

E-mail: info@picoelectronics.com

contents 8.26.10


48


50

DEPARTMENTS & COLUMNS

EDN online contents www.edn.com

ONLINE ONLY

Check out these Web-exclusive articles:

Researchers claim plastic "spintronics" alternative to traditional semiconductors
Researchers at Ohio State University have demonstrated what they are claiming to be the first plastic computer-memory device that uses the spin of electronics to read and write data.
→www.edn.com/100826toca

Outsourced chip-design starts grew as a percentage of total design starts in 2009
According to research company Gartner, chip-design outsourcing suffered heavily due to the economic recession, but it also benefited relatively as chip vendors faced with staffing shortages continued to outsource chip designs from third-party chip-design service providers.
→www.edn.com/100826tocb

BRIAN'S BRAIN

High-def DVD, 802.11n, digital TV, operating systems—if it's consumer-electronics-based, he's analyzed it. Visit *EDN*'s award-winning Brian's Brain blog, in which Senior Technical Editor Brian Dipert exposes, analyzes, and opines on diverse topics in technology.

Sample a few recent blog entries at the links below:

Tackling OSx86 means bugs to squash: building a Hackintosh
→www.edn.com/100826tocc

Solar abnormality: assessing the potential for future calamity
→www.edn.com/100826tocd

Hulu versus PlayOn: The tug of war goes on and on ...
→www.edn.com/100826toce

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, CA, and at additional mailing offices. SUBSCRIPTIONS—Free to qualified subscribers as defined on the subscription card. Rates for nonqualified subscriptions, including all issues: US, $150 one year; $250 two years; $300 three years. Except for special issues where price changes are indicated, single copies are available for $10 US and $15 foreign. For telephone inquiries regarding subscriptions, call 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 label as well as new address. Allow two months for change. NOTICE—Every precaution is taken to ensure accuracy of content; however, the publisher 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 40612608. Return undeliverable Canadian addresses to Pitney Bowes Inc, PO Box 25542, London, ON N6C 6B2.

Copyright 2010 by Canon Communications LLC. All rights reserved. Reproduction in whole or part without written permission is prohibited.

Volume 55, Number 16 (Printed in USA).

Simpler Power Conversion

IR's SmartRectifier™ chipset for AC-DC power converters dramatically simplifies design and improves efficiency.

SmartRectifier™ ICs

Part Number	IR1166 SPBF	IR1167A SPbF	IR1167B SPbF	IR1168 SPbF	IR11662 SPbF	IR11672A SPbF	IR11682 SPbF
Package	SO-8						
V_{CC} (V)	20						
V_{FET} (V)	200						
Sw Freq. max (kHz)	500						400
Gate Drive ±(A)	+1/-4	+2/-7		+1/-4	+1/-4	+2/-7	+1/-4
V_{GATE} Clamp (V)	10.7	10.7	14.5	10.7	10.7	10.7	10.7
Min. On Time (ns)	Program. 250 -3000			750	Program. 250 -3000		850
Enable Pin	Yes	Yes	Yes	No	Yes	Yes	No
Channel	1			2	1		2
Automatic MOT Protection	No	No	No	No	Yes	Yes	Yes

For more information call 1.800.981.8699 or visit www.irf.com

International IOR Rectifier
THE POWER MANAGEMENT LEADER

Yes, chip inductors are among Coilcraft's biggest sellers. But did you know we also offer a full range of other RF products like these?

They're all in stock for immediate shipment and all available as free samples for testing and evaluation.

For the full picture, visit **www.coilcraft.com/RF**

Broadband Conical Inductors

High impedance from 10 MHz to 40 GHz. Perfect for RF to millimeter-wave choking and bias tees. Available with leads or in surface mount versions for ruggedness and easy mounting.

Air Core Inductors

For the highest possible Q and current handling, nothing beats our air core "Spring" inductors. New models offer more inductance values and smaller size.

RFID Transponder Coils

A variety of antenna coils for 125 kHz systems. Automotive grade models for tire pressure and keyless entry applications.

Wideband Transformers

Our low insertion loss transformers come in a wide range of turns ratios. Use for baluns, isolation or impedance matching.

Some people only think of us for chip inductors.

BY RICK NELSON, EDITOR-IN-CHIEF

The grand challenge of employment

The employment situation in the United States took another hit in July, with the Bureau of Labor Statistics reporting a drop of 131,000 in nonfarm-payroll employment. The Bureau reported that 6.6 million have been jobless for 27 weeks or more, and 8.5 million are working part-time despite wanting full-time employment. If there is good news, it's that much of the employment decline represented the layoff of temporary government census workers. Private-sector payroll employment increased 71,000 over the month, with 36,000 of that number representing manufacturing jobs.

As Robert Reich, professor of public policy at the University of California—Berkeley, notes, however, "We need 125,000 new jobs per month simply to keep up with the growth of the American population seeking jobs." Clearly, a new golden age of manufacturing in the United States is nowhere in sight.

To former Intel executive Andy Grove, that fact is seriously bad news. He contends that a nation's manufacturing prowess is the key to its ability to innovate. Start-ups alone cannot continue a cycle of innovations (**Reference 1**). Start-ups are wonderful, Grove writes, but what should follow "that mythical moment of creation in the garage" is equally important, as companies learn to scale up to mass production. Scaling, he says, is "necessary to make innovation matter," but, unfortunately, it's no longer happening in the United States. He cites personal experience with failure to scale, pointing out that Intel's hesitancy to expand production of memory chips enabled its offshore competitors to dominate the market.

Grove notes that Intel did not repeat this mistake with microprocessors. To help other US companies avoid the same pitfall, he proposes strong medicine, including taxing the products of offshore labor, dedicating the proceeds to companies that will scale up their US production facilities, and creating jobs that can absorb the increasing numbers of people entering the US work force.

If—absent Grove's strong medicine, which Congress seems unlikely to soon administer—the manufacturing-employment outlook is bleak, prospects for *EDN* readers should be considerably better, according to speakers at National Instruments' NIWeek event, which took place this month in Austin, TX. Keynote speaker Michio Kaku, PhD, a theoretical physicist and TV personality, said that the future is bleak for middlemen, agents, tellers, brokers, and anyone performing repetitive tasks but that the future is bright for artists, leaders, creative people, and intellectual workers of the type who attend NIWeek.

During a panel discussion, NI executives painted a similarly bright picture for engineers. James Truchard, PhD, president, chief executive officer, and co-founder of NI, commented on recent corporate failures, from the tragic BP oil spill to the nearly comical "antennagate" problems of Apple. Such cases, he said, stem from a lack of healthy communication up the chain of command—which can lead to situations in which safety takes a back seat to the bottom line, as in BP's case, or in which aesthetic concerns outweigh performance issues, as in Apple's case. The consensus seems to be that corporations need to foster an environment in which engineers can have a stronger role in challenging the decisions of dysfunctional management.

As Jeff Kodosky, co-founder and fellow at NI, put it, "Engineering is the only solution to the grand challenges we face. Those challenges can be solved only by engineers."

The NI executives aren't seconding Grove's prescription. "I believe the world is flat, and we must compete on a global basis," said Phil Hester, senior vice president for R&D at the company. And that idea pertains to engineering as well as manufacturing, he added, with the sun never setting on dispersed teams of innovators. Alex Davern, chief financial officer and senior vice president of NI, said that the goal should center on eliminating low-value jobs and on driving investment that increases the standard of living for everyone.

As the various executives explained, there are no shortages of grand challenges for engineers to solve—from perfecting fusion to safely extracting shale gas. Add to that the challenge of providing meaningful employment for laid-off workers who will never become certified LabView programmers. Let the work begin. EDN

REFERENCE

1 Grove, Andy, "How America Can Create Jobs," *Bloomberg Businessweek*, July 1, 2010, http://bit.ly/bQGEYv.

Contact me at richard.nelson@cancom.com.

FIX YOUR MANUFACTURING VARIABILITY PROBLEMS AND YOUR REPUTATION WILL PRECEDE YOU. If you're designing chips for high functionality, high speed and lower power consumption at the most advanced process nodes, you've got variability issues. We have the solution that will increase your yield, performance and prestige by a wide margin. | Get more information at mentor.com/solutions/manufacturing-variability.

Mentor Graphics®

THE EDA TECHNOLOGY LEADER

©2009 Mentor Graphics Corporation. All Rights Reserved. Mentor Graphics is a registered trademark of Mentor Graphics Corporation.

EDN

PUBLISHER, *EDN* WORLDWIDE
Russell E Pratt, 1-781-869-7982;
russell.pratt@cancom.com

ASSOCIATE PUBLISHER, *EDN* WORLDWIDE
Judy Hayes, 1-925-736-7617;
judy.hayes@cancom.com

EDITOR-IN-CHIEF, *EDN* WORLDWIDE
Rick Nelson, 1-781-869-7970;
richard.nelson@cancom.com

MANAGING EDITOR
Amy Norcross
1-781-869-7971;
fax: 1-781-862-4853;
amy.norcross@cancom.com
Contact for contributed technical articles

ANALOG
Paul Rako, Technical Editor
1-408-745-1994;
paul.rako@cancom.com

MASS STORAGE, MULTIMEDIA, PCs, AND PERIPHERALS
Brian Dipert, Senior Technical Editor
1-916-548-1225;
brian.dipert@cancom.com

NEWS
Suzanne Deffree, Managing Editor
1-631-266-3433;
suzanne.deffree@cancom.com

POWER SOURCES, ONLINE INITIATIVES
Margery Conner, Technical Editor
1-805-461-8242;
fax: 1-805-461-9640;
margery.conner@cancom.com

DESIGN IDEAS EDITOR
Martin Rowe,
Senior Technical Editor,
Test & Measurement World
edndesignideas@cancom.com

SENIOR ASSOCIATE EDITOR
Frances T Granville
1-781-869-7969;
fax: 1-781-862-4853;
frances.granville@cancom.com

ASSOCIATE EDITOR
Jessica MacNeil
1-781-869-7983;
jessica.macneil@cancom.com

CONSULTING EDITOR
Jim Williams, Staff Scientist,
Linear Technology
edn.editor@cancom.com

CONTRIBUTING TECHNICAL EDITORS
Dan Strassberg,
strassbergedn@att.net
Robert Cravotta,
robert.cravotta@embeddedinsights.com

COLUMNISTS
Howard Johnson, PhD, Signal Consulting
Bonnie Baker, Texas Instruments
Pallab Chatterjee, SiliconMap
Kevin C Craig, PhD, Marquette University

LEAD ART DIRECTOR
Marco Aguilera

ASSOCIATE ART DIRECTOR
Tim Burns

PRODUCTION
Michael Ciardiello,
Director of Premedia Technologies
Jeff Tade,
Production Director
Brian Wu,
Publications Production Manager
Jeff Polman, Derric Treece,
Senior Production Artists
William Baughman, Lucia Corona
Ricardo Esparza,
Production Artists

***EDN* EUROPE**
Graham Prophet,
Editor, Reed Publishing
gprophet@reedbusiness.fr

***EDN* ASIA**
Wai-Chun Chen,
Group Publisher, Asia
waichun.chen@cancom.com
Kirtimaya Varma,
Editor-in-Chief
kirti.varma@cancom.com

***EDN* CHINA**
William Zhang,
Publisher and Editorial Director
william.zhang@cancom.com
Jeff Lu,
Executive Editor
jeff.lu@cancom.com

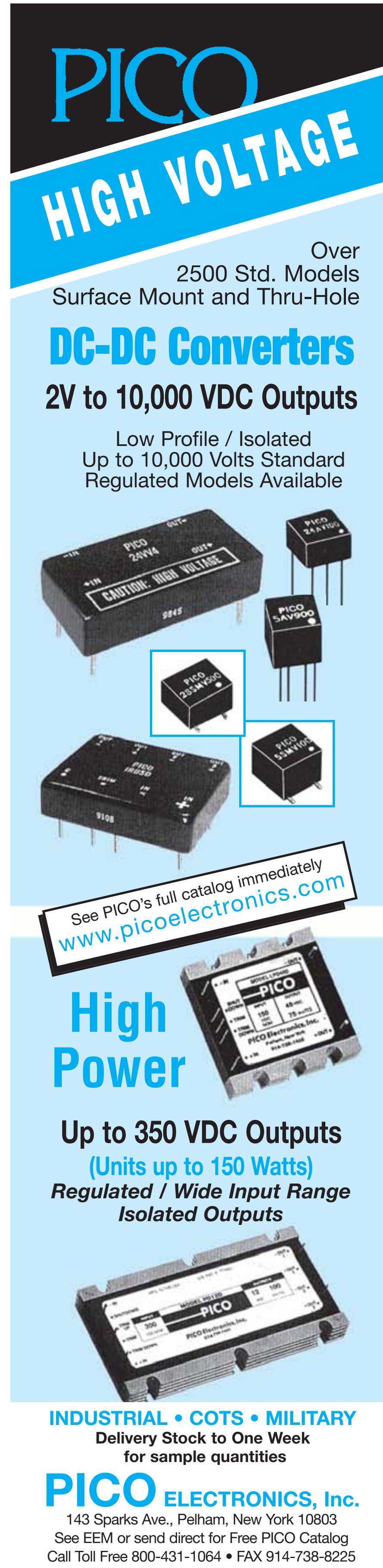
***EDN* JAPAN**
Katsuya Watanabe,
Publisher
katsuya.watanabe@cancom.com
Ken Amemoto,
Editor-in-Chief
ken.amemoto@cancom.com

EXECUTIVE OFFICERS
Charles G McCurdy,
Chief Executive Officer
Fred Gysi,
Chief Financial Officer
Mike Deering,
Chief Technology Officer
Ron Wall,
Senior Vice President, Publications
Kevin O'Keefe,
Senior Vice President, Events Division
Roger Burg,
Vice President, Operations
Jason Brown,
Vice President, E-media

EDN. 33 Hayden Avenue, Lexington, MA 02421. **www.edn.com**. **Subscription inquiries:** 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

Handheld 7-GHz spectrum analyzer quickly and easily makes precise measurements

Agilent Technologies has introduced the 100-kHz to 7-GHz (tunable to 9 kHz) N9342C HSA (handheld spectrum analyzer), which targets engineers and technicians who install, maintain, and monitor the performance of RF systems in the field. The new unit provides broader frequency coverage and more features than earlier members of the manufacturer's HSA family. To simplify making quick, accurate, and repeatable measurements under difficult field conditions, the 7.5-lb, 12.5×8.15×2.7-in. N9342C provides user-customizable capabilities.

The instrument targets use in aerospace/defense, microwave, satellite, wireless-communication, broadcasting, spectrum-regulation, and general-purpose spectrum-analysis applications. Measurements include transmitter and component test, receiving-path signal monitoring, and antenna tuning. RF-environment measurements include band clearance, signal coverage, and interface hunting. A task-planner feature automates routine measurements, reducing test-setup time by 95%, thereby increasing efficiency.

The HSA provides a set of standard, one-button measurements, including occupied bandwidth and in-channel and adjacent-channel power, which help you to characterize signal quality. The keypad design allows access to most measurement functions with no more than two button presses.

A rugged, fanless design suits the unit for challenging field environments, and an optional three-in-one ergonomic backpack ensures comfort and provides true hands-free operation. Moreover, with the LCD's automatic brightness adjustment and the keypad's backlight control, you can easily view the instrument's screen and enter measurement parameters by day or night.

You can use free HSA PC software to remotely control the instrument through a USB (Universal Serial Bus)/LAN connection. The device also has a dedicated user key, a customizable frequency and channel table, and frequency and amplitude correction.

Key N9342C options include a built-in 7-GHz tracking generator, a built-in GPS (global-positioning-system) receiver and antenna that provide precise location information, a spectrum monitor with spectrogram record and playback functions, support for the manufacturer's U2000 USB power sensors that offer high-accuracy power measurement to 24 GHz, a user data-sanitization feature for security purposes, an 8-GHz directional antenna that enables users to hunt for interference, and a built-in power connector for an active RF probe that ensures precise in-circuit measurements. The N9342C HSA's US base price is \$11,113; a typical configuration costs \$12,567.

—by Dan Strassberg

▷**Agilent Technologies**, www.agilent.com/find/n9342C.

FEEDBACK LOOP

"Anybody out there in hardware land care about the user experience? Solve that, and they'll flock to whatever you've got. Where to start? Try the 'on' button."

—Ski Milburn, in *EDN*'s Talkback section, at http://bit.ly/c5YbhX. Add your comments.

The N9342C handheld spectrum analyzer thrives in rugged environments, such as installing and maintaining an RF system, doing on-site troubleshooting, monitoring the RF environment, or analyzing interference.

Isolated dual-channel gate driver delivers 4A

Analog Devices' new ADuM3220 isolated dual-channel gate-driver IC provides 2500V isolation and lets you control two FETs or transistors. The device delivers 4A of peak output current. Input voltage ranges from 3.3 to 5V, and output voltage ranges from 4.5 to 18V. Both inputs and outputs feature an undervoltage lockout at 2.5 and 4.1V, respectively.

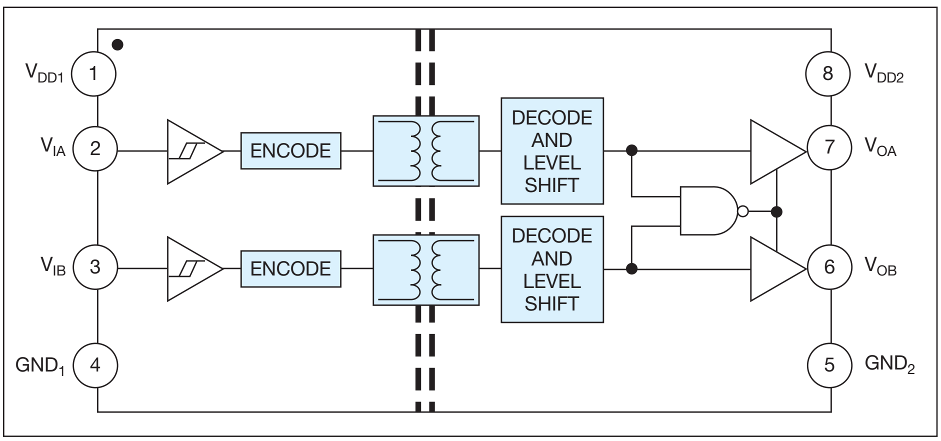
The default output voltage is 0V, and the maximum signal-propagation delay is 62 nsec, with 5-nsec matching between channels. The unit operates from dc to 1 MHz; typical input-stage quiescent current is 1.2 mA, and typical output-stage quiescent current is 4.7 mA. The IC provides 2500V/μsec common-mode transient immunity and has an overtemperature-shutdown circuit that activates at a die temperature of 150°C. UL (Underwriters Labs) UL1577 ratings and CSA (Canadian Standards Association) and European DIN (Deutsches Institut für Normung) approvals are pending.

The device uses the manufacturer's patented iCoupler technology. It has 60-nsec maximum isolator and driver-propagation delay; junction temperature is 125°C. It comes in an eight-pin SOIC, operates over a –40 to +125°C temperature range, and has a suggested retail price of $1.84 (1000).

—by Paul Rako

▷**Analog Devices**, www.analog.com.

> Both inputs and outputs feature an undervoltage lockout at 2.5 and 4.1V, respectively. Default output voltage is 0V.



You can use the ADuM3220 isolated-gate-driver IC to operate FETs and insulated-gate bipolar transistors.

DILBERT By Scott Adams

LEDs DELIVER HIGH BRIGHTNESS OR HIGH EFFICIENCY FOR OUTDOOR LIGHTING

Outdoor lighting is subject to the same trade-offs in upfront costs versus long-term operating costs as most other capital investments. You can optimize for LED-light output to reduce the number of emitters per lamp and lower the initial cost of the light, or you can optimize for lamp efficacy and go for the long-term lower operating costs through lower power bills.

To let you make that choice, Philips Lumileds has tweaked its Luxeon Rebel ES product line and lets you continue to use the same Rebel ES emitter. At 1000 mA, the new Rebel ES delivers more than 300 lumens at an efficacy of 100 lumens/W. If you choose to go for system efficiency, lower the current to 350 mA, and efficacy can exceed 125 lumens/W. These LEDs target overhead outdoor lighting for streets, roadways, tunnels, and high- and low-bay lighting, with CCTs (correlated color temperatures) centering at 4100 and 5650K.

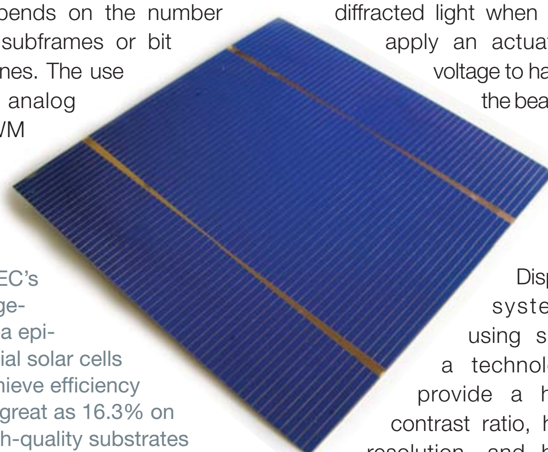
The devices' typical efficacy is more than 125 lumens/W, and typical light output is more than 300, 220, or 125 lumens at 1000, 700, and 350 mA, respectively. Typical forward voltage is 2.85 to 3.1V. Price is $3.89 (100) each.—by Margery Conner

▸Philips Lumileds, www.philipslumileds.com.

