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VOICE OF THE ENGINEER

September 1
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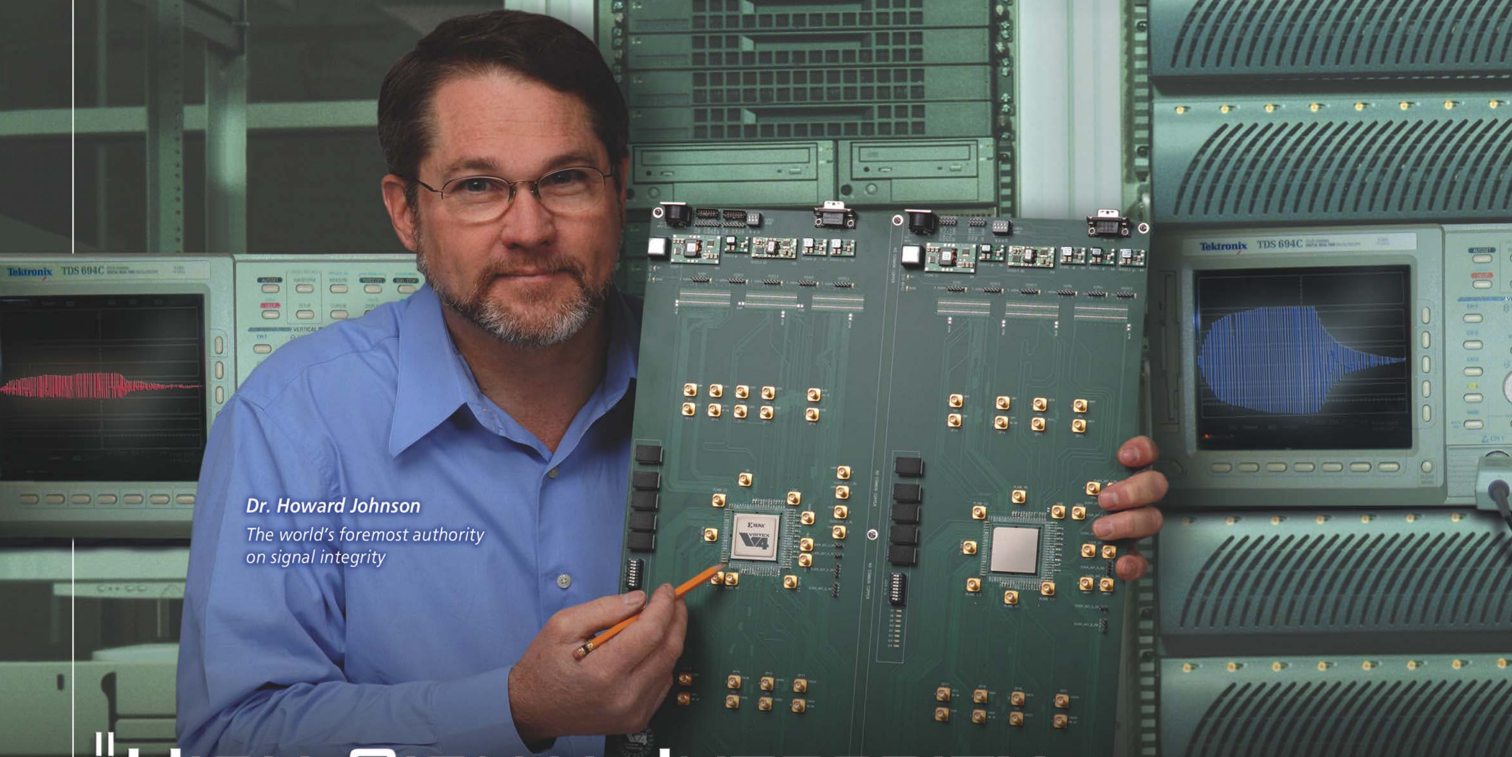

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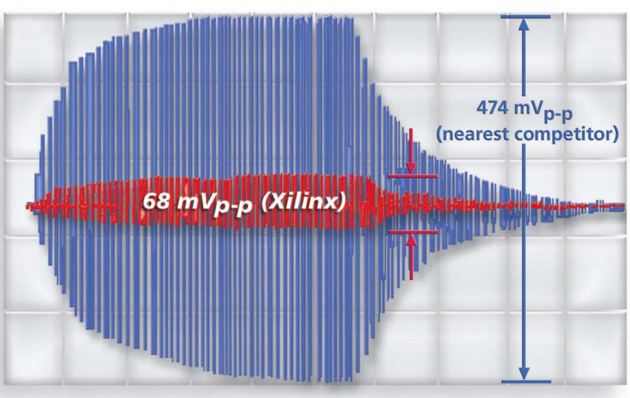