IMEC touts silicon-germanium MEMS, gallium-nitride-on-silicon, and solar-cell technologies

IMEC (Interuniversity Microelectronics Center) highlighted the capabilities of its silicon-germanium-on-MEMS (microelectromechanical-system)-technology platform at Semicon West last month in San Francisco. It also announced new partners in its gallium-nitride-on-silicon initiative and claims that its researchers have achieved efficiencies as high as 16.3% for large-area epitaxial solar cells.

The MEMS capability centers on the development of a 15-micron silicon-germanium micromirror and a grating light valve for high-resolution displays. IMEC realized the devices with its generic CMOS-compatible MEMS process for the monolithic integration of MEMS devices directly on CMOS metallization. The micromirror, targeting use in display systems, uses an electrostatic actuation mechanism relying on six electrodes. The design enables analog PWM (pulse-width modulation) instead of the binary-weighted PWM of current MEMS-based micromirrors. IMEC's novel actuation mechanism allows display of a large range of gray-scale values, whereas binary-weighted PWM depends on the number of subframes or bit planes. The use of analog PWM thus leads to higher response speed, less image-processing hardware, and less memory. Moreover, IMEC implements the analog PWM on the MEMS level instead of on the CMOS level.



IMEC's large-area epitaxial solar cells achieve efficiency as great as 16.3% on high-quality substrates and as great as 14.7% on low-cost substrates.

The grating light valve employs MEMS-reflection grating and produces bright and dark pixels in a display system. Diffraction of incident light due to electrostatic deflection of microbeams in suspension over an electrode controls the display system. The display system can modulate the intensity of the diffracted light when you apply an actuation voltage to half of the beams. Display systems using such a technology provide a high contrast ratio, high resolution, and high brightness. IMEC realized both the mirrors and the grating light valves with a 300-nm-thick silicon-germanium structural layer.

IMEC developed the devices within the framework of the Flemish SBO's (Strategic Basic Research's) Project Gemini, a collaboration among IMEC, Ghent University (www.ugent.be), and Katholieke Universiteit Leuven (www.kuleuven.be). Micron Technology (www.micron.com), Applied Materials (www.appliedmaterials.com), and Ultratech (www.ultratech.com) have also joined the IIAP (IMEC Industrial Affiliation Program, www2.imec.be/content/user/File/iiap_litho.pdf) on gallium-nitride-on-silicon technology. This multipartner R&D program focuses on the development of gallium-nitride-on-silicon-process and -equipment technologies for manufacturing solid-state lighting, such as LEDs, and next-generation power electronics components on 8-in. silicon wafers. Manufacturers currently build state-of-the-art LED processes on expensive 4-in. sapphire substrates. Depositing the gallium-nitride material on 8-in. silicon substrates could boost the productivity of gallium-nitride-based device-manufacturing processes.

IMEC also announced 70-cm^2 epitaxial solar cells with efficiency as great as 16.3% on highly doped, high-quality substrates. Efficiencies reached as much as 14.7% on large-area, low-cost, UMG (upgraded-metallurgic-grade) multicrystalline silicon substrates, showing the potential for the industrial manufacturing of thin-film epitaxial solar cells.

—by Rick Nelson

▷**IMEC**, www.imec.be.

POE computers operate on less than 25.5W

A list of devices running POE (power over Ethernet) usually comprises low-power applications, such as VOIP (voice-over-Internet Protocol) phones and videocameras. If you need computer access, you'd likely be limited to a terminal-only device because of the low-power requirements of POE. Even the recently adopted higher-power version, IEEE 802.3at, limits the power available to individual devices to 25.5W over Category 5 cable.

The SkinnyBytes POE computers come in 10.1- and 15.6-in. sizes.

SkinnyBytes sees an opportunity here for low-power AIO (all-in-one) computers that use less than 25.5W. The devices target use in classrooms, in which the cost of adding ac outlets and the hazards of daisy-chaining ac power strips can be prohibitive. To minimize power needs, Skinny Bytes computers use solid-state drives, low-power Intel (www.intel.com) Atom processors, and fanless passive cooling.

Prices for the touchscreen-based systems, which include Windows 7, start at $699 for the 10.1-in. tablet, and prices for the 15.6-in. AIO system start at $899.

—by Margery Conner

▶**SkinnyBytes, www.skinnybytes.com.**

08.26.10

Rarely Asked Questions

Strange stories from the call logs of Analog Devices

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

Watch for Those Multiple Clocking Edges!

Q. How can I improve system performance when using multiple clocks?

A. A common problem that arises when using multiple clocks generated from the same source is noise—usually a spur popping out of the noise floor—because the single clock source is multiplied or divided into several versions of the same clock. Skewing the adjacent edges of each clock allows you to reduce the noise spur, or get rid of it completely, depending on the system's timing margin. This phenomenon indicates a time-variant system, in which corruption on the clock signal is related to the location of the interference in the time domain. The location of the interference is fixed, so the degree of clock corruption is proportional to the magnitude of the interference, just like in a linear system.

As an example, let's take two outputs of the AD9516 clock generator. One output, at 100 MHz, is connected to an ADC; the other, at 25 MHz ($1/4\times f_{SAMPLE}$), clocks an FPGA. Rising and falling edges occur on both output clocks at nearly the same time. The result is a coupling effect, because two fast moving, high-bandwidth edges occur every 10 ns instead of one as desired. During this transition period, the noise—intrinsic or extrinsic—must be low, as jitter or noise can only corrupt the ADC's timing when present during the transition region of the clock. Making the edge faster (and hence the threshold region smaller) by increasing the slew rate will inevitably reduce the amount of time that noise can be present during the threshold period, effectively reducing the amount of rms (root-mean-square) jitter introduced to the system. During the steady-state period of the clock—the high and low levels—the clock noise is irrelevant. Therefore, simply delaying either the 25 MHz or 100 MHz clock will spread them apart in time, moving the location of the interference. In other words, arrange for the transition edges of one clock to happen during the steady-state period of the other clock.

In essence, what is happening here is crosstalk-induced jitter (noise) from one trace to an adjacent trace. If one trace carries a signal, and a nearby parallel trace carries a varying current, a voltage will be induced in the signal trace; if it is a clock signal, the time at which the clock edge occurs will be modulated. This causes problems if these edges are taking place at nearly the same time.

To Learn More About Clock Distribution
http://dn.hotims.com/27753-101

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

For Analog Devices' Technical Support, Call 800-AnalogD

SPONSORED BY
ANALOG DEVICES

VOICES

Mentor's role in IC and system design

In an interview that took place on July 14 at Semicon West, Walden C Rhines, chairman and chief executive officer of Mentor Graphics, addressed the challenges the EDA and semiconductor industries face as geometries shrink, EUV (extreme ultraviolet) arrives, and ICs go 3-D. He also commented on embedded-system design. An excerpt of the interview follows. Read the full interview at www.edn.com/100826pa.

How is Mentor addressing the challenges of 3-D?

A We are working directly with customers to ensure that the tools we provide are available ahead of the need. Physical verification is one of the straightforward pieces that people look to us to set standards for. Today, beyond memory, most of the 3-D usage is still pseudo 2-D—that is, stacked memory with logic or memory with analog. You can treat the design as 2-D, so it really hasn't created the big challenges that we have ahead.

What are the challenges ahead?

A Ahead, more and more we will be facing issues with parasitic extraction, timing, and floorplanning.

Are there still issues to address even in the 2-D chips, and does process shrinkage drive those issues?

A It's driven by a couple of things. Manufacturing variability, of course, is a driving force that becomes a bigger percentage of impact on a design with time. But I think the big discontinuity came when an EDA company—Mentor—was able to correlate the database from test results with the database from physical layout.

Will there be issues with EDA when going to EUV?

A EUV will require resolution enhancement, just as 193-nm immersion does. There is no scenario I know of where it will hit at such a time that you won't require resolution enhancement to go with it.

Is there still more work to be done with the 193 nm?

A Yes, it's a real workhorse light source. If you look [at it] compared to other generations of lasers, we've really stretched 193 nm a long way and will continue to push it, and it's very clear to us that our computational lithography will be able to bear the burden of shrinking to 20 nm.

What about power-aware design?

A It is probably the single biggest challenge of designers today. It clearly supersedes performance and density in terms of being the limiter of new designs. To me, the big opportunity ahead is moving the power analysis earlier in the design phase.

Mentor Graphics has products for embedded-system design. One thing that came out of the Design Automation Conference was the keynote address by the corporate vice president of innovation products at Motorola Mobile Devices Inc, who talked about designing the Droid phone. He said his big problem was that design tools did not let him optimize power, for example, at the end-product level. Are there prospects for addressing that problem?

A Yes. So system-level optimization, which involves multiple chips or board-level design, is not only a big opportunity; there are also tools available. First, there are power-integrity tools at the system level available, and one has actually been the fastest-growing system-design tool in our history. This year we went from zero to millions of dollars of sales in a period of about six months. So that's one piece. Another is the ability to have an embedded operating system that allows for power optimization. In fact, we have such an embedded operating system, Nucleus, and we have customers who have achieved order-of-magnitude improvements in power consumption simply by how they did things in the real-time operating system.

What about combining mechanical and EMI (electromagnetic) simulations at the system level, as well?

A Multiphysics simulation has been a major focus for us for many years now. It's been slow-growing, but it's been quite popular with the systems companies—solving problems, typically in the mechanical, electrical, and optical domains. We provide multiphysics simulation, optimization, and modeling capabilities, and that's a very promising area that's growing rapidly for us.

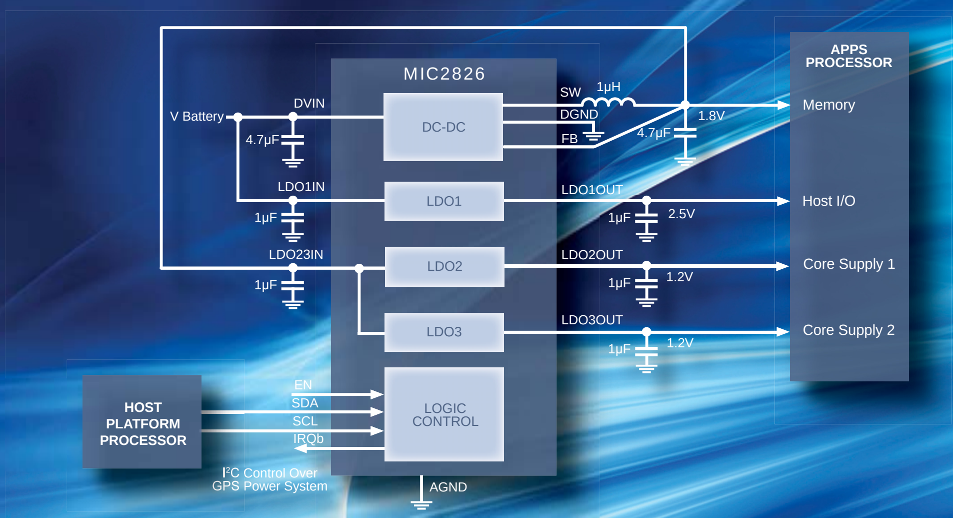
Within Mentor, do you see a shift in revenue you get from semiconductor products versus system-level products?

A I believe that, first of all, we see continued strengthening in system-level products, meaning system-design, analysis, embedded-software, thermal-analysis, and other system-level tools. And it will represent a growing share of our total revenue as we move out in time.

—interview conducted and edited by Rick Nelson

Advanced Portable System Power Management ICs

Quad Output PMIC with HyperLight Load™ DC/DC, 3 LDOs and I²C Control



Applications


Mobile Applications


GPS Subsystems


General Purpose PMIC

- Fast-mode 400kHz I²C Control Interface
- Dynamic Voltage Scaling & Sequencing
- Extremely High Light Load Efficiency
- Tiny 2.5mm x 2.5mm MLF® Package

Today's advanced portable electronics require highly integrated power system solutions for complex system power, small size, and long battery life. Micrel provides complete system power solutions, such as the MIC2826, to meet these needs.

The MIC2826 integrates a single 500mA HyperLight Load™ synchronous buck (step-down) regulator with three Low Dropout Regulators in a tiny 2.5mm x 2.5mm Thin MLF® package. The MIC2826 also features a standard 400kHz Fast-mode I²C interface that provides Dynamic Voltage Scaling (DVS), programmable power sequencing, and individual output control, making it the perfect integrated power system solution.

For more information, contact your local Micrel sales representative or visit Micrel at: www.micrel.com/ad/mic2826.

Ideal for use in:

- Application Processors
- GPS Subsystems
- Mobile Phones/PDAs
- Portable Media Players
- General Purpose PMIC

MICREL®
Innovation Through Technology®
www.micrel.com

© 2010 Micrel, Inc. All rights reserved. Micrel and Innovation Through Technology are registered trademarks of Micrel, Inc. HyperLight Load is a trademark of Micrel, Inc.
MLF is a registered trademark of Amkor Technology, Inc.

BY BONNIE BAKER

How voltage references affect mixed-signal parts

You might blame your ADC's or DAC's lack of output stability on the converter itself. After all, these types of devices can be complex. Try not to pass judgment too fast, though, because the circuitry around your converter might be the culprit. This circuitry, which includes a voltage reference, can change the converter's performance more than you may imagine.

In your initial evaluation of your converter, you may not even see the ill effects of your voltage reference. In the past, when evaluating an ADC or a DAC, I would first make sure that the converter's digital interface was in order and check to see whether the converter's output generally represented the input signal. I then looked at the zero-input converter noise. When you measure the noise of an ADC, you short the inputs and connect close to ground. With a DAC, you program the digital input to an analog zero output.

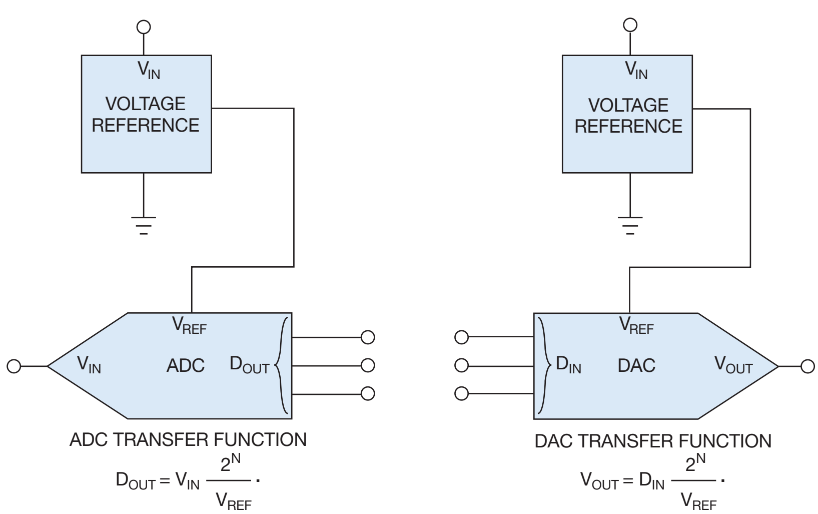
Where might you look for an ADC or DAC voltage-reference error? The key to answering this question is in the transfer function of these devices. In **Figure 1**, the numerator on the right-hand side of these functions has the input signal times 2^N, where N is the number of converter bits, and the denominator has the magnitude of the voltage reference in volts. The 2^N and V_{REF} values are constant. The impact of the voltage-reference value—and its errors—increases with an increasing input signal.

The best way to analyze and evaluate your data converter's voltage reference is with a full-scale output signal. A voltage reference with an offset error creates an ADC or a DAC gain error. If your voltage reference is noisy or marginally stable, you will also see this noise or instability, which will become worse when the converter's output is close to full-scale.

The analog output of an ADC or the digital results of the DAC can be only as good as the voltage reference in your circuit. When you choose your voltage-reference source, consider the following tips.

Using the system power-supply voltage at your converter's voltage-reference pin is a good technique only when dealing with 8-bit ADCs at best. Consider the origin of the power-supply voltage. For instance, dc/dc or switching converters produce acceptable dc outputs for circuits. However, they usually have an internal switching network that produces noise on the dc signal. Even when you implement lowpass filtering, remnants of the switching action in the dc/dc converter may transmit to the output of your ADC or DAC device. You may also try to follow a dc/dc or switching converter with a linear regulator. Linear-regulator power-supply-rejection and output noise levels are improving, but you may find that 10-bit devices and those operating at more than 10 bits still have problems.

An even riskier source for your converter's voltage-reference pin is your computer's USB port. The power-supply voltage from your USB port has the computer's digital noise riding on it—a poor environment for these types of devices. For higher-resolution ADCs and DACs, the best strategy is to start your design with a low-noise, stable, standalone reference. EDN



$$D_{OUT} = V_{IN}\frac{2^N}{V_{REF}}. \qquad V_{OUT} = D_{IN}\frac{2^N}{V_{REF}}.$$

Figure 1 D_{OUT} is the decimal representation of ADC's output code, A_{IN} is the ADC's input voltage, N is the ADC's and DAC's number of bits, V_{REF} is the reference voltage in volts, and D_{IN} is the decimal representation of the DAC's input digital code.

Bonnie Baker is a senior applications engineer at Texas Instruments.

Accelerating Your Success.™

BELL MICRO

AVNET® Embedded

Embedded Solutions

Three Times the **Power**

People. Products. Services. The powerful combination of Avnet and Bell Microproducts provides the expertise you need to accelerate your success. Our combined team gives you access to world-class resources. Bringing industry leading line cards together, we now deliver the most extensive inventory of brand name systems, embedded hardware, displays, storage and software. And, with our enhanced services you have access to Avnet's leading ISO integration centers, financial solutions and supply chain strategies.

AVNET® Embedded

1 800 332 8638

www.em.avnet.com/embedded

NEDA Supplier Authorized Distributor

Follow us on Twitter!
www.twitter.com/avnetdesignwire

©Avnet, Inc. 2010. All rights reserved. AVNET is a registered trademark of Avnet, Inc.

Sony Ericsson's Xperia X10 mini: the teardown skinny

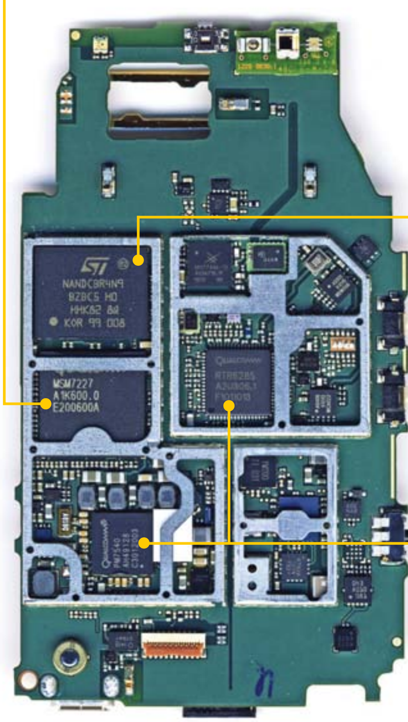
High-end smartphones, such as Apple's iPhone series and Google's Nexus One, might capture a disproportionate percentage of industry attention, but plenty of folks just want a handset that will make and take calls, handle e-mail and Web surfing, and fit comfortably into a normal-sized pocket, too. Sony Ericsson's Xperia X10 mini, which the company based on Google's Android operating system, aims to address this market need. Does it succeed? iFixit and *EDN* decided to find out (see http://bit.ly/bJLJPw).

PRY FURTHER AT EDN.COM

+ Go to the Brian's Brain blog at http://bit.ly/bm5Jrz for more analysis of the Xperia X10 mini.

The processing nexus of the Xperia X10 mini is Qualcomm's MSM7227 Snapdragon ARM-based chip set (see http://bit.ly/aSxHz5), which the company unveiled in February 2009. The MSM7227 targets system designs selling for less than $150; HTC's HD mini and Legend and Kyocera's Zio M6000 also use the MSM7227. It includes a 600-MHz application processor with a floating-point unit; a 320-MHz application DSP; a 400-MHz modem processor; hardware-accelerated 3-D graphics; integrated Bluetooth Version 2.1 with A2DP (advanced-audio-distribution-profile) capabilities; support for a still-image camera with resolution of as much as 8M pixels; and 30-frame/sec video capture at up to a WVGA (wide-VGA) resolution. This particular hardware design uses a 5M-pixel still-image camera module with VGA-resolution video capture, autofocus, and built-in LED-flash illumination.

The diminutive device measures 3.3×2×0.6 in. and weighs 3.1 oz. It comes in two versions: the conventional variant and a professional model that also includes a QWERTY physical keyboard and consequently weighs 1.1 oz more. Both devices leverage a Synaptics ClearPad 2000 capacitive touchscreen and a Samsung 2.6-in. LMS255GF02 QVGA (quarter-video-graphics-array) LCD, whose resolution limitations preclude the installation of some Android Market-sourced applications. A controller IC, also from Synaptics, drives the display. Although it supports two-finger-touch capabilities, the Android Version 1.6 variant currently running on the handset doesn't support multitouch functions. Sony Ericsson plans to offer an Android Version 2.1 upgrade for the entire Xperia X10 line by the end of the year. It also plans a variant of the "mini"-handset hardware design, currently code-named Yendo, with availability forecast by the end of this quarter. This version will dispense with Android and instead harness a Sony Ericsson-proprietary operating system.



The Xperia X10 mini's 2-Gbit NAND-flash memory, only half of which is user-accessible, comes from STMicroelectronics. The chip is a multidie stack; inside the package, you'll find not only the flash memory but also 2 Gbits of DRAM. MicroSD support enables Xperia X10 mini owners to somewhat augment the handset's built-in nonvolatile-memory capacity; the Android operating system currently allows only data storage—not application installation—on removable memory modules.

Qualcomm's chip set also comprises the PM7540 power-management IC and the RTR6285 UMTS (Universal Mobile Telecommunications System) HSPA (high-speed-packet-access) transceiver and AGPS (advanced global-positioning-system) receiver. Cellular-network-support options include GSM, GPRS (general packet-radio service), and EDGE (enhanced data rates for global evolution) at 850, 900, 1800, and 1900 MHz; UMTS HSDPA at 900 and 2100 MHz; UMTS HSDPA at 850, 1900, and 2100 MHz; and UMTS HSUPA at 850, 1900, and 2100 MHz.

The Xperia X10 mini offers IEEE 802.11b/g Wi-Fi as another wireless-connectivity option. Fueling all of the circuitry is a 3.7V, 950-mAhr lithium-polymer battery, which users cannot remove. Like the battery in Apple's iPhone 3GS, the Xperia's battery delivers approximately 53-mAhr/gram storage capacity.

The Design, Manufacturing, Assembly and Test Event for the Midwest's Electronics Industry

Electronics IPC Midwest

September 28–30, 2010
Donald E. Stephens Convention Center
Rosemont, IL (Adjacent to O'Hare Airport)

The Electronics Midwest Exhibition and Conference covers all aspects of electronics manufacturing, including:

- Components
- Subassemblies
- Software
- Contract Services
- Assembly
- Production Machinery
- Test and Inspection Products
- Printed Boards

...and much more

NEW!

Association Connecting Electronics Industries IPC

Conference, Courses & Standards Meetings

- Attend the IPC Conference on Innovation in Electronics and Design for Sustainability featuring sessions on hot topics such as Designing Electronics for Tomorrow and Manufacturing Electronics with Sustainability in Mind.
- Participate in IPC Standards Development Meetings where you can learn and contribute to the standards your customers, competitors, and suppliers rely upon.
- Attend Professional Development Courses featuring the industry's recently updated and most widely-used standards—IPC-A-600H, J-STD-001E and IPC-A-610E.

produced by Canon Communications LLC | Association Connecting Electronics Industries IPC

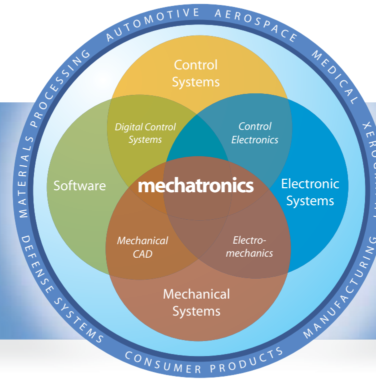
Register TODAY:
ElectronicsMidwest.com
Please use Promo Code AA to register.

15710_CH_EM10

Produced and Managed by Canon Communications LLC • 11444 W. Olympic Blvd., Los Angeles, CA, 90064-1549 • Tel: 310/445-4200 • cancom.com

MECHATRONICS IN DESIGN

FRESH IDEAS ON INTEGRATING MECHANICAL SYSTEMS, ELECTRONICS, CONTROL SYSTEMS, AND SOFTWARE IN DESIGN



Isn't there enough real inertia around?

Electronic inertia through acceleration feedback improves performance.

The word "inertia" in everyday use suggests resistance to change and an unwillingness to act. Inertia is hardly something you need in engineering practice to solve the urgent problems you face. Even in a motion-system context, the idea of adding inertia, or mechanical mass, to a system is not usually desirable because it slows system response. One familiar exception is adding a flywheel to an engine or a machine to smooth out speed fluctuations. Two of the most important benefits of feedback control are command following and disturbance rejection. The focus of attention in a control system is usually on command following, but the ability of a system to reject disturbances is paramount in many situations.

For a motor-velocity feedback-control system, increasing inertia reduces the high-frequency disturbance response—

For mechatronics engineers, adding inertia is desirable in one situation.

that is, it makes the system dynamically stiffer at high frequencies. However, it also degrades the closed-loop command following. How do you add inertia without degrading command-following performance?

A common industry motion-control system has cascaded feedback loops for motor current, velocity, and position. Newton's second law states that torque is proportional to angular acceleration. Thus, if you can measure or estimate acceleration, you can scale the acceleration by inertia, J, to give units of torque and then by $1/K_T$, the inverse of the motor-torque constant, to give current. You then multiply this result by a gain, K_{AFB}, and subtract it from the current command to the current-control loop. K_{AFB} has a similar effect in increasing inertia; hence, it has the alternative name "electronic inertia." To ensure that the command-following performance remains the same, you must scale the velocity-control gains by the same factor, $1+K_{AFB}$.

The value of K_{AFB} does not affect the velocity-command response because the loop gain increases in proportion to the inertia, producing no net effect. So, why add electronic inertia? The real benefit of acceleration feedback is that acceleration feedback through the entire frequency range improves the disturbance response in proportion to the term $1+K_{AFB}$ (**Figure 1**).

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

You cannot significantly realize this improvement above the bandwidth of the current loop because the acceleration-feedback signal cannot improve the system at frequencies in which the current loop cannot inject current. These cases require a robust acceleration-feedback signal. You can accomplish such a signal through differentiation of a position sensor signal and filtering or through the use of an observer.

For mechatronics engineers, adding inertia is desirable in one situation. In the virtual world in which we live, you almost expect electronic inertia. Peter Schmidt of Rockwell Automation and Robert Lorenz at the University of Wisconsin—Madison have done foundational work in this area, and you should consult their findings. For additional information, go to http://bit.ly/adSO1I. **EDN**

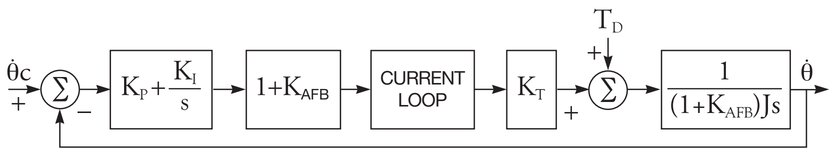


Figure 1 You realize the benefits of acceleration feedback when you scale up control-loop gains by the amount that the inertia increases—that is, by the factor $1+K_{AFB}$.

Visit the Mechatronics Zone for the latest mechatronics news, trends, technologies, and applications at http://bit.ly/kor7L.

Canon Communications LLC

Analog Devices: enabling the designs that make a difference in people's lives.

ADI's family of innovative smart meter solutions offers greater control, communication, and monitoring capabilities.

Measurement, processing, and communications solutions for intelligent energy systems. Optimizing the supply and demand for electricity is a goal we all share. At ADI, we provide data converter, amplifier, processor, and wired and wireless communications technologies to create leading-edge solutions for today's energy market. Our products give consumers precise, real-time smart meter information, enabling them to reduce energy consumption; utilities the ability to accurately monitor grid conditions, increasing system efficiency; and energy producers the ability to optimize solar and wind power generation, reducing fossil fuel dependence. For over 40 years, ADI has brought innovation and imagination to critical designs, including those that make our energy-sensitive world a better place. Learn more at *www.analog.com/energy*.

MAKEADIFFERENCE

www.analog.com

ANALOG DEVICES

BY TRITON HURD AND ISAAC SEVER • CYPRESS SEMICONDUCTOR

HARDWARE-CONTROLLED BRUSHLESS DC MOTORS EASE THE BURDEN ON CPUs

YOU CAN EMPLOY A HARDWARE-ONLY MOTOR-COMMUTATION SCHEME TO CONTROL MOTOR SPEED, FREEING THE SYSTEM CPU TO PERFORM FUNCTIONS SUCH AS RF COMMUNICATION AND DATA ENCRYPTION.

BLDC (brushless dc) motors have replaced other motors in applications ranging from air conditioners to remote-controlled cars, providing advantages in efficiency, reliability, and performance. The cost of BLDC motors has decreased dramatically over the last 10 years, causing their adoption rate to spike.

Controlling a BLDC motor is somewhat straightforward, and most microcontrollers can do it. However, in applications requiring a high revolutions-per-minute rate—for example, textile machines, remote-controlled cars, and industrial controls—the constant high-priority interrupts that increase in frequency as the speed of the motor increases can tax the CPU. That scenario would be OK if motor control were the microcontroller's only function. A better approach is to use a method of hardware-only motor commutation that offloads the CPU from the burden of maintaining a motor's speed, freeing it to perform other functions, such as RF communication, data encryption, or 3-D-position calculations.

When implementing a motor-control design, engineers can choose between fixed-function motor-control ICs and microcontrollers. In many designs, engineers choose microcontrollers because they provide flexibility and the ability to integrate a variety of other functions from the user interface, such as buttons, switches, and displays, to communication functions, such as UARTs (universal asynchronous receiver/transmitters) and SPIs (serial-peripheral interfaces). However, because of the high quantity and priority of interrupts necessary for controlling the motor, a motor-control microcontroller can implement only slow, non-CPU-intensive peripheral functions. If the end device requires functions such as data encryption, vector analysis, or other types of CPU-intensive features, you may have to use a faster and more expensive microcontroller or split the design into a dedicated microcontroller for the motor-control portion and another microcontroller for the other functions. This approach costs more in engineering time, board space, and overall BOM (bill-of-materials) expenses. As an alternative, you can employ a method of hardware-only motor control that offloads from the CPU these taxing periodic motor-control interrupts, freeing it to perform other functions and allowing full design integration into a single microcontroller. This method also lets you easily drive multiple motors at dif-

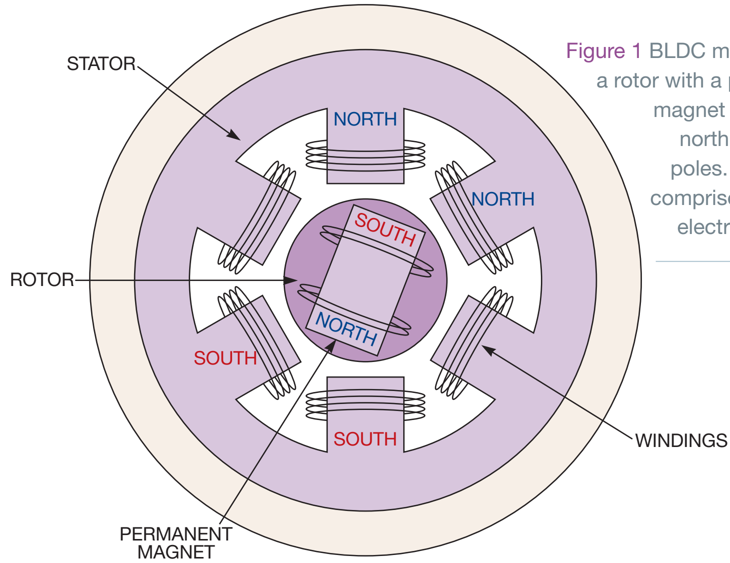


Figure 1 BLDC motors have a rotor with a permanent magnet containing north and south poles. The stator comprises multiple electromagnets.

ferent speeds, paving the way for BOM-expense reductions in applications requiring multiple motors that today use multiple dedicated microcontrollers.

To understand why BLDC-motor control is so prone to interruptions, consider how a microcontroller controls it. An electronically controlled BLDC motor requires you to energize the stator windings in a particular sequence (**Figure 1**). To implement this sequence, the control circuitry must know the rotor position. Sensor-controlled systems use sensors, such as Hall-effect sensors embedded in the motor stator; sensorless-control systems use back EMF (electromotive force). With Hall-effect-sensor-based systems, the rotor's magnetic poles pass near the Hall sensors, supplying a high or a low signal, indicating that the north or the south poles are passing nearby. The exact combination of the three Hall-sensor signals signifies the position of the rotor. Successively energizing stator windings with appropriate north and south poles keeps the motor turning (**Figure 2**).

A microcontroller rotates the BLDC motor by enabling and disabling external power devices that deliver current through the stator windings in the required sequence. Effective commutation requires that you energize the timing of the winding current in sequence with the rotation of the motor. For control of BLDC motors, a Hall sensor's change of state generates an interrupt, which indicates that the motor has rotated into the next commutation state. At this point, the CPU must determine which PWM (pulse-width-modulated) outputs to enable and disable based on the state it has just entered. The faster the motor is rotating, the more often the CPU interrupt will occur. The commutation-state interrupts must be high priority and have quick service to ensure smooth rotation and to maintain control of the speed of the motor.

Traditional six-step phase commutation requires six microcontroller service interrupts to complete one electrical cycle. Most motors contain multiple pole pairs around the circumference of the stator, requiring multiple electrical cycles and many more interrupts per rotation. This requirement increases the load on the processor and limits the maximum rotation speed.

In contrast, hardware-controlled commutation frees the processor to run other tasks, allows very-high-speed rotation, and enables higher levels of

AT A GLANCE

- BLDC (brushless dc) motors provide advantages in efficiency, reliability, and performance and have replaced other motors in a range of applications.
- Engineers can choose between fixed-function motor-control ICs and microcontrollers.
- Hardware-only motor commutation offloads from the CPU the burden of maintaining a motor's speed, freeing it to perform other functions, such as RF communication, data encryption, or 3-D-position calculations.
- You can directly map the various functions for controlling a BLDC motor in the resources of a microcontroller, creating hardware-only commutation.

Messe München International

24th International Trade Fair
New Munich Trade Fair Centre
09–12 November 2010

Time for embedded. Time for the future.

The entire range of key technologies and forward-looking innovations. Visit electronica and the embedded **Forum** and experience their incomparable significance to the entire industry—with today's solutions for tomorrow's applications.

Parallel event: hybridica. Trade fair for hybrid-component production. www.hybridica.de

get the whole picture

electronica 2010
embedded

www.electronica.de/embedded

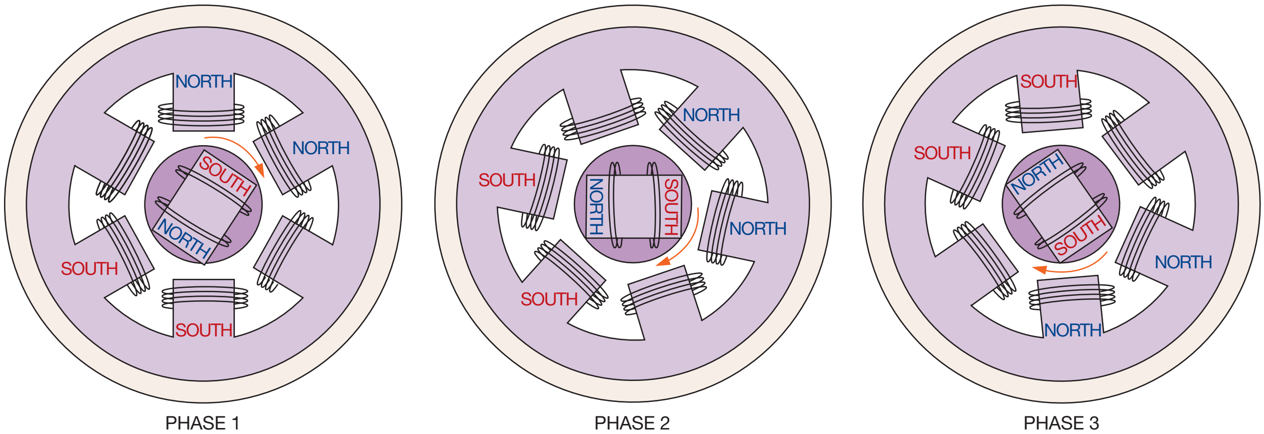


Figure 2 Control circuitry energizes windings in the stator to create north and south poles that attract and repel, respectively, south and north poles in the rotor.

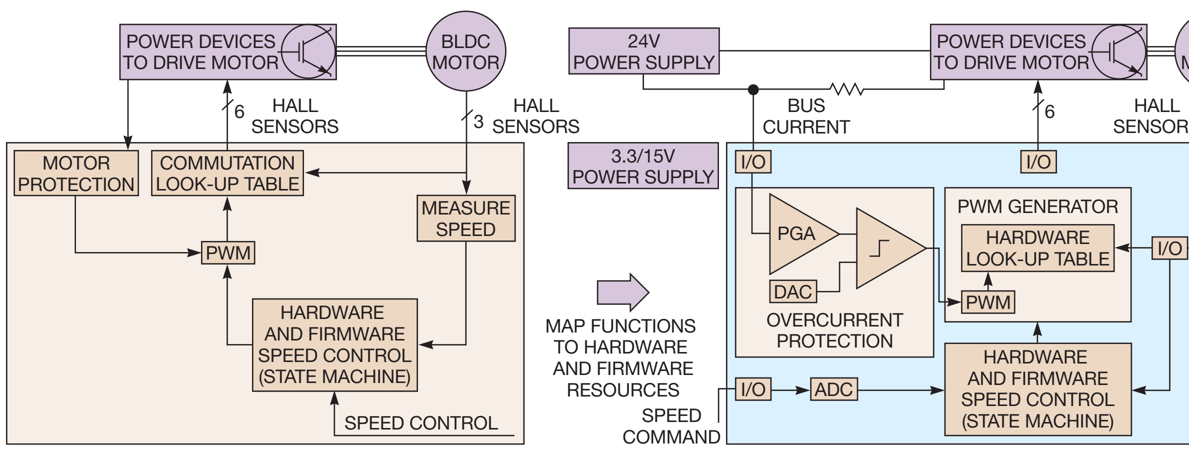


Figure 3 With hardware-controlled commutation, motor-control functions map into configurable analog and digital resources that avoid the involvement of the CPU.

integration of system functions into the microcontroller. In this implementation, the commutation functions that the CPU performs following each interrupt map into configurable analog and digital resources that control motor

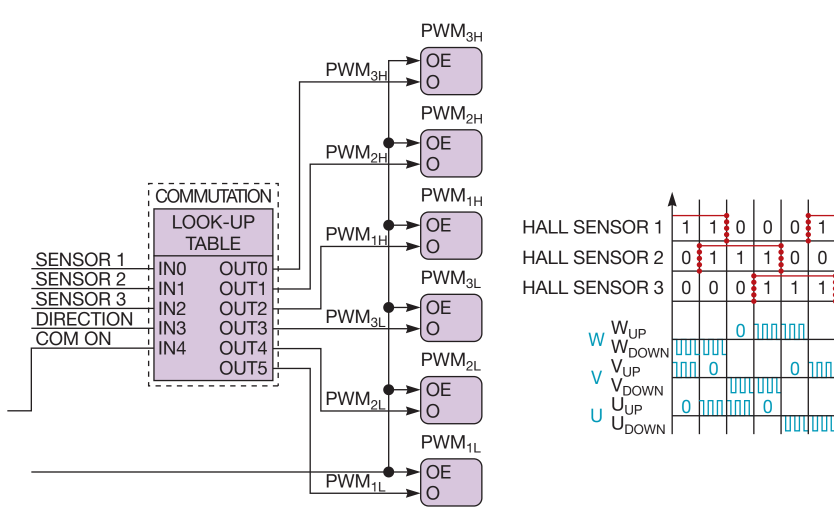


Figure 4 A hardware look-up table controls the commutation of the motor, creating the six PWM-control signals that route through GPIOs to the external power drivers.

rotation without involving the CPU. This step eliminates the interrupts and makes the motor-control function almost autonomous. This method is not possible in some cases. For example, you cannot use it in designs requiring more advanced control algorithms, such as sinusoidal or field-oriented control. **Figure 3** shows how you can directly map the various functions for controlling a BLDC motor into the resources of a microcontroller, creating hardware-only commutation.

You implement commutation control with configurable hardware resources, including a PWM, a hardware look-up table, and a hardware overcurrent-protection block. (You can view a schematic of a hardware-only BLDC-motor-control implementation in the Web version of this article at www.edn.com/100826df.) An integrated ADC measures a desired analog-speed-control input. Traditional designs execute commutation in firmware.