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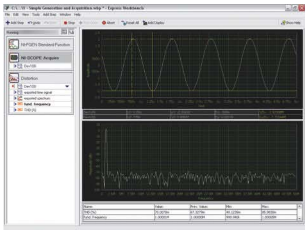

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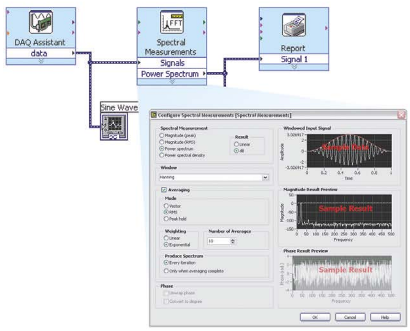

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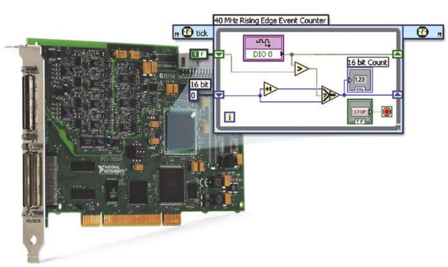

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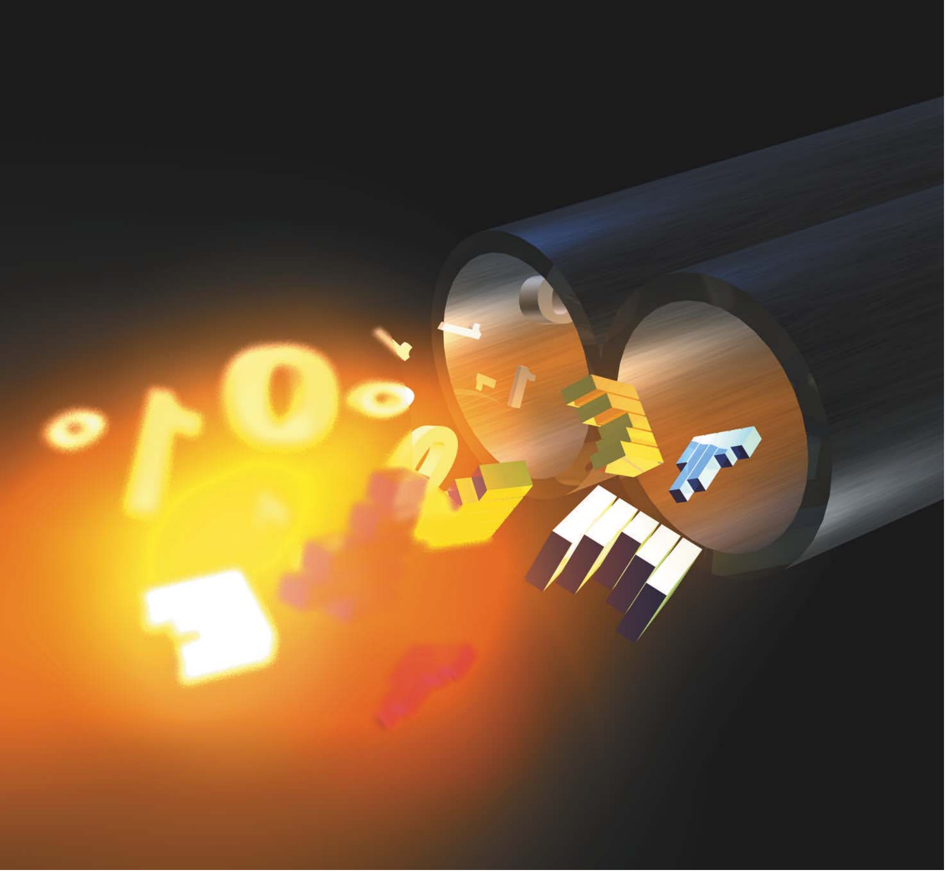

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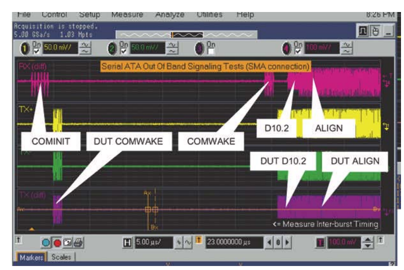