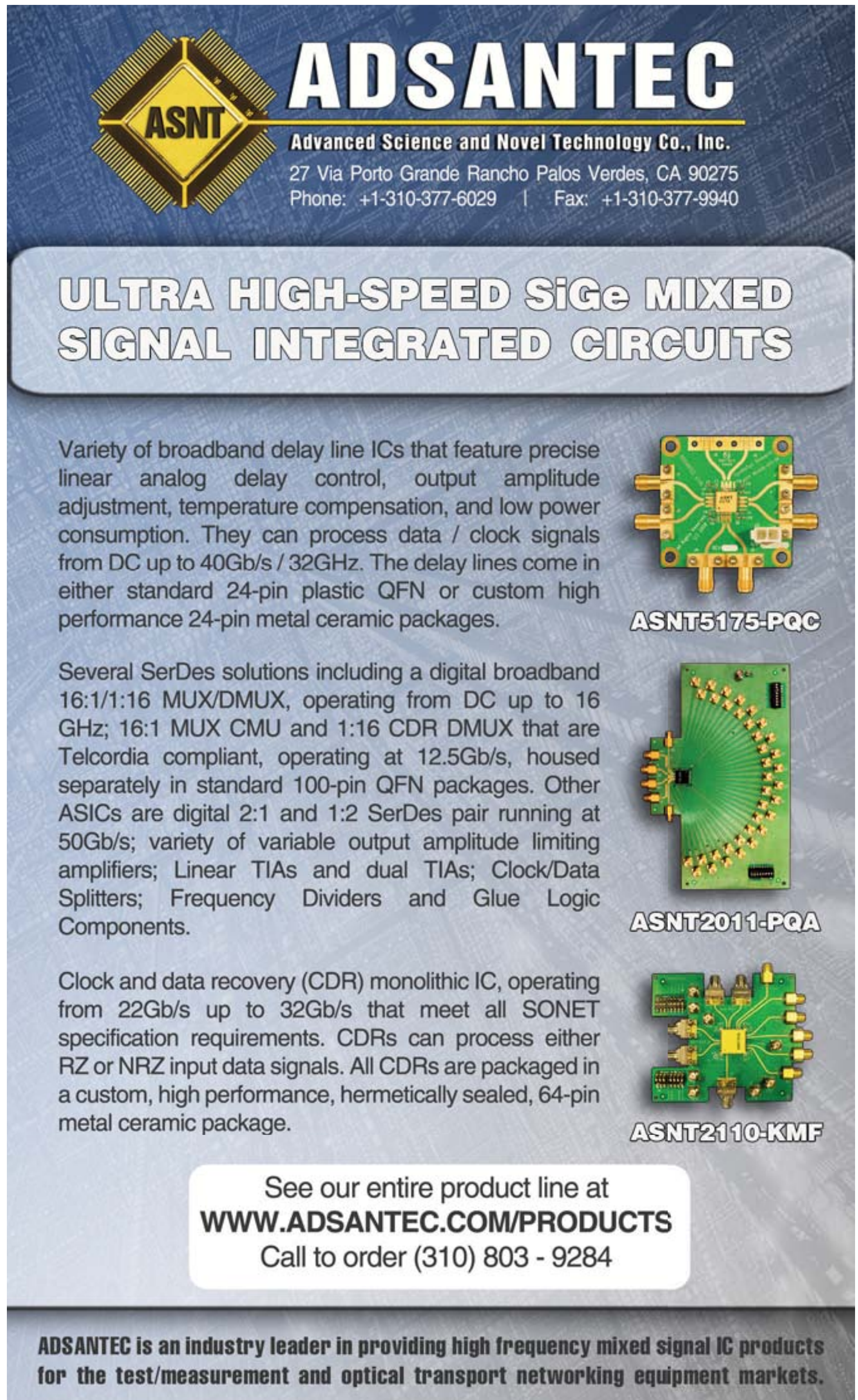
Input control signals to the hardware blocks include motor-current detection, which uses an analog input pin to detect and cut off the power-device driver to protect the motor when an overcurrent condition occurs. The signals also include three digital input pins that connect to the outputs of the Hall-effect sensors from the motor. These sensors provide the position of the rotor and control the commutation by varying the PWM's output signals to the power driver.

The design has three user-interface-control inputs: direction control, which comprises a digital input that connects to a switch to control the motor's clockwise and counterclockwise rotation; start/stop control, which comprises a digital input that connects to a switch to start and stop rotation of the motor; and speed command, an analog input pin that measures the voltage across a potentiometer to set the desired speed of rotation. Outputs from the motor controller include PWM signals to both the high and low sides of the power-device driver.

The circuit generates a PWM reference signal and routes it to a hardware combination-logic block, along with the three Hall-effect-sensor inputs and motor-direction and -enable controls. This logic block, a look-up table using PLD (programmable-logic-device) resources, creates the six PWM-control signals for routing through GPIOs (general-purpose inputs/outputs) to the external power drivers. **Figure 4** shows the configuration of the look-up table. A firmware-proportional-integral speed-control loop adjusts the duty cycle of the PWM output. Speed adjustment is the only function of motor control that the CPU needs to be involved in. However, this function is not taxing because the speed-control loop can be run at a much slower rate, and it need not be a high-priority interrupt.

The sequencing of the PWM-control signals to the external power drivers produces motor commutation. The PWM includes dead banding to prevent the enabling of wrong coils at the same time during signal transitions and creating unwanted shoot-through current. A timer with a hardware capture measures the rotation speed. The timer triggers from a rising edge of a Hall sensor, and the rotation speed is stored in a register that the firmware speed-control loop can read when necessary.

You can also fully implement overcurrent detection in hardware for fast and low-cost motor protection (**Figure 5**). R_1, a shunt resistor in the ground path of the power-inverter module, measures motor current. This voltage is level-shifted on the board and connects to the analog input, or current, pin on the microcontroller. The input voltage feeds into an internal PGA (programmable-gain amplifier) that multiplies the difference between the input voltage and the reference voltage, a buffered voltage at half the analog supply, and connects the output to a compar-



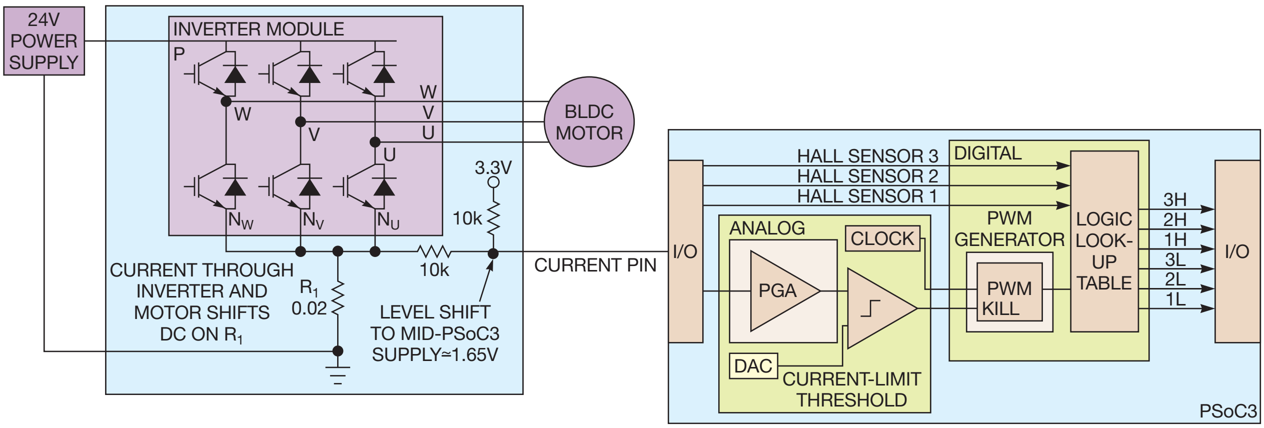


Figure 5 Hardware-implemented overcurrent detection provides fast and low-cost motor protection in a three-phase-motor, high-voltage power-module board (left). A comparator kills the PWM output when a current-detection input voltage is over the current-limit threshold that the DAC sets (right).

ator. The circuit compares the voltage level to the current limit. An 8-bit voltage DAC sets the current-limit value in a register and converts it to an analog voltage. The comparator output connects to the hardware kill input of the PWM and kills the PWM output when the current exceeds the limit threshold. This function provides cycle-by-cycle current limiting to the BLDC motor.

To configure overcurrent protection for a desired current limit, you must select values for the resistor and the current-limit threshold. The value of the overcurrent-detection shunt resistor represents a trade-off between head room for the motor operation and robustness of the detection blocks. For a given current limit, the motor current must generate enough change in voltage to accurately detect the change with the comparator. However, increasing the resistor increases the ground voltage of the inverter and reduces the head room to drive the motor.

The current-limit threshold is equal to $R \times G \times I + V_{REF}$, and the resistor equals $(THRESHOLD - V_{REF})/G \times I$, where G is the gain of the PGA, I is the desired current limit, and V_{REF} is the level-shifted reference voltage. For example, one application needs a 2A overcurrent-protection limit, shunt resistor R_1 has a value of 0.02Ω, and the PGA has a gain of eight. These values yield a current-threshold voltage of $0.02\Omega \times 8 \times 2A = 320$ mV$+V_{REF}=320$ mV$+1.65V=1.97V$. You use an internal 8-bit DAC to generate this voltage.

Implementing BLDC-motor control in hardware offers many benefits stemming from the reduced processing requirement of the CPU. Hardware control leaves the CPU free for other system-processing tasks, reducing the peak processing requirements of the full motor system and resulting in lower system power and cost. It also makes the motor-control design mostly autonomous and essentially a drag-and-drop function. It even makes it possible to control multiple independently operating motors with one microcontroller. This task requires high-performance microcontrollers without hardware commutation, which would cause two motors to simultaneously interrupt the CPU. This interruption would in turn cause one motor to see a delay in the updating of its PWM configuration if the response were too slow and would cause the motor to run unevenly. An 8-bit, 8051-based Cypress PSoC (programmable system on chip) 3 can control as many as six independent BLDC motors with sensors in hardware, leaving the microcontroller free to run other system tasks. The motors have independent hardware-commutation logic and fully independent speed control. Although this feature is possible without hardware commutation, it is not possible with an 8-bit microcontroller because its response time is too slow. However, you need to implement firmware commutation if your application requires more advanced control algorithms, such as sinusoidal or field-oriented control.

Using a microcontroller to control both the motor and the user-interface functions can yield large cost savings. Take, for example, an in-wall air-conditioning unit with a condenser motor, an air-blowing motor, and an oscillating air-direction motor. It also has buttons, a display, and an infrared remote control. Multiple microcontrollers on multiple boards previously would have had to perform most of these functions. With hardware commutation, however, one microcontroller could potentially integrate these functions, resulting in a major cost reduction. Some products cannot have a microcontroller controlling both functions, however, because the motor resides in a different location from the buttons or display. EDN

AUTHORS' BIOGRAPHIES

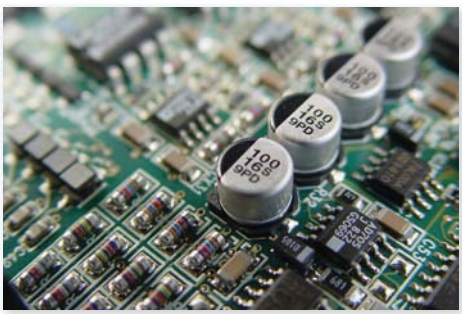
Triton Hurd is an applications engineer on the senior staff at Cypress Semiconductor (San Jose, CA). His responsibilities include project management for system-management control for the PSoC line. Hurd has a bachelor's degree in electrical engineering from California State Polytechnic University (San Luis Obispo, CA). In his free time, he enjoys snowboarding, biking, and throwing epic parties in San Francisco.

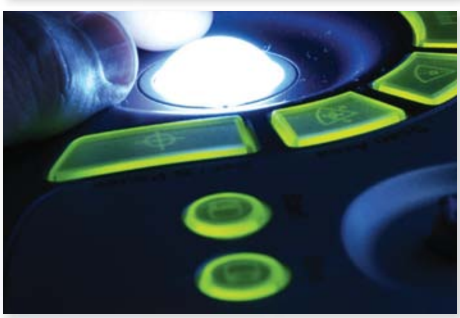
Isaac Sever is a systems engineer on the senior staff at Cypress Semiconductor (San Jose, CA). His responsibilities include system development for the PSoC-platform group. Sever has a bachelor's degree in electrical engineering from the University of California—Davis and a master's degree in electrical engineering from the University of California—Berkeley. In his free time, he enjoys spending time with his family, jogging, and reading.

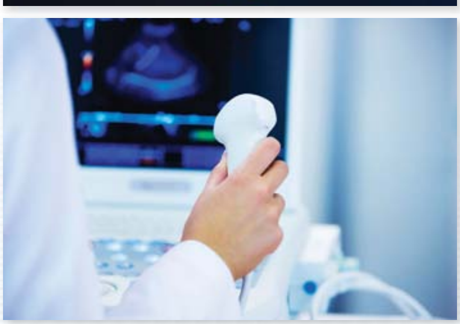
The New Resource Dedicated Exclusively to Designers and Developers of Medical Electronic Devices

DesignMED
Emerging Technologies for Medical Electronic Devices

CONFERENCE & EXPOSITION
February 8-10, 2011
Anaheim Convention Center
Anaheim, CA







Meet hundreds of the nation's leading suppliers presenting the latest in emerging technologies that can be incorporated into the next generation of medical electronics, including:

- Analog ICs
- Applied Systems
- Communications & Networking Devices
- Components
- DSPs
- EDAs
- Graphics/Graphics-Interface ICs
- Memory & Storage
- Microcontrollers & Processors
- Power
- Processors & Tools
- Programmable ICs
- RF
- Semiconductor Processes & IP
- Software
- Test & Measurement...*and much more!*

Supported by:
MED Medical Electronics Design
EDN
design news
Qmed

Co located with:
Medical Design & Manufacturing® MD&M WEST
Electronics® WEST

Produced and managed by:
Canon Communications LLC
cancom.com

Your Project Acceleration RESOURCE

For more information on attending or exhibiting, please visit
DesignMedWest.com
Submit your registration request online today. Please use Promo Code: AA

16401_W_DMD11

NEW POWER REGULATIONS
BRING POWER-FACTOR CORRECTION TO LOWER-POWER SUPPLIES

BY MARGERY CONNER • TECHNICAL EDITOR

Until recently, power factor and PFC (power-factor-correction) circuits were of concern only for utilities and manufacturers of motors. Utilities have for years specified the power-factor performance of large inductive motors. The utilities also generally can charge industrial customers for reactive-power consumption. However, residential customers are starting to introduce more reactive-power loads into the mix as energy-efficient lights, such as CFLs (compact fluorescent lights) and LED-based lights containing their own ac/dc lighting ballasts, begin to emerge. As a result, power factor has moved from the realm of large-scale industrial motors down to that of consumer electronics.

WITH THE INTRODUCTION OF NEW POWER-SUPPLY SPECIFICATIONS FROM ENERGY STAR, COMPUTER POWER SUPPLIES AS LOW AS 75W AND SOLID-STATE LIGHTS AS LOW AS 5W MUST MEET MINIMUM POWER FACTORS, MAKING POWER FACTOR A CONCERN FOR MOST ELECTRONIC EQUIPMENT THAT USES AC-LINE POWER.

Power factor is the ratio of real power to apparent power. When both current and voltage are sinusoidal and in-phase, the power factor is one. If they are sinusoidal but not in-phase, then the power factor is the cosine of the phase angle. Purely sinusoidal current and voltage waveforms occur when the load comprises resistive, capacitive, and inductive elements that are all linear.

In a purely resistive load, real power is the same as apparent power, and the power factor is one. When the load has inductance or capacitance, however, the apparent power is less than the real power because the capacitance and inductance introduce a phase lag between the current and the voltage. Although utilities currently charge residential customers only for the real power they consume, the utilities must add power to support the out-of-phase current and voltage. The additional power is wasted in the form of resistive losses on the grid's transmission lines. Because these losses increase as the square of the current increases, losses due to low power factor can quickly add up.

The ac line sees an SMPS (switched-mode power supply) as a nonsinusoidal, nonlinear impedance (**Figure 1**). **Figure 2** shows the voltage and current for the circuit of **Figure 1**. To more closely follow the input voltage and avoid

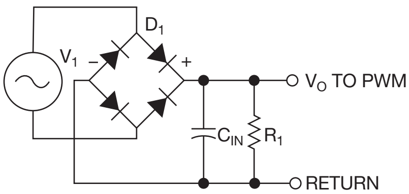


Figure 1 The SMPS presents a nonlinear load to the ac-power line.

sharp current spikes, the capacitor must charge over the entire positive portion of the cycle. In addition to upping the power factor closer to one, this shaping of the current allows for the use of a smaller capacitor and avoids the creation of harmonic noise, thus reducing THD (total harmonic distortion). This compensating additional circuitry is the PFC circuit. Energy-efficiency specifications regulate both THD and power factor as part of the power-factor specification.

Note that PFCs decrease rather than increase power-supply efficiency. "Power-supply designers are only moving to incorporating improved power factor in their supplies because of government mandates," says Steve Mappus, a systems engineer in the High Power Solutions group at Fairchild. The utility companies are the immediate beneficiaries of improved power factor, but consumers benefit downstream because utilities need not build additional power plants, holding pollution and carbon emissions in check.

Many topologies and approaches exist for enabling PFC (see **sidebar** "Utilities and PFC"). In general, PFC is either passive or active. Government and industry regulations specify only the power factor and the THD, leaving the decision about whether to use a passive or an active circuit to the design engineer (**tables 1** through **3**).

Passive PFC is a simple, relatively inexpensive approach, but it has drawbacks. Chief among them is that it's difficult, although not impossible, to get a power factor of more than 0.7, and the trend in global regulations is toward power factors of 0.9 and higher. Another difficulty with passive PFC is that the capacitors go directly on the ac line, necessitating capacitor ratings of 400V or higher. This requirement makes the use of electrolytic capacitors the most common approach. Electrolytic capacitors' lifetime drops with higher temperatures, so you must derate the capacitor if your system will need to work in a hot environment. To derate it, you must either choose a higher temperature, more-expensive capacitor or allow for a shorter capacitor lifetime. Another drawback with passive PFC

AT A GLANCE

- Agencies such as Energy Star and Climate Savers are setting power factors for relatively low-power consumer devices and computer servers.
- PFC (power-factor correction) does not improve a supply's efficiency.
- Digital PFC is becoming a cost-effective design approach, especially for designs already containing a DSP or a microcontroller.

TABLE 1 CLIMATE SAVERS CRITERIA FOR MULTI-OUTPUT POWER-SUPPLY UNITS

	Bronze Level		Silver Level		Gold Level	
Loading condition (%)	Efficiency (%)	Power factor	Efficiency (%)	Power factor	Efficiency (%)	Power factor
20	82	0.8	85	0.8	87	0.8
50	85	0.9	88	0.9	90	0.9
100	82	0.95	85	0.95	87	0.95

Source: Climate Savers, www.climatesaverscomputing.org/tech-specs

TABLE 2 LED-LIGHTING POWER-FACTOR CRITERIA

Equipment	Power factor
Solid-state-lighting luminaires	
Residential	≥0.7
Commercial	≥0.9
Integral LED lamps	≥0.7

Sources:
http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/lighting/ESIntegralLampsCriteria_Draft1.pdf
http://www.energystar.gov/ia/partners/product_specs/program_reqs/SSL_prog_req_V1.1.pdf

TABLE 3 ENERGY STAR POWER-FACTOR REQUIREMENTS FOR COMPUTER-SERVER POWER SUPPLIES

		10% load		20% load		50% load		100% load	
Type	Rated output power	Power factor	Efficiency (%)	Power factor	Efficiency (%)	Power factor	Efficiency (%)	Power factor	Efficiency (%)
AC/DC multi-ouput	All output levels	NA	N/A	0.8	85	0.9	88	0.95	85
AC/DC single-output	≤500W	NA	80	0.8	88	0.9	92	0.95	88
	500 to 1000W	0.65	80	0.8	88	0.9	92	0.95	88
	>1000W	0.8	80	0.9	88	0.9	92	0.95	88

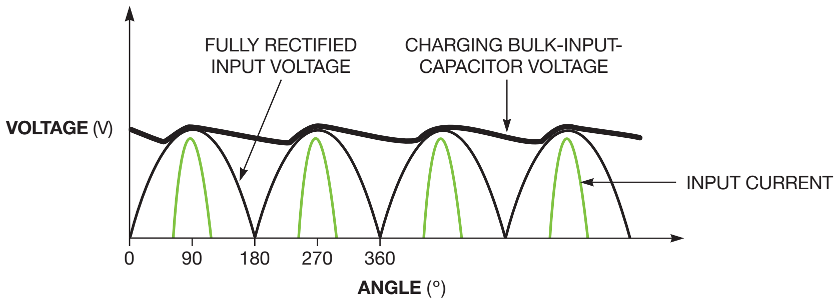


Figure 2 Superimposing the current over the voltage for the circuit in Figure 1 shows the need for a PFC to shape the current.

is that its voltage output is unregulated as it feeds into the dc/dc-conversion stage. For these reasons, the trend is toward active PFC, usually in the form of a boost-converter circuit between the bridge rectifier and the storage capacitor.

The most common configurations for an ac/dc power supply with PFC are two-stage and single-stage designs. In a two-stage design, the ac line feeds into an ac/dc converter, usually comprising a bridge rectifier feeding into a capacitor whose output is usually full of second-harmonic ripple. A dc/dc converter follows the ac/dc converter to provide electrical isolation and voltage regulation. This approach keeps the two stages separate, is easy to troubleshoot, and is simple. However, the double conversion is less efficient, and costs are higher because of the need for two stages. As PFC becomes more prevalent, single-stage PFC is becoming more common.

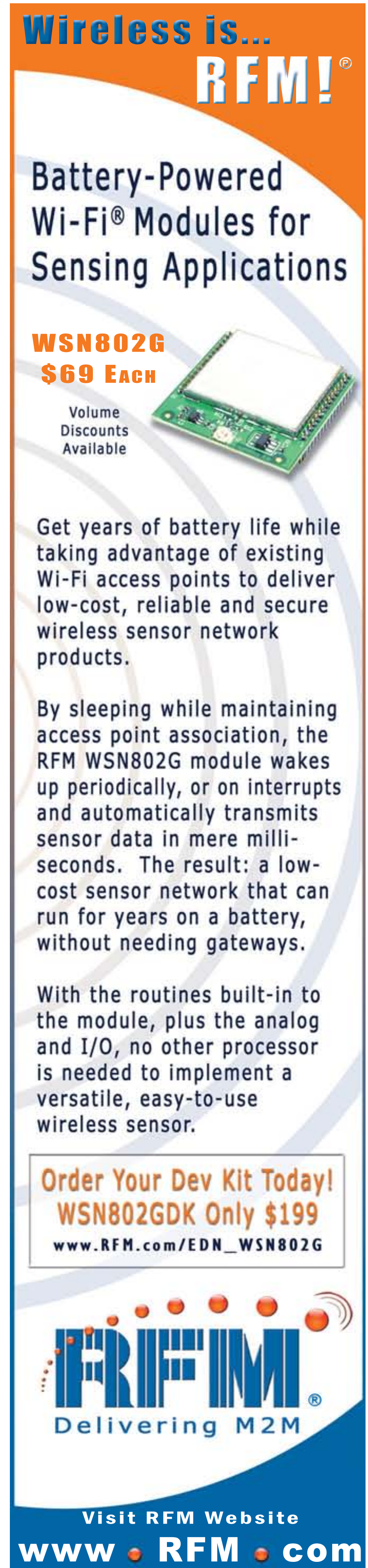
Kishore Manghnani, vice president of Green Technology for Marvell, argues that single-stage power-converter/PFC ICs are the best design approaches for LED lighting. "With two-stage you end up using two separate chips—one for PFC and the other for the LED-driver circuit, which includes dimming and the TRIAC [triode-alternating-current-switch] interface," he says. "In a single-stage converter/PFC chip, you need no additional components: You put the LED driver and the PFC all in one chip." You might wonder whether you can use cheaper passive PFC, given that cost is a pacing item in LED lighting, but Manghnani advises against this approach. "The biggest advantage of active PFC is that you can use a low-voltage capacitor," he says. "In passive PFC, the capacitor must support 400V. In the active single-stage [approach], the capacitor is only 40V. Plus, the lifetime of the capacitor [for the same cost] could be four to five times longer."

Currently, Energy Star's draft proposal for energy-efficient luminaires calls for a power factor of 0.7 in residential lighting and 0.9 in commercial, but Marvell argues that the power factor for LED lighting should be 0.9 for all lights with wattage higher than 5W, which is currently the specification in Europe and Korea. "The United States is a bit behind in this area," Manghnani says. "Europe and Korea require lighting power to be more than 0.9. It doesn't cost anything extra, so why not add it?"

The mandate for minimum power-factor requirements comes at the same time as the industry is imposing increasingly tight efficiency standards on power supplies, causing a double whammy on designers, who must strive for more stringent efficiencies as power factor creeps up. Thus, research is ongoing on the most efficient ac/dc-converter/PFC circuits. It's important to understand the general categories for control and which power-supply types these methods can work with. A brief overview of active-PFC methods follows. For more information and circuit diagrams, see **references 1** and **2**.

The main control methods for active-PFC circuits are DCM (discontinuous-conduction mode), CCM (continuous-conduction mode), and CRM (critical-conduction mode). Various chip manufacturers have their own versions of CRM control, such as BCM (boundary-conduction mode) and TM (transition mode). "Current conduction" in these terms refers to the inductor current.

Low-power supplies typically use DCM. CCM works for all power levels but involves a hard reverse recovery of the output diode when the MOSFET switch turns on. This recovery can



cause high losses in a standard inexpensive diode. For high efficiency, therefore, you must use a more expensive diode, such as one made from silicon carbide.

In contrast, BCM circuits switch on the MOSFET with no current in the diode, allowing you to use inexpensive output silicon rectifiers. The trade-offs are that BCM uses a more complex variable-switching-frequency scheme, and its higher peak currents result in higher losses at higher power, limiting most BCM designs to less than 300W. At higher power levels, the CCM boost is more effective due to its lower ripple currents that result in lower peak currents and lower differential-mode EMI (electromagnetic interference).

However, recent innovations in converter/PFC design interleave multiple-phase BCM-controller ICs, such as those from Fairchild, On Semiconductor, and Texas Instruments. Interleaved designs parallel two or more BCM power stages, allowing your design to reach 1 kW or more and reducing the ripple current in the output, which allows for smaller inductors. "If you look at the costs of the controller in comparison to the costs of the PFC, which includes the inductor and all the power components, the controller is not a significant cost," says Jim Aliberti, product-marketing engineer at Texas Instruments. "It's the magnetics. People are looking for a way to reduce the costs, and inter-

UTILITIES AND PFC

According to Ken Lau, consulting engineer for PG&E (Pacific Gas and Electric), a California electric utility, the utilities perform PFC (power-factor correction) by switching in banks of capacitors at preset times. In a residential area, you can expect a surge in power use at about 7 a.m., so the substation automatically switches in a capacitor bank at that time, switching it out after 8 a.m. No communication or real-time adjustment is necessary for this type of correction. In five to 10 years, however, many houses will have their own photovoltaic installations or perhaps even wind turbines, so the smart grid will be able to communicate with each house's power-subsystem inverter to perform PFC on the fly.

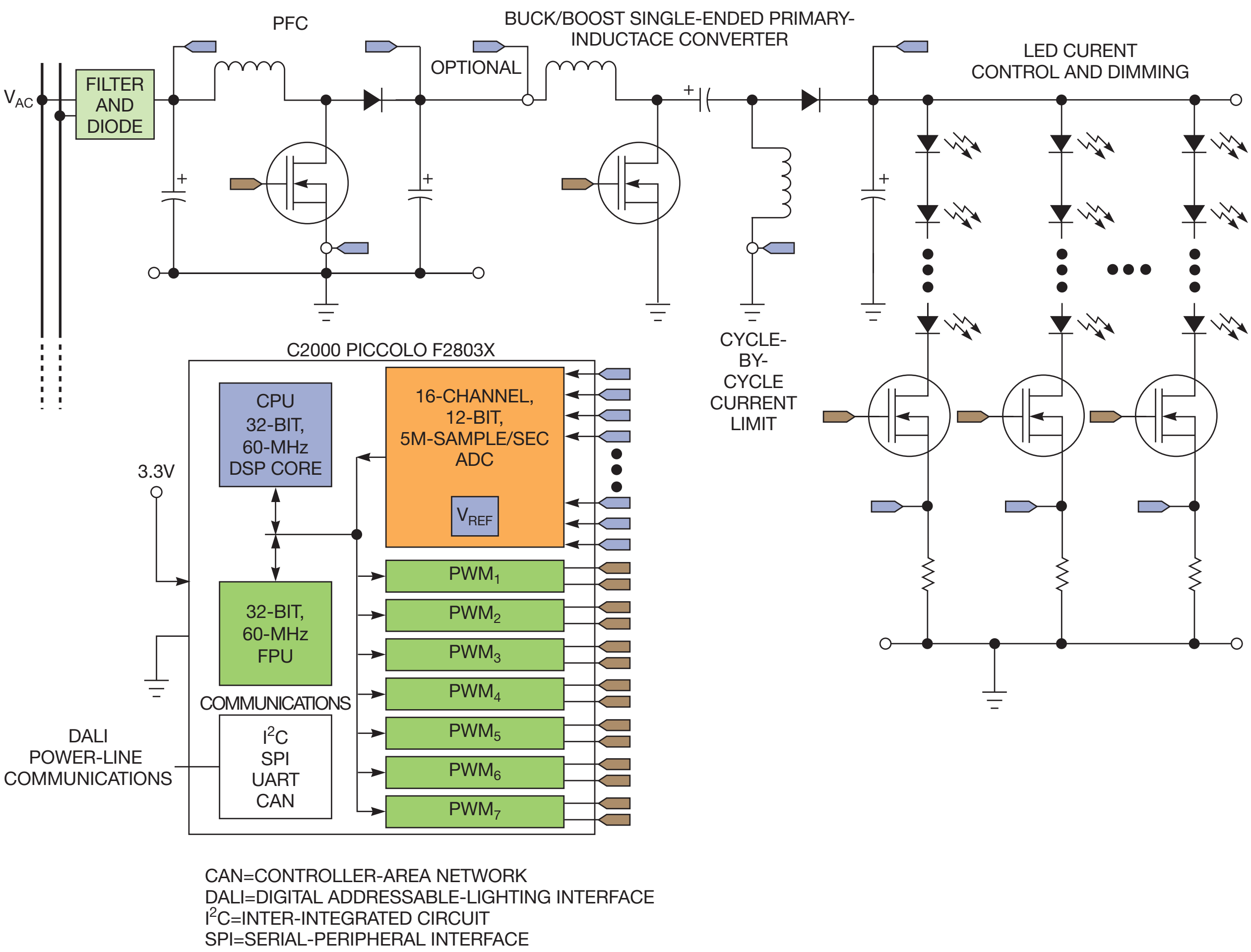
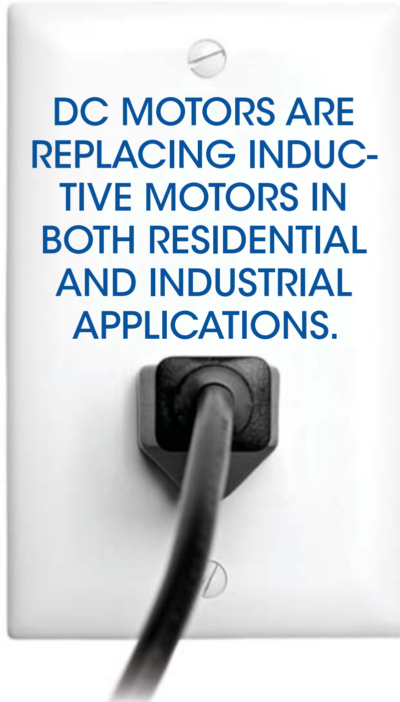


Figure 3 A microcontroller performs PFC by controlling the current so that it is sinusoidal and in-phase with the input voltage. The TI C2000 uses one control loop at 100 kHz to keep this input current sinusoidal and uses a second, slower control loop to keep the output voltage stable. The C2000 has sufficient CPU bandwidth to perform this task and multiple others for the system.

leaved design has enabled lower system costs because you don't have to process as much ripple current, allowing you to use smaller magnetics."

As with most power-conversion applications, digital power is making inroads into PFC, as well. For example, Cirrus Logic offers an IC for digitally controlled PFC. The active-PFC CS1500 and CS1600 DCM ICs target use in power supplies requiring as much as 300W. The CS1500 addresses power supplies for applications such as laptops, digital TVs, and PCs, and the CS1600 targets electronic-lighting ballasts. At approximately 30 cents (high volumes), the chips compare in price with analog PFC ICs but use 30% fewer additional components and fewer parts for EMI filtering. The power factor, which varies with the input line voltage and the load, is greater than 0.95. The iW3620 LED driver from iWatt is also a digital single-stage, active-PFC device. Texas Instruments offers a development kit for high-voltage PFC, which includes hardware and software to implement two-phase interleaved digital PFC for regulation compliance. The kit can work with the company's application-development kits for the C2000 Piccolo microcontrollers, such as the C2000 ac/dc developer's kit, as well as end-product kits, such as motor-control and LED-lighting-control kits.

Providing efficiency of as much as 30% in applications such as air conditioners and refrigerators, dc motors are replacing inductive motors in both residential and industrial applications. Because of their complex control algorithms, most dc-motor controllers use a DSP. Designers can add digital PFC to designs that already have a DSP—often with no additional components. The cost in engineering learning time can be considerable, though, which is why TI offers its DSP-developer kits for several applications. The digital-PFC kit can work to provide a PFC block for a DSP-motor controller. Another likely application for digital PFC is LED lighting. For example, a DSP such as the C2000 can run PFC in addition to powering an LED array (**Figure 3**).



Do you remember the advertising push several years ago for the smart refrigerator that would track when you were low on milk and autonomously order more? That idea didn't catch on. Perhaps the more likely intelligence will be a DSP that controls all of the power-efficient function of home appliances. EDN

REFERENCES

1. "Power Factor Correction (PFC) Basics," Fairchild Semiconductor, 2004, www.fairchildsemi.com/an/AN/AN-42047.pdf.
2. *Power Factor Correction Handbook*, On Semiconductor, September 2007, www.onsemi.com/pub_link/Collateral/HBD853-D.PDF.

FOR MORE INFORMATION

Cirrus
www.cirrus.com

Climate Savers
www.climatesaverscomputing.org

Energy Star
www.energystar.gov

Fairchild Semiconductor
www.fairchildsemi.com

iWatt
www.iwatt.com

Marvell
www.marvell.com

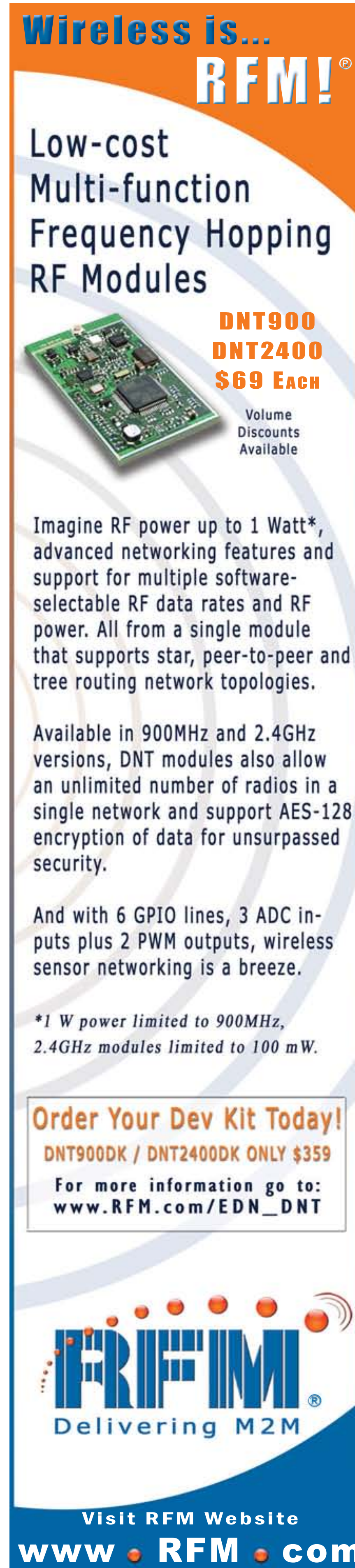
National Semiconductor
www.national.com

On Semiconductor
www.onsemi.com

PGE
www.pge.com

STMicro
www.st.com

Texas Instruments
www.ti.com



BY HEINZ MATHIS • INSTITUTE FOR COMMUNICATION SYSTEMS, UNIVERSITY OF APPLIED SCIENCES

Architecture combines low- and zero-IF receivers

A SWITCH-MATRIX MIXER PROVIDES THE DOWNCONVERSION FUNCTION IN THIS NOVEL RADIO.

Low-IF (intermediate frequency)-receiver architectures are increasingly popular for many wireless standards. You can detect the signal at the IF or downconvert it to baseband after the ADC stage. This circuit does the final downconversion using a switch-matrix mixer before the analog-to-digital conversion. You use analog filters following the mixer stage. This approach reduces the dynamic range the following ADC stage requires. By doing simulations and taking measurements on a prototype, you can investigate the effect of nonideal switches in the matrix.

Before delving into the details, you should understand the history of this architecture. The superheterodyne receiver has for decades been the architecture of choice because it provides excellent receiver properties, such as selectivity and sensitivity. The architecture does not easily lend itself to integration, however, because you must implement the image-rejection filters in a discrete circuit.

Direct-conversion, or zero-IF, receivers have recently gained importance (**Reference 1**). This architecture is appropriate for integration, but it causes other problems. A direct-conversion architecture has dc-offset problems that necessitate a dc-nulling strategy (**references 2** and **3**). In body-worn radio equipment, the antenna's impedance matching changes frequently. In this case, it is difficult to build a well-behaved dc-nulling circuit. Furthermore, modern high-speed modulation schemes must have a continuous baseband spectrum without gaps.

To avoid this problem, you can build low-IF, or quasi-direct-conversion, receivers (**Reference 2**). The desired signal bandwidth after a low-IF-conversion step is on either the positive- or the negative-frequency side, but it does not include any dc part of the spectrum. You can then ac-couple the subsequent ADC.

The final downconversion to baseband usually takes place in the digital domain. You multiply the complex signal with a rotating phasor. Choosing a low IF that is one-quarter of the sampling frequency eases these operations by reducing the number of multiplications to those for swapping samples and changing their signs every other time.

To illustrate this approach, you denote the incoming signal at low IF as s(t) and mix down the signal with frequency f_{LO} (**Equation 1**):

$$\tilde{s}(t)=s(t)\times e^{-j2\pi f_{LO}t}. \tag{1}$$

You then sample **Equation 1** with a sampling frequency f_S of $1/T_S$:

$$\tilde{x}(t)=\sum_{k=-\infty}^{\infty} s(KT_S)\times e^{-j2\pi f_{LO}kT_S}. \tag{2}$$

You choose f_{LO} to satisfy **Equation 3**:

$$f_{LO}=\frac{f_S}{4}=\frac{1}{4T_S}. \tag{3}$$

Equation 2 then results in **Equation 4**:

$$\begin{aligned}\tilde{x}(t)&=\sum_{k=-\infty}^{\infty} s(kT_S)\times e^{-j\frac{\pi}{2}k}\\ &=\sum_{k=-\infty}^{\infty} s(4kT_S)-j\sum_{k=-\infty}^{\infty} s((4k+1)T_S)\\ &-\sum_{k=-\infty}^{\infty} s((4k+2)T_S)+j\sum_{k=-\infty}^{\infty} s((4k+3)T_S).\end{aligned} \tag{4}$$

If you represent signal s(t) in its I/Q (in-phase/quadrature) form as a real and an imaginary part, you can rewrite **Equation 4** as **Equation 5**:

$$\begin{aligned}\tilde{x}(t)=&\sum_{k=-\infty}^{\infty}\Big[\mathrm{Re}(s(4kT_S))+\sum_{k=-\infty}^{\infty}\mathrm{Im}(s((4k+1)T_S))-\sum_{k=-\infty}^{\infty}\mathrm{Re}(s((4k+2)T_S))-\sum_{k=-\infty}^{\infty}\mathrm{Im}(s((4k+3)T_S))\Big]\\ &+j\Big\{\sum_{k=-\infty}^{\infty}\Big[\mathrm{Im}(s(4kT_S))-\sum_{k=-\infty}^{\infty}\mathrm{Re}(s((4k+1)T_S))-\sum_{k=-\infty}^{\infty}\mathrm{Im}(s((4k+2)T_S))+\sum_{k=-\infty}^{\infty}\mathrm{Re}(s((4k+3)T_S))\Big]\Big\}.\end{aligned} \tag{5}$$

This form represents the switching function. The major drawback of this technique is if only real analog filters are applied before the analog-to-digital conversion, the ADCs must have a high dynamic range. Wireless-communication equipment has adjacent-channel rejection on the order of 70 dB. In this case, the adjacent channel is the image frequency corresponding to the negative frequency of the desired signal. The ADC must provide more than 12 bits of dynamic range, including the possible signal dynamics of nonconstant envelope-modulation schemes. These ADCs are expensive, and they consume a lot of power.

A possible approach is to apply polyphase filters, which can separately filter the negative and positive frequencies (**Reference 4**). This approach increases the circuit's complexity for a given order of filters because the coefficients of such filters are both real and imaginary.

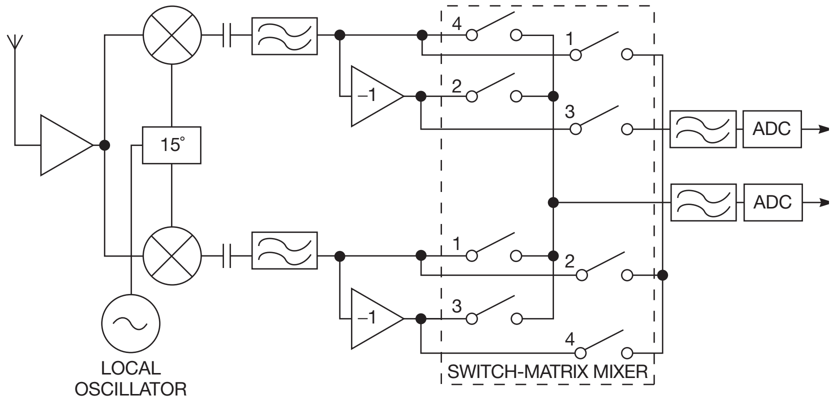


Figure 1 A switch-matrix mixer changes a low-IF architecture into a zero-IF receiver.

Downconverting the signal from low IF to zero IF before filtering and analog-to-digital conversion eliminates the need for polyphase filters and still uses an ADC with reduced dynamic range.

ARCHITECTURE AND CIRCUIT

You can use switches as mixers in downconversion architectures by assuming that you have both the inverse and the noninverse of the real and imaginary parts of the signal (**Reference 5**). The switch-matrix mixer comprises eight switches operating in four phases that feed the four signals, I+, I–, Q+, and Q–, to the input of a subsequent filter. You can implement the matrix with transmission-gate FET switches. The equivalent operation of these switches is mixing by one-fourth of the sampling frequency (**Equation 6**):

$$f_{LO}=-\frac{F_S}{4}. \tag{6}$$

You insert the switch matrix into the receiver chain (**Figure 1**). The numbers assigned to the switches denote the phases when they are closed. You drive the switches with phase-shifted signals (**Figure 2**). The switching function, G(t), applies the mixing process to signal s(t) (**Equation 7**):

$$\tilde{s}(t)=s(t)\times G(t). \tag{7}$$

The switching function, G(t), has some harmonics, requiring you to apply some filtering after the mixing process (see **sidebar** "Fourier coefficients of a switch-matrix mixer," available with the Web version of this article at www.edn.com/ms4373). You can combine this filter with the ADC's antialiasing filter.

A low-IF-receiver architecture has adjacent channels in the negative-frequency range of the desired signal (**Figure 3**). A real antialiasing filter can filter out only adjacent Channel 2. Adjacent Channel 1 is the image of the desired channel and passes through the antialiasing filter without attenuation. The antialiasing filter must be good enough to prevent aliasing from adjacent Channel 2. The ADCs require a dynamic range greater than 70 dB.