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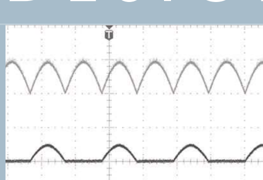

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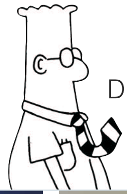

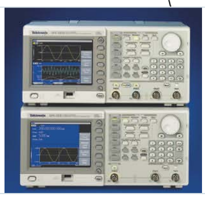

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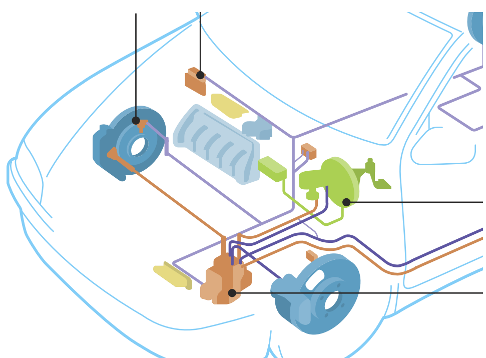

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DEPARTMENTS & COLUMNS

PRODUCT ROUNDUP

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COMPLETE DESIGN SOLUTION
SIMULATION

BY BILL SCHWEBER, EXECUTIVE EDITOR

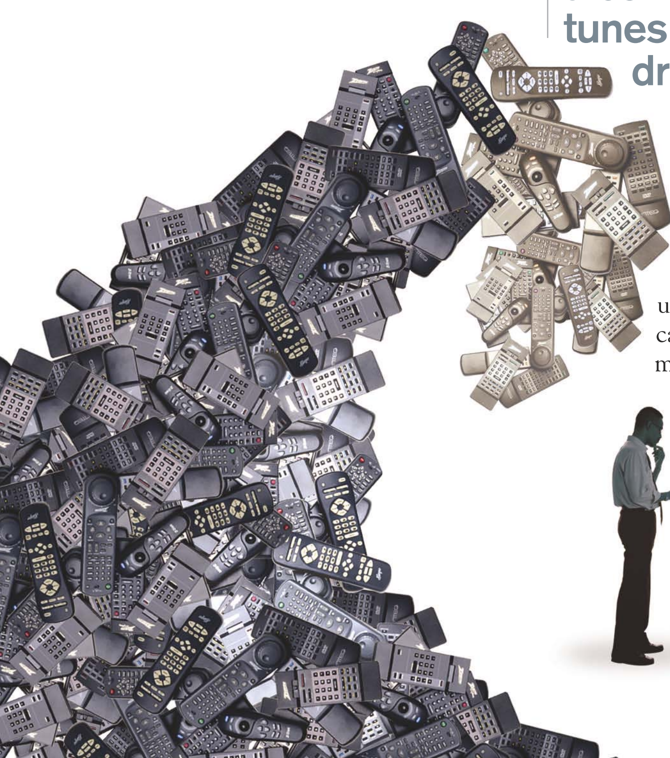
When "the next big thing" isn't

We're in an industry that is defined by change. We've learned to live with it and profit from it, even if we don't like it, it unsettles us, or it changes our business model.

One of the most significant changes that we have seen is the increasing role of consumer electronics in our industry—from ICs through end products and software. This trend is a distinct shift from the industrial, instrumentation, commercial, and military/aerospace applications that traditionally dominated and defined our products and applications. Now, we need extremely high volumes to support the incredibly expensive fabs that implement the progression of Moore's Law. Or, is it the other way around, and we need the costly fabs to provide the volume of components? It's hard to say which comes first, because both factors—chip demand and fab capacity—tend to drive each other in a recursive, positive-feedback, reinforcing manner.

How much of the electronics business depends on mass-market consumer products? It's hard to say, because there are so many legitimate ways to define and measure it, as well as inherent data inaccuracies. You can use component dollars, final-product dollars, number of units of either of those, allocation of R&D efforts, and more. The numbers I have seen put the consumer part of our industry at 30 to 50% of the total business, up from around 10 to 20% just 20 years ago.

When the next big thing doesn't happen or it happens with someone else, a company's fortunes may change dramatically.



With this change in industry focus comes a change in business strategy, for both established vendors and newer players. Everyone is looking for the next big thing, to ride the wave of success that will drive volume, yield enormous returns on investment, lock up a market for a few years, and magically solve all sorts of problems for the winners. Being on the right side, at the right time, of this "killer app" is the objective.