The addition of the switch-matrix mixer moves the desired signal into the baseband (**Figure 4**). The antialiasing filter must filter out not only the adjacent channels but also the mixing terms from

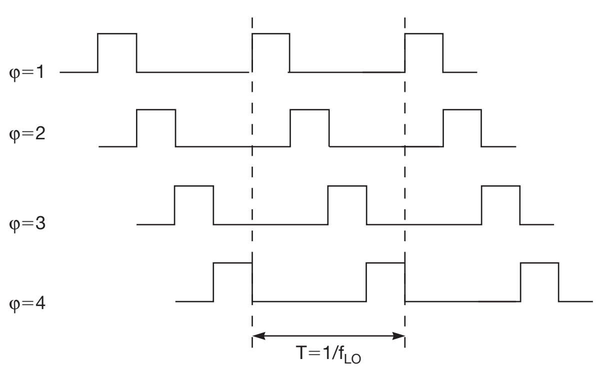
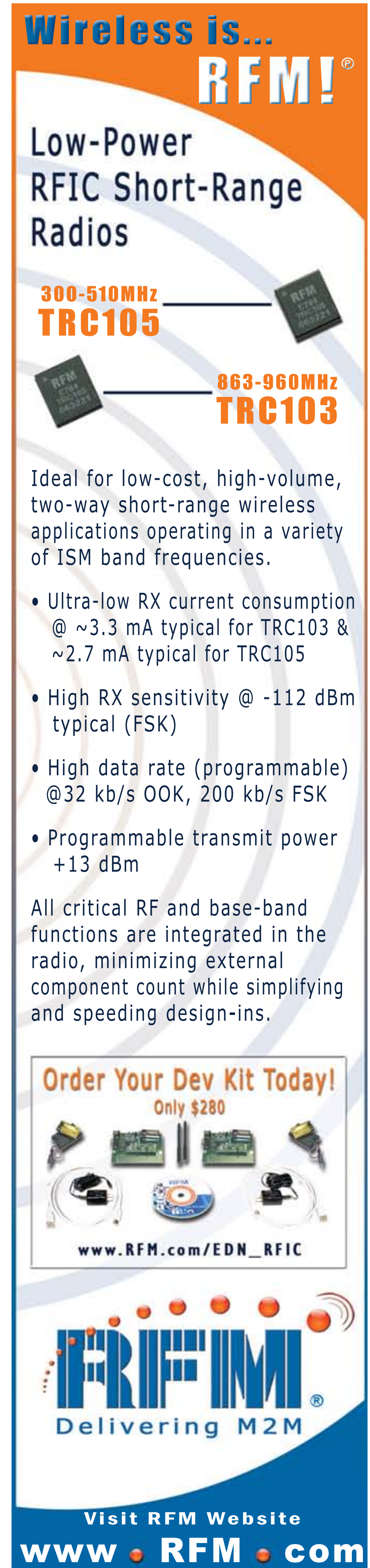


Figure 2 The control signals for switch-matrix mixers have four phases.



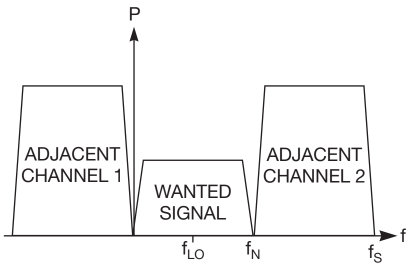


Figure 3 The spectrum of a low-IF system may have strong adjacent channels. Here, f_S denotes the sampling frequency; f_N, the Nyquist frequency; and f_{LO}, the low IF.

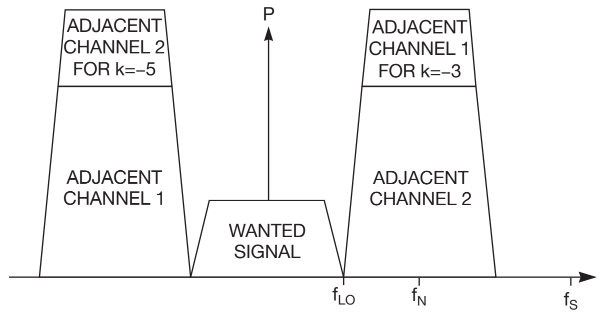


Figure 4 A switch-matrix mixer shifts the spectrum to zero-IF but also adds switching Fourier components to the adjacent channels.

the harmonics of the switching function. In this case, however, the antialiasing filter's bandwidth is half that of the previous case. Maintaining the same filter order results in a sharper antialiasing filter. The filter suppresses both adjacent channels, dramatically reducing the ADC's required dynamic range.

Other channels outside the adjacent channels may fall into the baseband due to mixing with the harmonics of the switch function. To address this problem, you must apply an image filter in front of the switch-matrix mixer. This filter is more relaxed than the antialiasing filter. Both adjacent channels are filtered, so the antialiasing filter allows the ADC to have a lower number of bits.

SIMULATION RESULTS

You can do a simulation using The MathWorks (www.mathworks.com) Matlab to illustrate the process of an ideal low-IF mixer (**Figure 5**). You can simulate a 100-kHz RF signal with a strong interferer at 70 kHz. The spectrum at this point is symmetric, corresponding to a real signal. A complex-valued mixer shifts down the signal to the low IF, making the spectrum asymmetric. An interferer signal appears at the image frequency with respect to zero. Derotating with the remaining IF yields a zero-IF baseband signal. You can filter away the interferer using a real-valued filter.

You can also simulate an ideal switch-matrix mixer (**Figure 6**). The first two plots are the same as those in **Figure 5** because the switch-matrix mixer replaces only the low-IF derotation process. The third plot depicts that, even with perfect switches, some spectral interleaving occurs. You can separate these interlaced higher-order products using filtering, as the bottom plot shows. Introducing a gain error causes even more spectral interleaving (**Figure 7**). These additional subbands are filtered off and do not cause a problem. However, I/Q imbalance results in the usual image problem, quantitatively of the same order as with any low-IF mixer.

A prototype PCB (printed-circuit board) of the switch-matrix mixer includes the clock-phase generators (**Figure 8**). Lowpass filters surround the switch-matrix mixers. You mix a 2.40002-GHz RF signal, which is 20 kHz offset from 2.4 GHz, with a 20-kHz IF using a Maxim (www.maxim-ic.com) MAX2701 image-rejection mixer. You send the I and the Q part of the low-IF signal to the test board. It down-converts the signal to a baseband signal using a clock frequency of four times 14 kHz to get four phases, resulting in 56 kHz. After the first mixing process, the resulting frequency spectrum of this signal has three peaks (**Figure 9**). One peak is the image at –20 kHz, or 40 dB down. The second peak is the dc offset. The third peak is the signal of interest at 20 kHz.

After the second mixing process, the signal of interest now shifts to 6 kHz (**Figure 10**). The previous dc peak shifts to –14 kHz, and the switch-matrix mixer generates a new dc-offset peak; 40 dB also suppresses the image of the switch-matrix mixer at –6 kHz. Choose the cutoff frequencies of the lowpass filters before and after the switches as 30 and 15 kHz, respectively.

A switch-matrix mixer reduces the dynamic range needed in a subsequent ADC. Apart from the switches, only an additional low-order filter is necessary to prevent unwanted harmonics from fall-

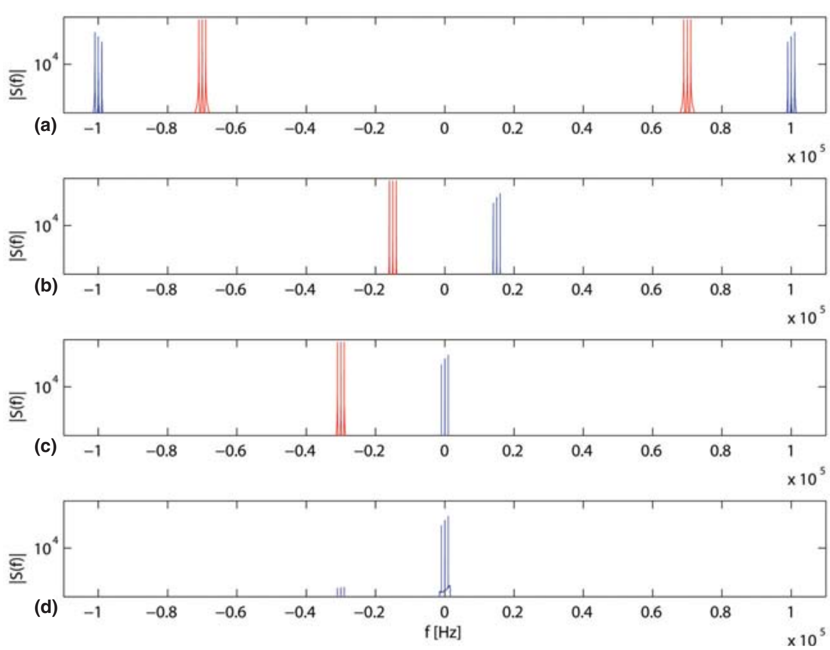


Figure 5 Using ideal mixers, you can move the spectrum to a zero-IF baseband. Starting with an RF signal and a strong interferer (a), the first conversion makes the low-IF signal (b). Derotation moves the desired signal to the baseband (c), and filtering removes the unwanted negative-frequency components (d).

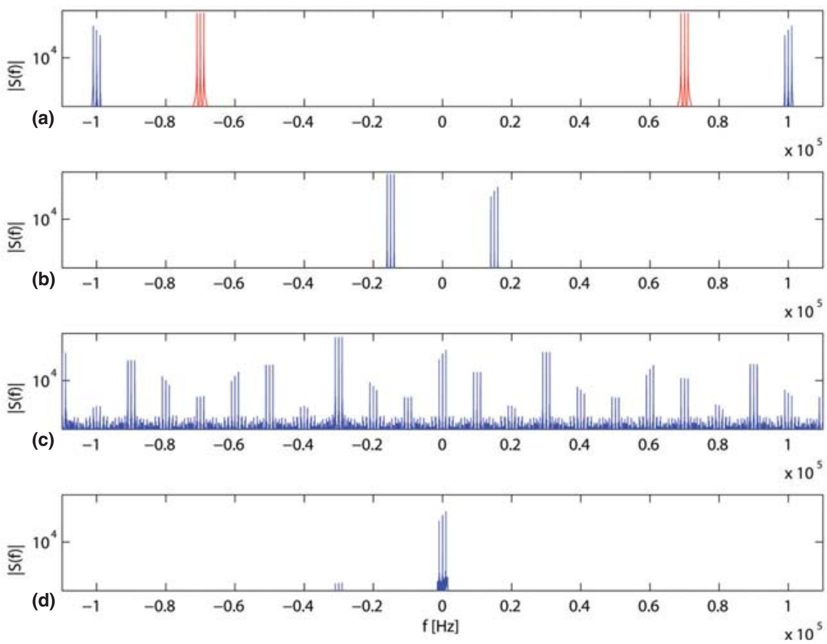


Figure 6 A switch-matrix mixer using ideal switches can also make a zero-IF signal. Starting with an RF signal and a strong interferer (a), the first conversion creates the low-IF signal (b). The switch-matrix mixer moves the signal to the baseband (c). Filtering removes the unwanted frequency components (d).

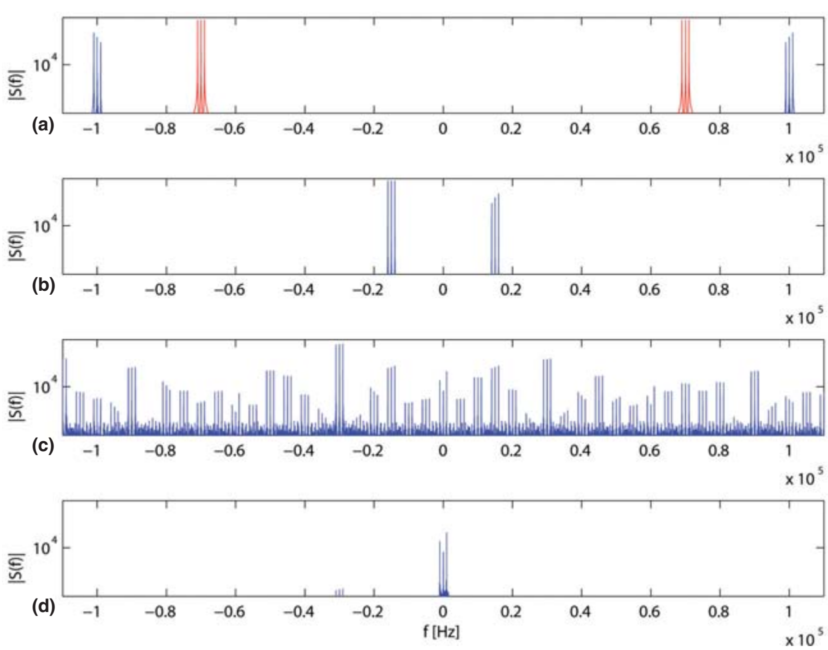


Figure 7 A switch-matrix mixer with a gain error in the signal chain exhibits problems. The RF signal and strong interferer (a) move to low IF (b). The gain error causes worse interleaving (c). The filtered signal has typical image problems due to I/Q imbalance (d).

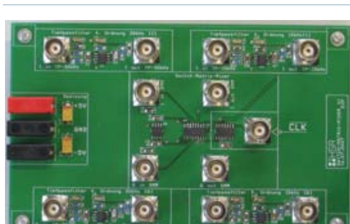


Figure 8 You can fabricate a hardware test board for a switched-matrix-mixer proof of concept.

PICO

Transformers and Inductors

...think PICO small!

think... low profile from .19" ht.

Over 5000 Std. Ultra Miniature

Surface Mount (and Plug-In) Models

Audio / 400Hz / Pulse Multiplex Data Bus / DC-DC Converter Transformers / Power & EMI Inductors

See Pico's full Catalog immediately
www.picoelectronics.com

ISO9001:2000
ANAB BSI
AS 9100 REV B

PICO units manufactured and tested to MIL-PRF-27 requirements. QPL units are available. Delivery stock to one week for sample quantities.

PICO Electronics Inc.

143 Sparks Ave, Pelham, NY 10803-1837
Call Toll Free: 800-431-1064
E Mail: Info@picoeletronics.com
FAX: 914-738-8225

VISA MasterCard AMERICAN EXPRESS

MILITARY•COTS•INDUSTRIAL
TRANSFORMERS & INDUCTORS

Beat the heat and toss the fan!

PFE SERIES

Conduction Cooled Power Supplies

The search for a high power, conduction cooled power supply has just ended. TDK-Lambda's PFE series of base plate cooled AC-DC power modules are ideal for harsh, high temperature applications. Beat the heat and toss the fan to make your system quieter and more reliable.

Contact TDK-Lambda for an evaluation board or visit our website for the reference design.

http://us.tdk-lambda.com/lp/products/pfe-series.htm

- Operation from -40 to +100°C
- 300 to 1000W, AC-DC Power Modules
- Universal Input (85-265VAC)
- 12, 28 or 48V Outputs
- Brick Style Construction

For more information on how TDK-Lambda can help you power your unique applications, visit our web site at
www.us.tdk-lambda.com/lp/
or call **1-800-LAMBDA-4**

TDK-Lambda
Innovating Reliable Power

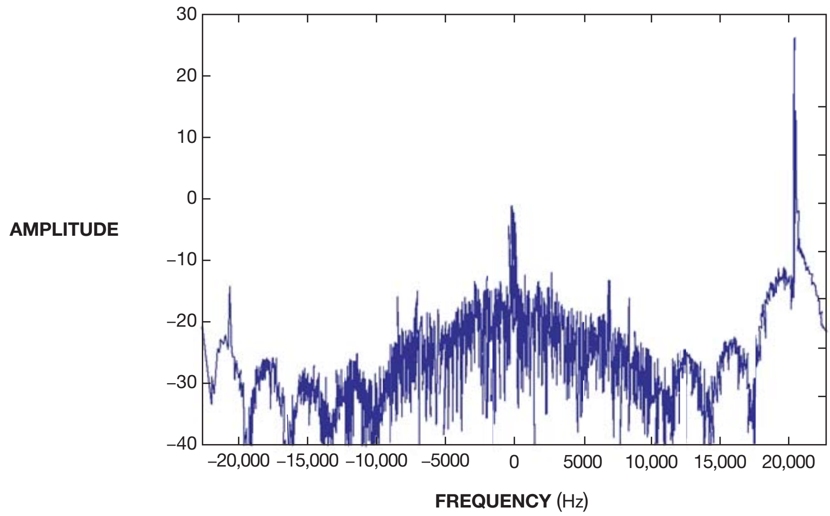


Figure 9 The input spectrum to the test board has the desired signal of 20 kHz.

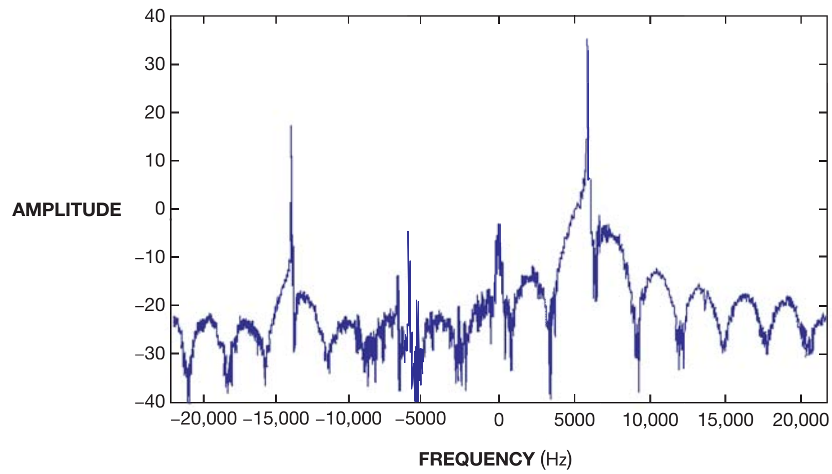


Figure 10 The spectrum at the output of the switch-matrix mixer moves the desired signal to 6 kHz.

ing into the baseband. You can integrate these functions into a single IC.EDN

REFERENCES

1 Mirabbasi, Shahriar, and Ken Martin, "Classical and modern receiver architectures," *IEEE Communications Magazine*, November 2000, pg 132, http://bit.ly/9ZUtJ8.

2 Gray, PR, and RG Meyer, "Future directions in silicon ICs for RF personal communications," *IEEE Custom Integrated Circuits Conference*, Santa Clara, CA, May 1995, pg 83, http://bit.ly/afcmCg.

3 Crols, J, and MSJ Steyaert, "Low-IF topologies for high performance analog front ends of fully integrated receivers," *IEEE Transactions on Circuits and Systems–II*, Volume 45, No. 3, March 1998, pg 269. http://bit.ly/9Srxtt.

4 Martin, Ken, "Complex signal processing is not complex," *IEEE Transactions on Circuits and Systems—I*, Volume 51, No. 9, September 2004, pg 1823, http://bit.ly/aGRw0w.

5 Pun, Kong-Pang; JE da Franca; C Azeredo-Leme; and R Reis, "Quadrature sampling schemes with improved image rejection," *IEEE Transactions on Circuits and Systems–II*, Volume 50, No. 9, September 2003, pg 641, http://bit.ly/bnvAte.

AUTHOR'S BIOGRAPHY

Heinz Mathis is a professor of mobile communications at the University of Applied Sciences (Rapperswil, Switzerland). He received master's and doctorate degrees in electrical engineering from the Swiss Federal Institute of Technology (Zurich, Switzerland). His research interests include signal processing for wireless-communication systems and positioning systems.

Control a dc motor with your PC

Firas M Ali Al-Raie,
Polytechnic Higher Institute of Yefren, Yefren, Libya

The circuit in this Design Idea controls the speed of a 5V permanent-magnet dc motor through the PC's parallel port (**Figure 1**). You use the C++ computer program, available at www.edn.com/100826dia, to run the motor at three speeds. The circuit uses PWM (pulse-width modulation) to change the average value of the voltage to the dc motor. You connect the motor to the PC's parallel port with an interface circuit. The design comprises IC_1, a 74LS244 buffer; IC_2, a ULN2003 driver; relay switches S_1, S_2, and S_3; IC_3, a 555 astable multivibrator circuit; and Q_1, a 2N2222 driving transistor. The 555 timer operates as a variable-pulse-width generator. You change the pulse width by using relays to insert or split resistors in the 555 circuit.

The computer program controls these resistors. When S_1 is on and both S_2 and S_3 are off, the timer output is set to logic one, thereby driving the motor with its maximum speed. When S_1 and S_2 are on, the 555 timer generates a pulse signal with a 50% duty cycle. In this case, the charging resistor, R_{A1}, is equal to the discharging resistor, R_B. In the third case, S_1 and S_3 are on, and the charging resistor is R_{A2},where R_{A2}=0.1×R_B, reducing the on time of the pulse signal and, consequently, the speed of the motor to the lower limit. **Table 1** summarizes the on/off-operation conditions of the relays and the corresponding dc-motor speeds.

DIs Inside

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

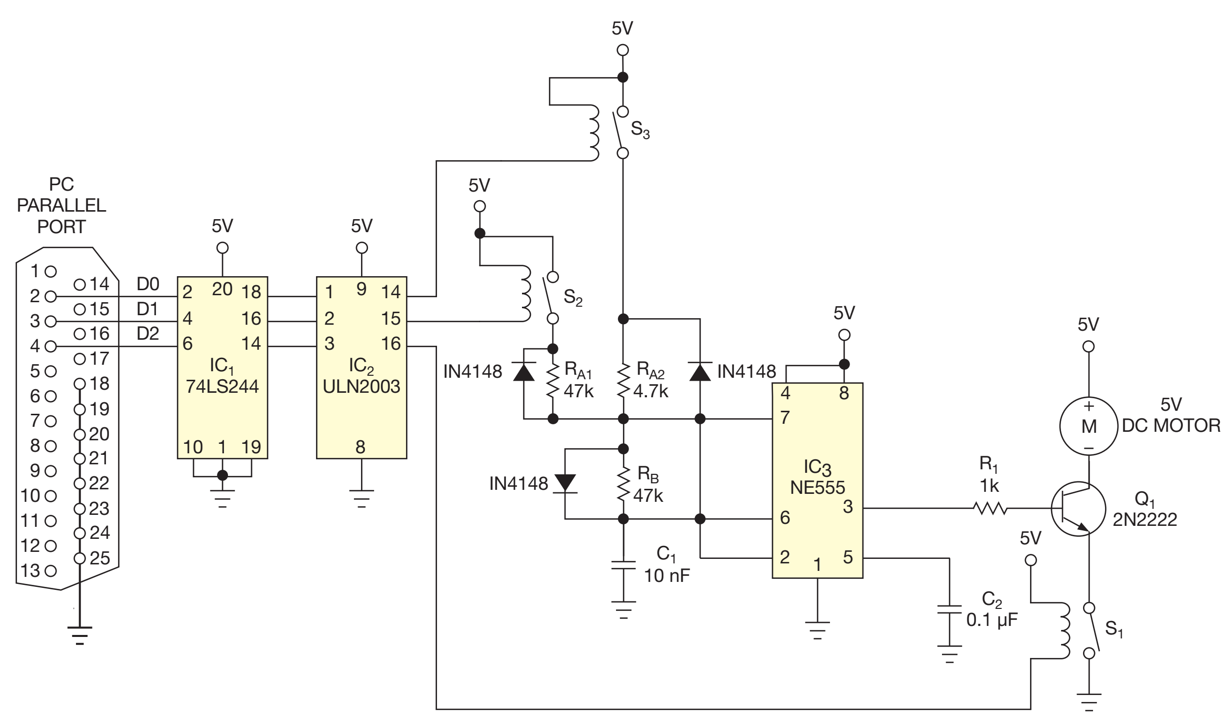


Figure 1 This circuit controls the speed of a 5V permanent-magnet motor through the PC's parallel port.

The code prompts you to select a certain speed, stores your selection as an integer variable choice, generates the proper digital sequence, and stores it at another integer variable. You place the value of the integer variable data at a PC's parallel port using the outportb function. The program uses the kbhit function to stop the motor when you hit any key on the keyboard.EDN

TABLE 1 SWITCH STATES AND GENERATED PC SEQUENCES

S_3	S_2	S_1	Equivalent digital sequence	Motor speed
Off	Off	Off	000	Stop
Off	Off	On	001	Maximum
Off	On	On	011	Medium
On	Off	On	101	Minimum

Look-up table eliminates the need for an IC

Abel Raynus, Armatron International, Malden, MA

When you need to connect a microcontroller to a seven-segment LED display, you can use a BCD (binary-coded-decimal)-to-seven-segment decoder. **Figure 1** shows a typical circuit that uses a CD4511 to translate a 4-bit code into BCD.

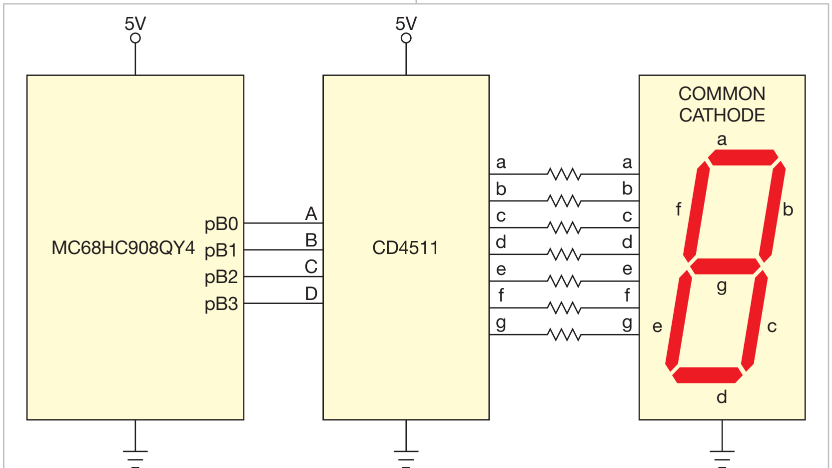


Figure 1 A CD4511 converts BCD codes to seven-segment-displays.

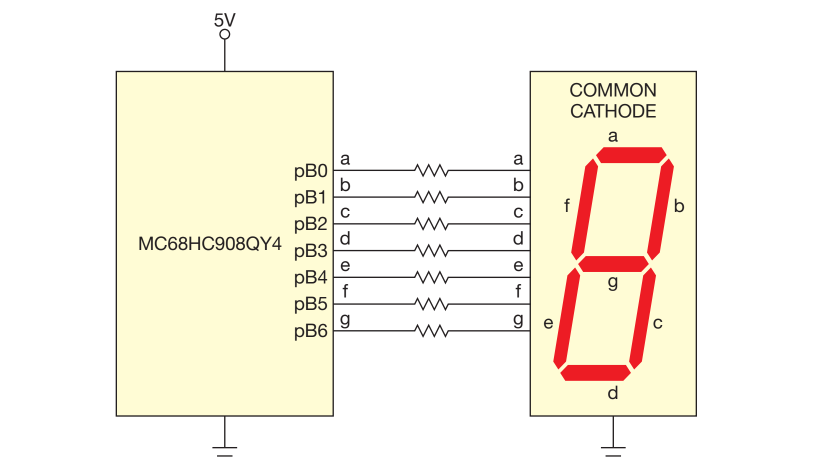


Figure 2 The look-up table lets the microcontroller produce a seven-segment output.

Unfortunately, a limited size and budget may force you to omit components whenever possible. This requirement is especially critical with consumer products. Simple firmware allows you to overcome this limitation by directly connecting the display to a microcontroller (**Figure 2**).

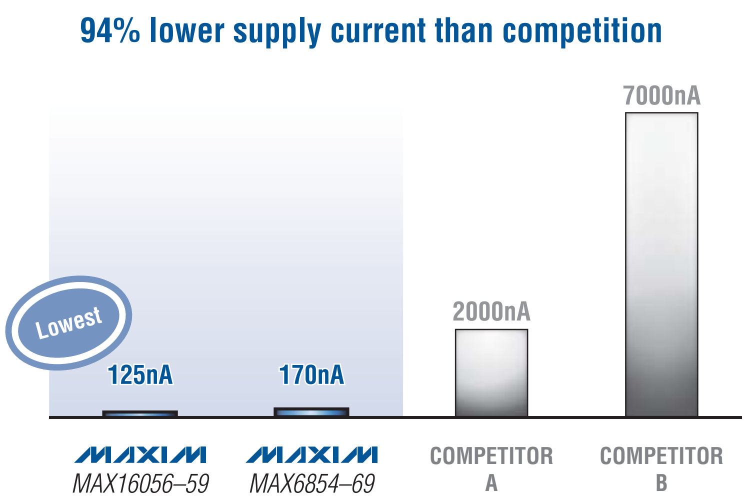
A recent project used the 8-bit Freescale (www.freescale.com) MC68HC908QY4 microcontroller. When you write code for a microcontroller, you often represent data in decimal, hexadecimal, or BCD formats. A numeric display needs a special seven-segment code, the value of which depends on the common point of the display LEDs—common cathode or common anode—and on microcontroller outputs you choose for display. **Tables 1** and **2** show how to obtain seven-segment code values for common-cathode and common-anode displays, respectively.

A NUMERIC DISPLAY NEEDS A SPECIAL SEVEN-SEGMENT CODE, THE VALUE OF WHICH DEPENDS ON THE COMMON POINT OF THE DISPLAY LEDs.

No mathematical connection exists between seven-segment code and any of these formats. Thus, you must use a table that a previous Design Idea

Industry's lowest power supervisory IC...AGAIN!

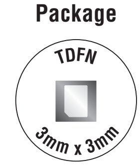
Conserve battery life with Maxim's adjustable-timeout, 125nA watchdog solution



- Reset thresholds from 1.575V to 4.625V in 100mV increments
- Fully specified over the -40°C to +125°C automotive temperature range
- Capacitor-adjustable reset watchdog timeouts

Part	Watchdog Timer	Reset Output	Package
MAX16056	✓	Push-pull	8-TDFN
MAX16057	—		6-TDFN
MAX16058	✓	Open drain	8-TDFN
MAX16059	—		6-TDFN

Small Package



www.maxim-ic.com/MAX16056-9-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.

Innovation Delivered and Maxim are registered trademarks of Maxim Integrated Products, Inc. © 2010 Maxim Integrated Products, Inc. All rights reserved.

TABLE 1 CODE FOR COMMON-CATHODE DISPLAY

Decimal number	pB7 —	pB6 (g)	pB5 (f)	pB4 (e)	pB3 (d)	pB2 (c)	pB1 (b)	pB0 (a)	Seven-segment code
0	0	0	1	1	1	1	1	1	$3f
1	0	0	0	0	0	1	1	0	$06
2	0	1	0	1	1	0	1	1	$5b
3	0	1	0	0	1	1	1	1	$4f
4	0	1	1	0	0	1	1	0	$66
5	0	1	1	0	1	1	0	1	$6d
6	0	1	1	1	1	1	0	0	$7c
7	0	0	0	0	0	1	1	1	$07
8	0	1	1	1	1	1	1	1	$7f
9	0	1	1	0	1	1	1	1	$6f

TABLE 2 CODE FOR COMMON-ANODE DISPLAY

Decimal number	pB7 —	pB6 (g)	pB5 (f)	pB4 (e)	pB3 (d)	pB2 (c)	pB1 (b)	pB0 (a)	Seven-segment code
0	0	1	0	0	0	0	0	0	$40
1	0	1	1	1	1	0	0	1	$79
2	0	0	1	0	0	1	0	0	$24
3	0	0	1	1	0	0	0	0	$30
4	0	0	0	1	1	0	0	1	$19
5	0	0	0	1	0	0	1	0	$12
6	0	0	0	0	0	0	1	1	$03
7	0	1	1	1	1	0	0	0	$78
8	0	0	0	0	0	0	0	0	$00
9	0	0	0	1	0	0	0	0	$10

describes (**Reference 1**). The project described here used one seven-segment LED display to show the digits 0 through 9. A table makes the firmware simple and short.

Using the assembly-language code that you can download from the online version of this article at www.edn.com/100826dib, you need just 7 bytes to execute the program, plus 10 bytes of memory for the code table. A decimal number for conversion goes into register DECreg and acts as an index, X, applying to the code table. The result appears at the microntroller's Port B output. EDN

A DECIMAL NUMBER FOR CONVERSION GOES INTO A REGISTER AND ACTS AS AN INDEX APPLYING TO THE CODE TABLE.

REFERENCE

1 Raynus, Abel, "Tables ease microcontroller programming," *EDN*, April 22, 2010, pg 76, www.edn.com/article/457500-Tables_ease_microcontroller_programming.php.

Operate circuits at voltages as high as 540V ac

Vipin Bothra and John Lo Giudice, STMicroelectronics, Schaumburg, IL

Energy meters, HVAC (heating/ventilation/air-conditioning) systems, and high-power equipment that runs on three-phase ac inputs pose a challenge to power-supply designers because nominal input voltage can be as high as 540V ac. The challenge increases if the power supply must operate from 100 to 540V ac. Design choices are numerous, and final system costs can vary dramatically with those choices. An abundance of parts is available for power supplies with input power as high as 240V ac. High-voltage input-power supplies are, however, still a niche area for most semiconductor companies.

The power-supply circuit in **Figure 1** uses an input-chopper circuit that allows the clamping of input voltage to the flyback power stage so that the power is less than 400V. That voltage lets you use a standard design technique for the flyback stage. The input chopper provides many advantages over prevailing high-voltage-input power supplies.

Unlike a standard flyback converter, this circuit eliminates the need for a high-voltage MOSFET for the switch, thereby letting you use lower-cost, commonly available MOSFETs. Moreover, overall switching losses in the power supply decrease dramatically with the reduction in bus voltage. The circuit can use smaller and lower-cost transformers because of a reduction in creepage-clearance requirements.

This circuit's reduced bus voltage eliminates the stacked-FET-flyback topology and the need for two or more high-voltage capacitors. It also improves the overall efficiency of the system by eliminating the high losses of a stacked FET, replacing them with small losses from a bypass switch.

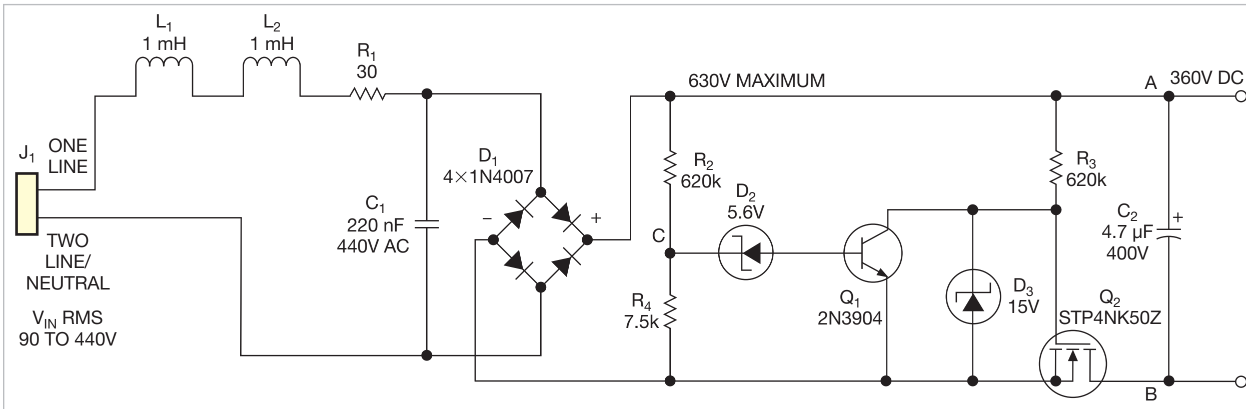


Figure 1 A chopper circuit reduces power-bus voltage to less than 400V dc per pin.

The 500V, 2.7Ω STP4NK50Z N-channel MOSFET switches at the line frequency. It turns on at a predetermined voltage, and it turns off at any higher voltage. It limits the voltage on C_2 to approximately 360V dc. When the voltage at the divider of R_2 and R_4 reaches approximately 6.3V, or 360V at the top of the divider, Q_1 turns on and steals current from the gate of Q_2, and the MOSFET turns off. The divider sets the level at which Q_2 switches. All resistors are 0.25W except for R_1, which can be 2W to survive surge. The circuit underwent testing with 12W of output power at 90 to 440V-ac input. The maximum input current to the power supply depends on the thermal performance of Q_2. EDN

THE 500V MOSFET TURNS ON AT A PREDETERMINED VOLTAGE; IT TURNS OFF AT ANY HIGHER VOLTAGE.

Bricks-On-A-Plate™

Quick, Rugged, Flexible Power Solutions

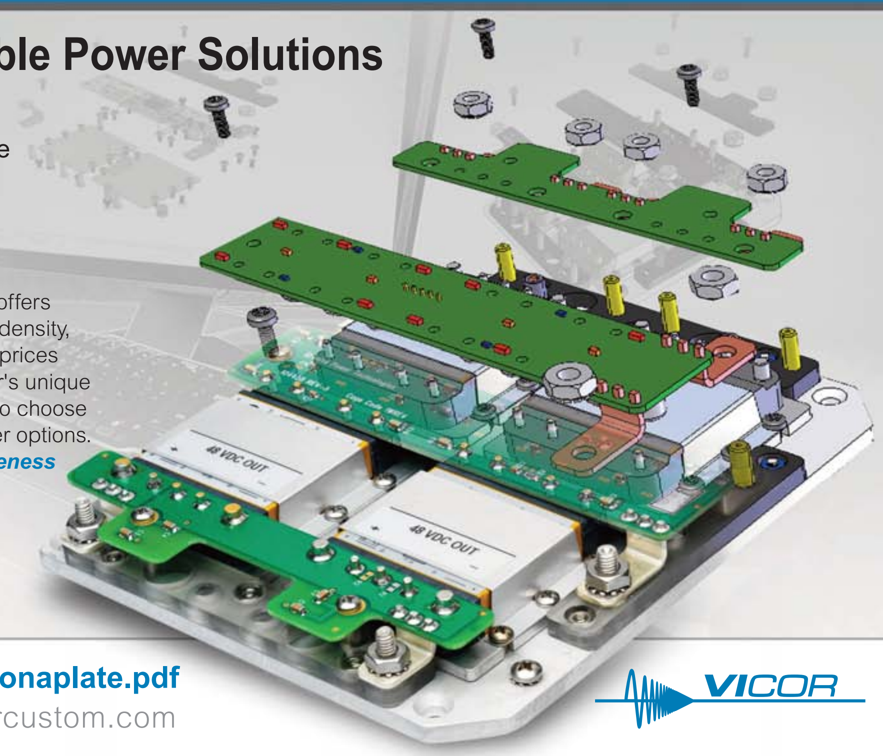
Field proven component power
- Save valuable engineering time
- Risk mitigation
- Reduce cost
- Improve time to market

Vicor's "Bricks-On-A-Plate" power solution offers unique configuration flexibility, high power density, high reliability, and quick time to market at prices not usually found in custom solutions. Vicor's unique mass-customization capability allows you to choose from thousands of power modules and filter options. *You'll get the small company responsiveness with large company resources.*

VICOR CUSTOM POWER

www.vicorpower.com/bricksonaplate.pdf
800-496-5570 or apps@vicorcustom.com

VICOR



Microcontroller supervises 0- to 20-mA protection circuit

Anatoly Andrusevich, Maxim Integrated Products, Moscow, Russia

The 0- to 20-mA current loop is a reliable means of data communication in industrial applications. These circuits use a precision shunt in the receiver to convert the current signal into a voltage signal. Accidentally connecting the precision shunts to the current-loop power supply can cause damage, after which you must replace the shunt and recalibrate the system. To avoid that expense, you can use a microcontroller-controlled protection circuit (**Figure 1**).

With conventional techniques, you protect the shunt with a fast fuse or by turning off the loop with an automatic switch, which then turns back on after a specified period. The circuit in **Figure 1** provides protection that is much faster than a fuse. IC_1, the slowest device in the circuit, switches off in less than 500 μsec. It offers a higher-precision switching threshold than a fuse, and, of course, there's no fuse to replace. Rather than making you cycle power to restore the loop, the microcontroller provides control of the protection circuit. The microcontroller also logs the event, thereby providing a record that the system invoked the protection circuit.

The protection circuit has virtually

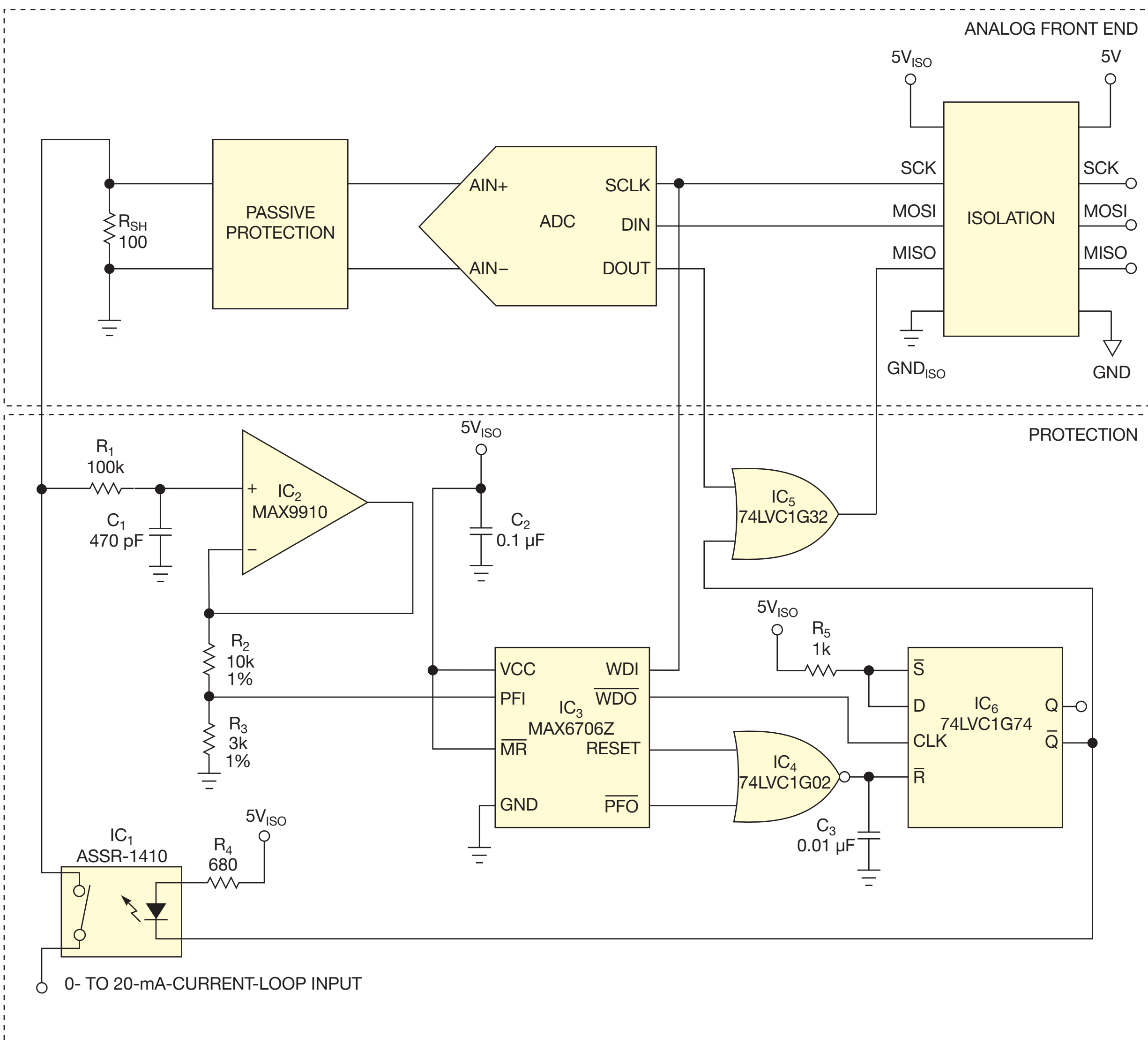


Figure 1 This circuit protects the isolated analog front end of a current loop. For simplicity, the drawing omits power and ground connections for IC_2, IC_4, IC_5, and IC_6.

no effect on the analog front end. The IC_2 buffer ensures an input current of less than 30 pA. The on-resistance of IC_1 is less than 2Ω. The circuit needs no additional isolated data channels or microcontroller-I/O ports, and it prevents damage during system installation or repair. It also turns off the loop after power-up and when no power is available.