There are short- and long-term downsides to this quest. It is impossible for 100 companies to each get 10% of the market, and, when you bet big, you can lose big, too. This situation contrasts sharply with the climate just a few years ago, when companies would boast about diverse customer bases and note that no single customer or application accounted for more than a tiny fraction of their businesses. Now, they proudly note the opposite: that relatively few big customers are significant portions of their revenue. Of course, that's true only until a few of those key accounts go elsewhere. When the next big thing doesn't happen or it happens with someone else, a company's fortunes may change dramatically.

There's another side effect that should concern you. The application-engineering departments at most vendors are usually key resources in helping users successfully implement and complete solid, respectable designs. As vendors focus on that handful of key customers representing the next big thing, they have less incentive to provide support to the individually smaller, but broader, potential-user base. In fact, for many application-specific ICs, there are only a few viable customers. (After all, how many OEMs specialize in integrated disk-drive controllers and read/write channels?) So, some application departments are really auxiliary design teams for key customers. This approach might make business sense, but it could hinder the long-term development of industry engineering talent, depth, and versatility. **EDN**

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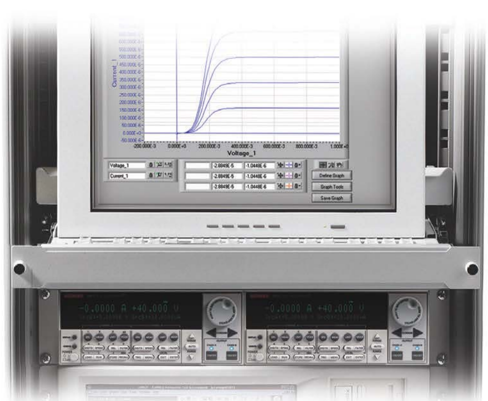

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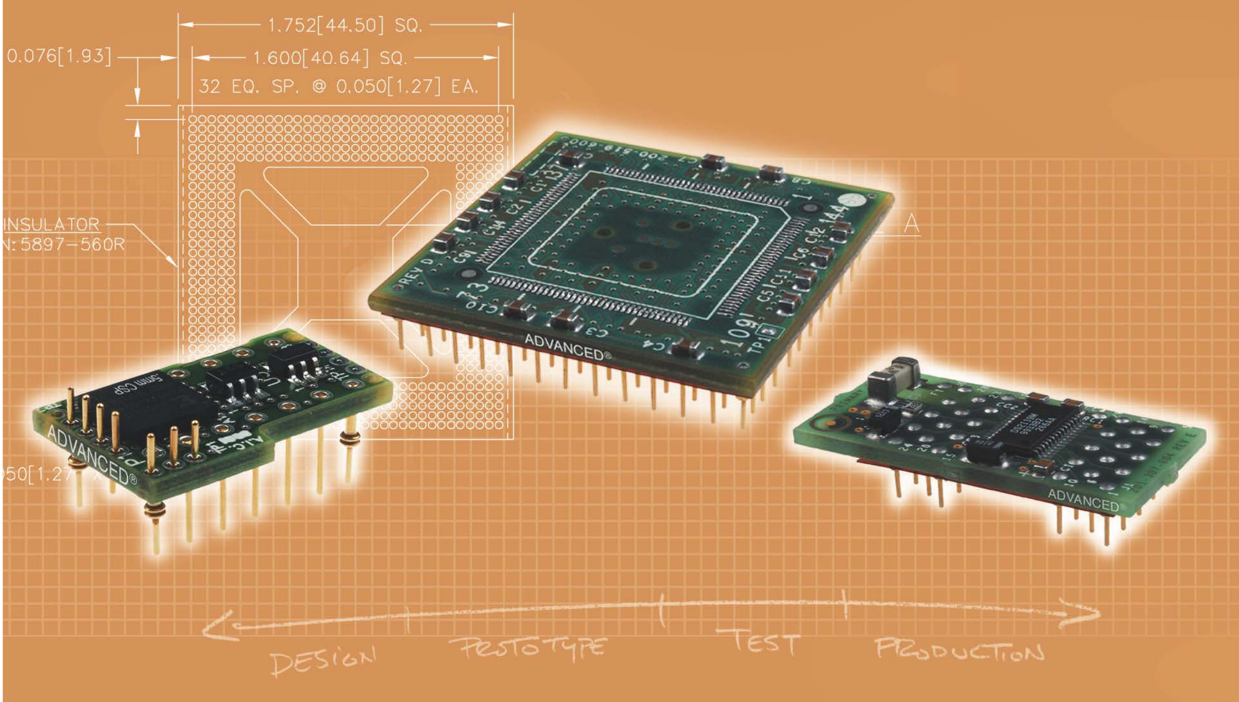
No one wants to go back to the drawing board when device packages change.