You implement the protection algorithm with a power-fail comparator and a watchdog circuit, available as separate outputs on IC_3, together with IC_6, a D-type flip-flop.

At power-up, the flip-flop is in the reset state, and the current loop is open,

THE CIRCUIT NEEDS NO ADDITIONAL ISOLATED DATA CHANNELS, AND IT PREVENTS DAMAGE DURING SYSTEM INSTALLATION.

due to a high-level reset signal from IC_3 driving IC_4, a NOR gate. After the first low-to-high transition on the SCK (clock-signal) line, a rising edge from IC_3's $\overline{WDO}$ (watchdog output) sets the flip-flop and pulls current through the solid-state relay, IC_1, thus connecting the input to the loop.

In the event of a loop-current overload greater than 27 mA, a high level from the $\overline{PFO}$ (power-fail-output) comparator on IC_3 resets the flip-flop and switches off IC_1. Thanks to the IC_5 gate, the microcontroller inputs ones at the MISO (master input/slave output), meaning overcurrent.

To again switch on the loop, the micro controller must stop the SCK line for at least 2.4 sec. The next low-to-high transition on SCK then reconnects the current loop. EDN

LED indicates power source

Brian Conley, Circuitsville Engineering LLC, Beaverton, OR

LED circuits with current-limiting resistors find extensive use as power indicators and for debugging circuits (**Reference 1**). In some cases, however, your design may require a different approach. Bipolar transistors have a little-discussed behavior: reverse active region. For low voltages and small currents, an NPN transistor can operate in reverse with a significantly lower gain,

THE LED ILLUMINATES WHEN THE BOARD RECEIVES VOLTAGE FROM THE WALL WART, BUT NOT FROM THE USB PORT.

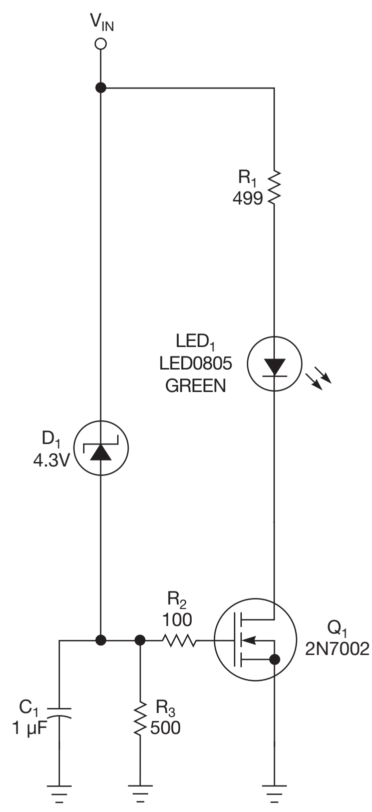
which can be undesirable. Some linear regulators also operate in this way.

The circuit in **Figure 1** gets its input-voltage power primarily from a wall-wart dc-power supply that can provide 7 to 12V. It may also get 5V from a USB (Universal Serial Bus) port. This design requires a circuit that indicates whether the board is receiving voltage from the wall wart or from the USB port.

The circuit uses Q_1, a 2N7002 FET, and zener diode D_1 to solve the problem. The FET is in series with LED_1 and current-limiting resistor R_1. Diode D_1 is a Vishay (www.vishay.com) AZ23C4V3-V, which has a typical reverse voltage of 4.3V within a range of 4 to 4.6V. When Q_1's gate-to-source voltage exceeds its threshold-voltage range of 1 to 2.5V, the LED turns on. The voltage coming from the USB port is insufficient to turn on LED_1 because of the voltage drop across D_1. Thus, the LED illuminates when the board receives voltage from the wall wart, but not from the USB port.

Under testing, the LED illuminates when the input voltage is at least 7.1V. When it is below that voltage, the LED is off, indicating that the USB port is powering the circuit.

Resistor R_3 comprises two 1-kΩ resistors in parallel. This setup is necessary because the input voltage is 12V and the zener diode's minimum voltage is 4V. A voltage of 8V appears across R_3, producing 0.128W—too much power for one resistor in a 0805 package. EDN



NOTE: R_3 COMPRISES TWO 1-kΩ RESISTORS IN PARALLEL.

Figure 1 This circuit gets its power from a wall-wart dc-power supply or from a USB port. The LED illuminates when the board receives its voltage from the wall wart. When it is off, the USB port is powering the circuit.

REFERENCE

1. Conley, Brian, "Go on green," *EDN*, June 24, 2010, http://www.edn.com/article/509479-Go_on_green.php.

productroundup

COOLING ENCLOSURES

10-in. ac fans move 547 to 850 cfm in confined spaces

The OA254 series of ac fans measure 254×89 mm (10×3.5 in.) and feature airflow ranging from 547 to 850 cfm. The fans are available in 115 and 230V-ac versions. The OA254 series ac fans feature voltage ranges of 80 to 130 and 160 to 260V ac for the 115 and 230V-ac versions, respectively. Rated power ranges from 35 to 75W, and speed ranges from 1650 to 2700 rpm. Maximum static pressure ranges from 0.39 to 1.14 in. in water, with noise levels of 69 dB. Prices range from $61 to $71 (one to 99).

Orion Fans, www.orionfans.com

Weatherproof-steel enclosures have factory-installed toroidal power transformers

Products in this line of custom- and standard-design toroidal power

and isolation transformers come in factory-installed weatherproof-steel enclosures. The enclosures come in six standard sizes ranging from 250×200 mm (9.8×7.9 in.) to 500×400 mm (19.7×15.7 in.). All sizes are 150 mm (5.9 in.) deep. The largest size is also available with a depth of 200 mm (7.9 in.) and can hold three transformers for 60-Hz, three-phase operation, with a total power rating as high as 7500 VA. The smallest enclosure has room for a 1500-VA transformer. The size of transformers for 60-Hz-only frequency can be 20% smaller, and a 400-Hz transformer is typically half the size. Prices for the smallest enclosure with one 1000-VA transformer start at $185.

Tortran Inc, www.tortran.com

Fan-tray assembly has digital temperature controller

The FT-1986 fan-tray assembly comes with a digital temperature controller and six fans providing 540-cfm airflow. Users need only to position the assembly in place, plug it in, and set the desired temperature setting on the digital controller. It features a standard EIA 19-in.-wide, 1U, 1.75-in.-high

panel with mounting brackets and measures 1.75×19×18.56 in. The digital temperature controller operates at 0 to 50°, and its accuracy is ±1°C. Prices start at $209 (15).

Bud Industries Inc, www.budind.com

Spotlight cooler targets track and directional down lights

The SynJet spotlight cooler for track and directional down lights works in spaces with diameters as small as 75 mm, such as window displays in retail, commercial, and general light-

ing. The device enables 2000 lumens in a small profile, offers silent operation, and provides more than 100,000 hours of lifetime in cooling applications. It suits many light engines from companies such as Bridgelux, Citizen, Osram, and Philips.

Nuventix Inc, www.nuventix.com

SWITCHES AND RELAYS

USB switch integrates a headphone amplifier

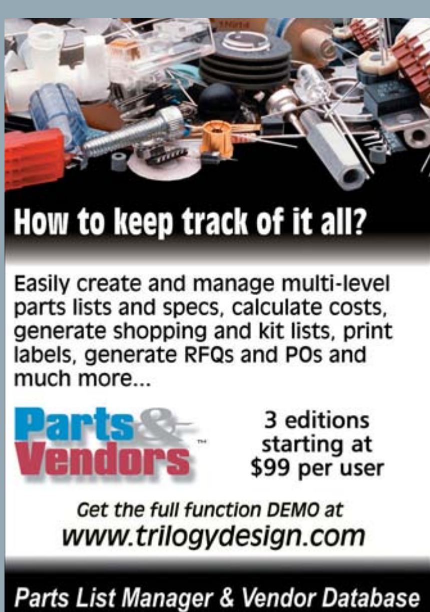
The FSA2000 integrates an autoselecting USB 2.0 full-speed and high-speed-compliant switch with a Class AB headphone audio amplifier and can autoswitch to USB when the bus voltage is present. During this process, it does not need to power up the headphone amplifier, saving power. The devices sell for 70 cents (1000).
Fairchild Semiconductor,
www.fairchildsemi.com

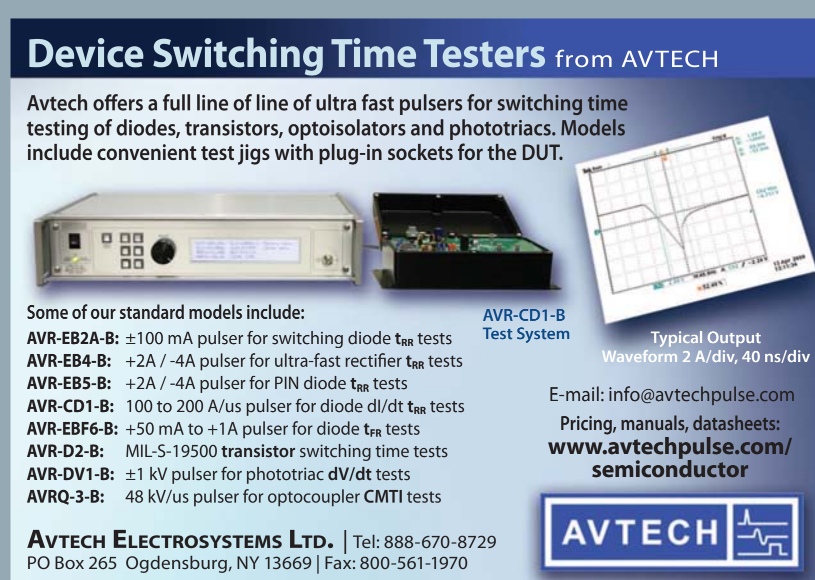
EDN ADVERTISER INDEX

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

EDN productmart

This advertising is for new and current products.





DAC days, sleepless nights

DANIEL VASCONCELLOS

A few years ago, I was working on a drive board for a thermal-radiation-sensor array that required testing. The serially multiplexed sensor output needed a multistep closed-loop correction scheme to even out sensor nonuniformity.

To perform the test, I employed a design with a dual serial DAC. I coded the software for the correction scheme, and it was then time to check out the operation. I decided to look at the DAC chip and its operation independently of the other components. I hooked up a board with the DAC to the microcontroller controlling the operation. To verify the controller's output, I used an oscilloscope that was monitoring the serial signal arriving at the DAC. It checked out fine and met all the parameters that the DAC manufacturer had set.

However, the analog output from the DAC was incorrect. At start-up, one DAC channel read 200 mV, and the other read 5V. After the DAC received the data packet, the outputs read 0 and 5V. Suspecting some software issue that I had overlooked, I spent an entire afternoon going over the details of the correction scheme and the serial data packet's transmission to the DAC from the controller. I also checked the connections and wiring to the DAC and found everything to be correct.

The DAC chip was a new unit, and I did not consider it a likely suspect. After much hair pulling and teeth gnashing, nothing fruitful emerged. In frustration, I gave up for the day, hoping that the next day would yield some clue.

Sleep that night was elusive. I kept having visions of how the serial-packet transmission matched the timing diagram on the DAC manufacturer's data sheet. The power supply checked out, the hardware wiring checked out, and the software checked out. What else was left to check? By all accounts, the DAC should have behaved correctly. Maybe it was a faulty chip after all. These thoughts occupied my sleepless night until the next morning, when I headed back to the lab.

I removed the DAC board from the controller and powered it up. The DAC had a power-on-reset feature that should have zeroed the DAC outputs at start-up, but this feature did not seem to be working. One channel was still 5V, and the other was still about 200 mV. When the DAC received the serial packet of data from the controller, the 200-mV channel would drop to 0V, and the other one remained at 5V. I verified the serial-packet data again and found it to be correct. I carefully checked the wiring of the DAC and the serial connection and found nothing wrong. It looked indeed as if the chip was faulty.

Unfortunately, I seemed to have run out of parts to try a replacement. Loathing the thought of more sleepless nights until I solved the problem, I rummaged through my parts bin, hoping desperately to find another chip to test. Lo and behold, there at the corner of my bin was one last remaining DAC chip. Eagerly grabbing the part, I got ready to replace the chip on the board. This chip was a DIP, and I used an extractor to remove the suspicious chip from the board.

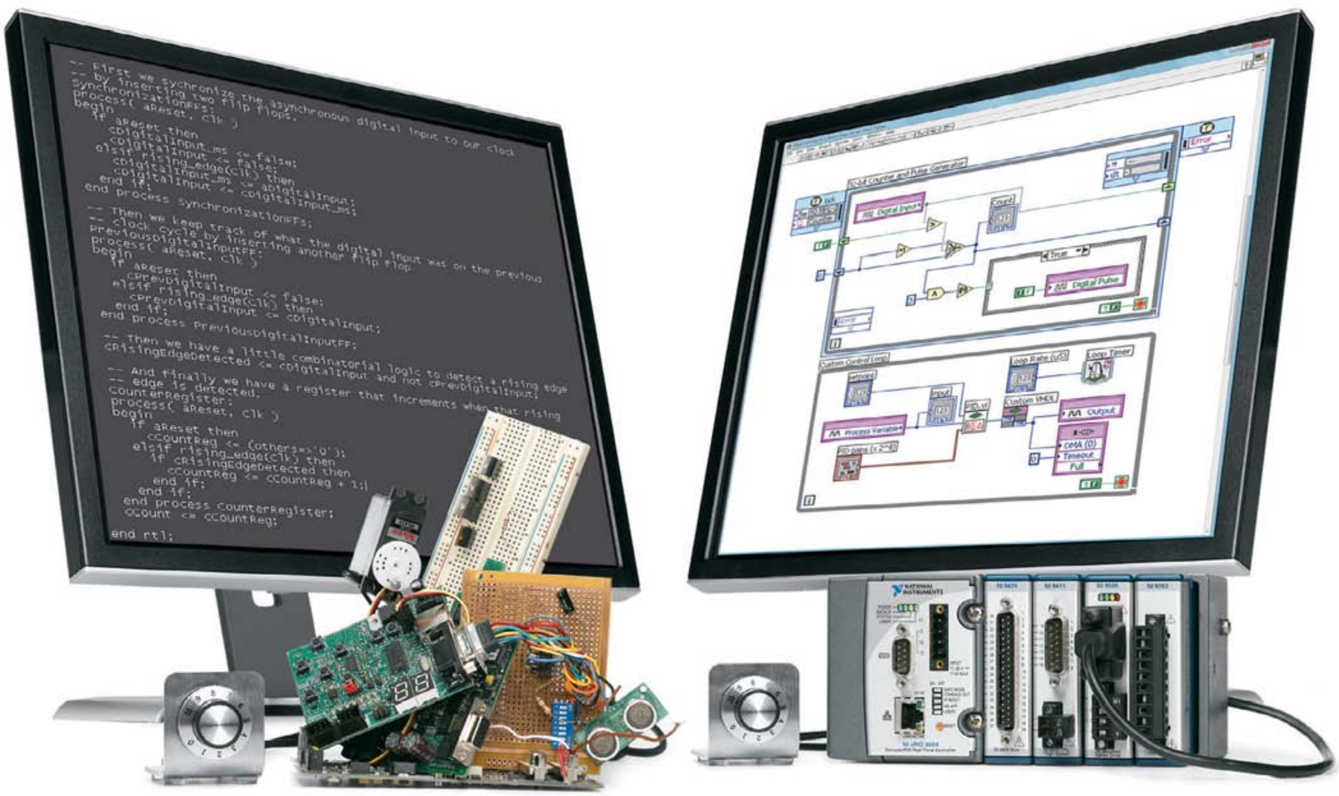
As I closely examined the chip and positioned the extractor on it, I was shocked to find that the faded part-number marking showed that it was not a DAC chip at all but a dual op amp! I was doing all my testing with the wrong part in the socket! Cursing myself and thanking my lucky stars that I didn't blow anything else, I wrenched it out and replaced it with the correct part, hooked up the controller, and found that everything worked like a charm.

As one version of Murphy's Law states, "When you have removed the last of the 40 screws holding down an access door, you will find that you have removed the wrong access door." My sleep that night was indeed satisfying. EDN

Vinoo Narayanan is a mechatronics engineer with En'Urga Inc (West Lafayette, IN).

+ www.edn.com/tales

Embedded Prototyping. Simplified.



Traditional Prototyping Tools **Graphical System Design Tools**

Get to market faster and reduce development costs with graphical system design, an approach that combines open, graphical software and off-the-shelf hardware to help you quickly iterate on designs and easily implement them on an NI embedded platform. The NI CompactRIO system offers an ideal embedded prototyping platform with a built-in microcontroller, RTOS, programmable FPGA, integrated signal conditioning, and modular I/O, as well as tight integration with intuitive NI LabVIEW software.

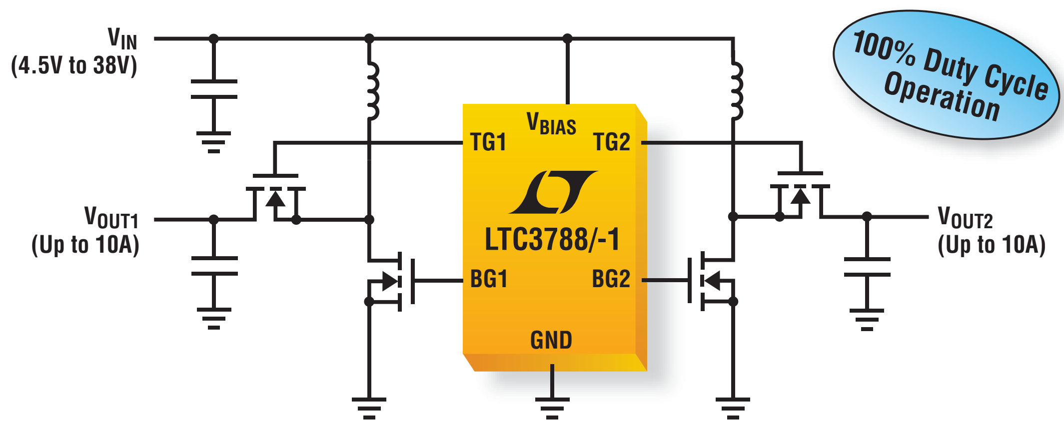
>> Learn how to simplify embedded design at **ni.com/embedded** **888 279 9833**

NATIONAL INSTRUMENTS™

©2009 National Instruments. All rights reserved. CompactRIO, LabVIEW, National Instruments, NI, and ni.com are trademarks of National Instruments.
Other product and company names listed are trademarks or trade names of their respective companies. 2008-101795-305-101-D

High Power Dual Synchronous Boost

ALL SURFACE MOUNT – NO HEAT SINK

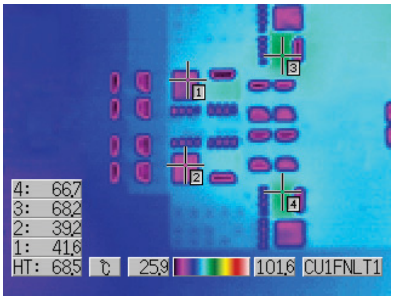


Our LTC®3788 is a new generation dual synchronous boost controller with the performance and features to power high current circuits such as fuel injection systems and audio power amplifiers. Its powerful on-chip N-channel MOSFET drivers deliver up to 10A of continuous output current per channel to voltages as high as 60V with efficiencies over 95%. The LTC3788's synchronous operation ensures superior thermal performance, greatly simplifying mechanical design.

Features

- Input Voltage: 4.5V to 38V
  - Down to 2.5V After Start-up
- Output Voltage: Up to 60V
- Minimal Input Ripple
- Multiphase Capable for Higher Output Current & Low Input Ripple
- Up to 97% Efficient
- Standby Quiescent Current: 125µA
- Powerful 1.5Ω Gate Drivers
- R_{SENSE} or Inductor DCR Sensing
- LTC3787: 2-Phase Single Output

Minimal Temp Rise in the MOSFETs
No Heatsink or Air Flow



1, 2, 3 & 4 are Top and Bottom MOSFETs
V_{IN} = 9V, V_{OUT} = 12V, I_{OUT} = 8A (96W)
Max Temp Rise = 43.7°C

Info & Free Samples

www.linear.com/3788

1-800-4-LINEAR

Free DC/DC Controllers Brochure

www.linear.com/dcdcsolutions

LT, LT, LTC, LTM, Linear Technology and the Linear logo are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

LINEAR TECHNOLOGY