Don't redesign...Adapt.

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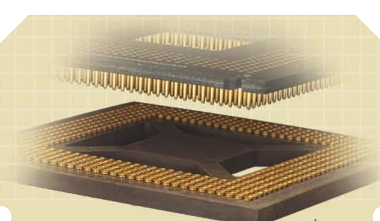

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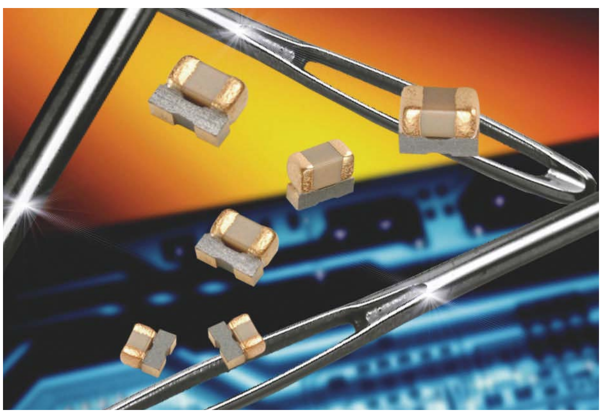
Passives step up to meet gigahertz needs

It's not just that ICs are getting faster; their critical support passives have to move up in bandwidth, as well. The GZ capacitor series from AVX Corp provides dc-blocking operation at the 15-kHz to 40-GHz bandwidth that optical transceivers use. The surface-mount, MLCs (multilayer capacitors) use Ni-Al (nickel-aluminum) terminations and feature resonance-free performance of less than 0.5-dB dip through at least 26.5 GHz. Their footprints match the 0.015-in. (0.38-mm) and 0.020-in. (0.51-mm) microstripline-design widths that are common in pc boards for these frequencies. Prices range from $1 to $4.



Reaching the 40-GHz world of optical transceivers, the GZ capacitor series from AVX targets the implementation of dc-blocking functions in packaging that matches standard microstripline widths.

The company also offers 0603-sized units based on porcelain and ceramic MLC design and featuring high Q and low ESR (equivalent series resistance). The SQCS series has capacitance of 0.1 to 100 pF. The 250V units target use in 1-MHz to 10-GHz systems, and they also sport the desirable NPO characteristic of stable specifications over an operating-temperature range of −55 to +125°C. They sell for 4 to 50 cents, depending on value and volume.

For inductance values of 0.82 to 6.8 nH, the gigahertz-range SQ series uses thin-film technology in 0402-sized land-grid-array cases. According to Product Manager Larry Eisenberger, "This is the thin-film equivalent of wirewound inductors, capable of any value in the range, at tolerances that are much tighter than those offered by wirewound." The SQ series devices sell for 10 to 30 cents.**—by Bill Schweber**

▷**AVX Corp**, www.avx.com.

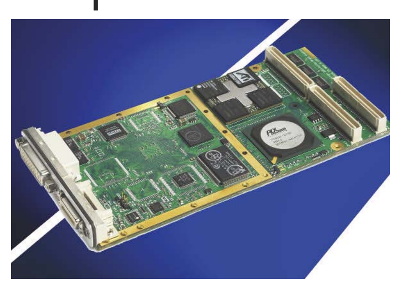
Dual-channel PMC card offers graphics options

Curtiss-Wright Controls Embedded Computing has introduced a dual-channel, high-resolution PMC graphics controller for VME, CompactPCI, and PCI systems. The company based the AtlasPMC/1D on ATI Technologies' (www.ati.com) Radeon M9 mobile graphics processor, which supports dual 2-D-, 3-D-, OpenGL-, and DirectX-compatible displays with as many as 16.7 million colors. The M9 integrates 64 Mbytes of memory, reduced-power features, a video output, and quad-pipeline 2- and 3-D acceleration to reduce host-processor overhead.

Operating in 0 to 70°C environments, the module displays analog-VGA screen resolutions as high as 1920×1200 pixels over both of its front-panel connectors, and designers can also configure it to output dual digital-video channels at resolutions as high as 1600×1200 pixels. The card's second channel supports NTSC or PAL TV-video-signal output. Curtiss-Wright provides software support for Linux, Windows, and Solaris operating environments. The AtlasPMC/1D sells for $1750 (one).

—by Warren Webb

▷**Curtiss-Wright Controls Embedded Computing**, www.cwcembedded.com.



The AtlasPMC/1D supports dual 2-D-, 3-D-, OpenGL-, and DirectX-compatible displays with screen resolutions as high as 1920×1200 pixels and optional digital video.

Support for small processors grows

Microchip's support of small processors includes new PIC devices, a new 4×4-mm QFN-package option for 14 devices ranging from eight to 20 pins, upgraded development tools, and a PICdem demonstration board. The new processor devices include the PIC16F690 family that incorporates improved peripherals, such as a new dual-comparator peripheral architecture. The PIC16-F690-family devices are available for sampling and in volume production in 20-pin PDIP, SOIC, SSOP, and QFN packages with prices starting at $1.78 (10,000). In addition to the new comparator architecture, the PIC16F506/12F510 devices feature a 1.125-msec device-reset timer and a faster internal oscillator that can operate at 8 MHz with strong stability across its rated voltage and temperature range. Both devices are available for general sampling with volume production planned for late 2005. The PIC12F510 sells for 81 cents (10,000), and the PIC16F506 sells for 90 cents (10,000).

The small-form-factor PIC-10F220/10F222 family integrates an 8-bit ADC in an SOT-23 package that is the size of a transistor. These devices are available for limited sampling in six-pin SOT-23 packages; volume production for both microcontrollers will begin in the fourth quarter of 2005. The processors are available for 65 to 74 cents (10,000). The PIC16F639 family rounds out the new device offerings by featuring a 125-kHz wireless-communication analog front end and Keeloq security to target passive-keyless-entry applications. The PIC16F639 is available for sampling in a 20-pin SSOP, and volume production will begin in the third quarter; the PIC16F639 sells for $2.18 (10,000).

To better support software development, the PICkit 2 starter kit will become available to designers in August for as little as $34.99. The PICdem Mechatronics demonstration kit shows engineers how to use the PIC microcontrollers in electromechanical or mechatronic systems; the kit includes nine projects showing designers how to read sensors, drive brush dc or stepper motors, and display values on LEDs or LCDs. The PICdem is available for $149.99.

—by Robert Cravotta

▷**Microchip**, www.microchip.com.

FEEDBACK LOOP

"Ah, yes—the Harvard MBA mentality. Focus only on next quarter's profits and not the big picture. Don't you know? We're all going to have a wonderfully advanced standard of living by selling hot dogs to each other ROHS (restriction of hazardous substances) be damned."

Steven J Ackerman, in *EDN*'s Feedback Loop at www.edn.com/article/CA601510. Add your comments.

Degausser ensures total magnetic-media erasure

Everyone is concerned about security at the network, format, and physical levels. So, how do you quickly and thoroughly wipe clean those hard disks, tapes, and floppy disks? Software can perform repeated overwrites, but the results may not be secure enough, the software takes time to run, and you may not even have a viable drive unit or controller for the old media.

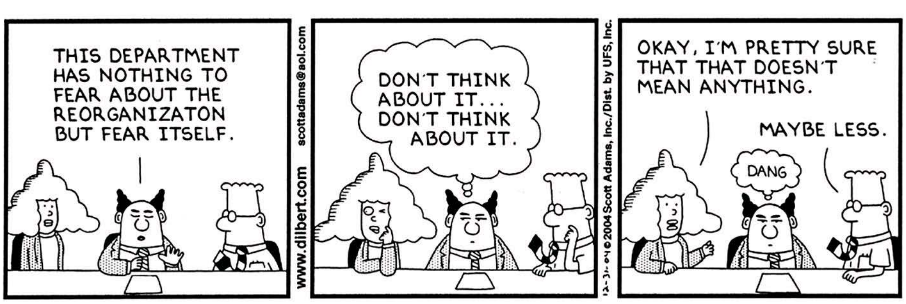
Instead, consider the Mobile Mag EraSure from Security Engineered Machinery. This permanent-magnet-based degausser requires no power supply and delivers flux density of 5000 to 13,000 gauss, corresponding to coercivity as high as 4200 oersteds. Using rare-earth NdFeB (neodymium-iron-boron) magnets, the unit includes a hand crank that, when the user turns it, pushes the subject drive or tape into and out of the box for total erasure in less than 60 sec. The 44-lb (20-kg) unit measures 24×11×7.5 in. (61×30×19 cm) and costs approximately $25,500. Just be careful where you put it and how you transport it.

You can completely erase tiny magnetic domains, whether they reside on hard-disk drive, floppy disk, or tape, using the Mobile Mag EraSure.

—by Bill Schweber

▶Security Engineered Machinery, www.semshred.com.

DILBERT *By Scott Adams*



DATA CONVERTERS

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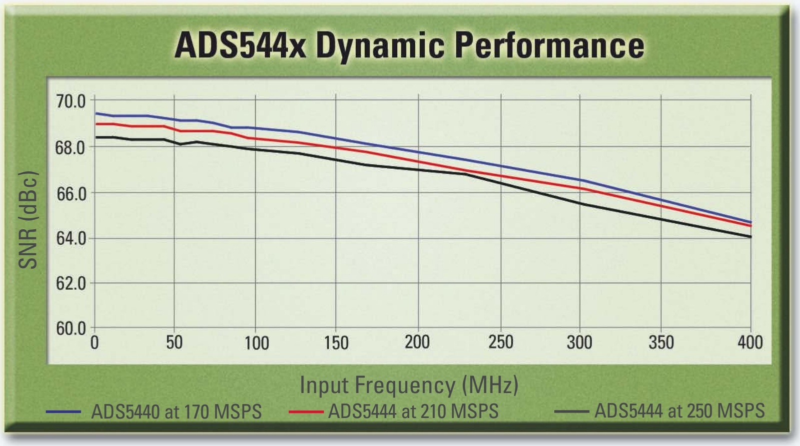
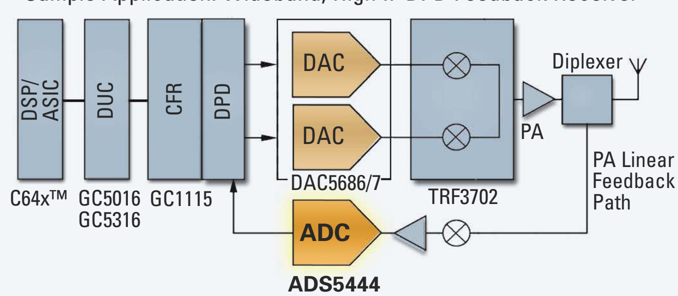
13-Bit, 250-MSPS ADC



Sample Application: Wideband, High IF DPD Feedback Receiver



The new **ADS5444** from Texas Instruments sets a new benchmark for high-speed ADCs, providing best-in-class performance at 250 MHz. Look to TI for a complete portfolio of high-speed ADCs, including the recently announced ADS5440 13-bit, 250 MSPS ADC.

Device	Resolution (Bits)	Speed (MSPS)	SNR (dBc)	SFDR (dBc)
ADS5444	13	250	68 at 230 MHz IF	75 at 230 MHz IF
ADS5440	13	210	68 at 230 MHz IF	79 at 230 MHz IF
ADS5500	14	125	69.5 at 100 MHz IF	82 at 100 MHz IF
ADS5424	14	105	74 at 50 MHz IF	93 at 50 MHz IF
ADS5541	14	105	71 at 100 MHz IF	86 at 100 MHz IF
ADS5423	14	80	74 at 50 MHz IF	94 at 50 MHz IF
ADS5520	12	125	68.7 at 100 MHz IF	82 at 100 MHz IF
ADS5521	12	105	69 at 100 MHz IF	86 at 100 MHz IF

▸ Applications

- Software-defined radio
- Base stations:
  - Wideband receiver
  - High IF receiver
  - PA linearization
- Instrumentation
- Test and Measurement

▸ Features

- 100 MHz IF: SNR = 68.7 dBc; SFDR = 73 dBc
- 230 MHz IF: SNR = 68 dBc; SFDR = 75 dBc
- Fully buffered analog inputs
- 2.2 Vpp differential input voltage
- 3.3 V LVDS compatible outputs
- TQFP-80 PowerPAD™ package
- Industrial temperature range –40°C to +85°C
- Price: $95 1k

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Technology for Innovators™ TEXAS INSTRUMENTS

2G-sample/sec waveform generators resolve 14 bits vertically, 12 digits in frequency

Six new arbitrary-function generators from Tektronix, the AFG-3000 series, generate sine, square, pulse, arbitrary, ramp, sin(x)/x, gaussian, Lorenz, exponential rise/decay, haversine, and noise waveforms, as well as dc voltages. The 9.9-lb units sell for $1780 to $8500 and are available in 6.2×13×6.6-in. cases approximately the size of the company's TDS-3000-series digital scopes. Three of the units produce single-channel outputs, and three produce two-channel outputs.

The lowest priced family members create sine waves with frequencies to 25 MHz; square waves, pulses, and arbitrary waveforms to 12.5 MHz; and other waveforms to 250 kHz. For the midpriced units, the three frequency ranges extend to 100, 50, and 1 MHz, and, for the top-of-the-line units, the ranges extend to 240, 120, and 2.4 MHz. For all six units, the lowest output frequency for all three waveform classes is 10^{-3} Hz; the frequency resolution is 1 µHz, or 12 digits; timebase stability is ±1 ppm/year; vertical resolution is 14 bits; and amplitude resolution is 0.1 mV p-p, or four digits.

The AFG3252 (top) and the AFG3251 (bottom), two- and one-channel arbitrary function generators, reconstruct waveforms at rates as high as 2G samples/sec.

The arbitrary-waveform memory of the lowest priced units is 1k to 64k samples, and the maximum rate at which the units convert digital values to analog is 250M samples/sec. The same sample rate applies to the midpriced and top-of-the-line units when waveform data sets comprise 16k to 128k samples. For data sets of 16k samples or fewer, the midpriced units can convert at 1G sample/sec. For data sets of the same size, the top-of-the-line units can convert at 2G samples/sec.

All units can perform amplitude, frequency, phase-width, and pulse-width modulation, as well as frequency-shift keying and linear and logarithmic sweeps. The low-priced and midpriced units deliver 10V p-p into 50Ω, and the wider bandwidth, top-of-the-line units deliver 5V p-p into 50Ω. The two lowest priced units include front and rear USB ports for attachment of a memory-stick device and connection to a host PC, respectively. To the USB ports, the midpriced and top-of-the-line units add LAN and IEEE 488 connections. AFG-3000 generators' proprietary-waveform format is compatible with Tektronix's free ArbExpress 2.0 waveform-creation and -editing software. ArbExpress, which is also compatible with most Tek oscilloscopes and with The MathWorks (www.mathworks.com) Matlab, also supports CSV (comma-separated-value) format for compatibility with many other applications, including Excel (www.microsoft.com).

All of the generators sport 5.6-in. LCDs, which, except for that of the lowest priced unit, produce color displays. The displays provide information in both numeric and graphical forms. Although the graphical displays resemble those of oscilloscopes, Tek points out that the generators are not scopes. For example, if you set the generator to produce a sine-wave carrier at, say, 500 kHz, with amplitude modulated by another sine wave at 1 kHz, you might expect to see the carrier sine waves scrunched-up. You might also expect them to be displayed as a bright band whose amplitude the modulating audio-frequency sine wave determines. Instead, the generator represents the carrier frequency by a much lower frequency, so you can see the carrier-frequency waves' sinusoidal shape. On the generator's screen, only 13 carrier-frequency sine waves appear in two cycles of the modulation—a far cry from the 1000 cycles in the waveform the generator produces.

—by Dan Strassberg

▷**Tektronix Inc**, www.tektronix.com.

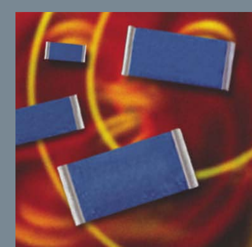
Resistors keep their cool, even when the system doesn't

Targeting operation in not-so-benign environments, new chip resistors, voltage dividers, and resistor networks from the IRC Division of TT Electronics meet all critical specs over the −65 to +200°C range. The PFCD-HT SMT voltage dividers come in a 1206 package, and the TaN (tantalum-nitrogen)-film-based PFC-HT chip resistors come in 0603, 0805, and 1206 packages. The 1900HT and 4700HT DIP and SIP networks are available in a variety of nominal values to match application needs. The voltage dividers have absolute tolerance of ±1% and temperature coefficient as low as ±25 ppm/°C with ratio tolerances to ±0.1% and tracking to ±5 ppm/°C over the full temperature range

Specifications for the chip resistors and DIP/SIP networks are similar. Power rating for the dividers is 125 mW; for the chip resistors, it spans 62.5 to 125 mW, depending on value. For the DIP networks, it is slightly greater than 1W, and, for the SIP networks, it is 0.24 to 0.32W. Prices range from $1 to $5.

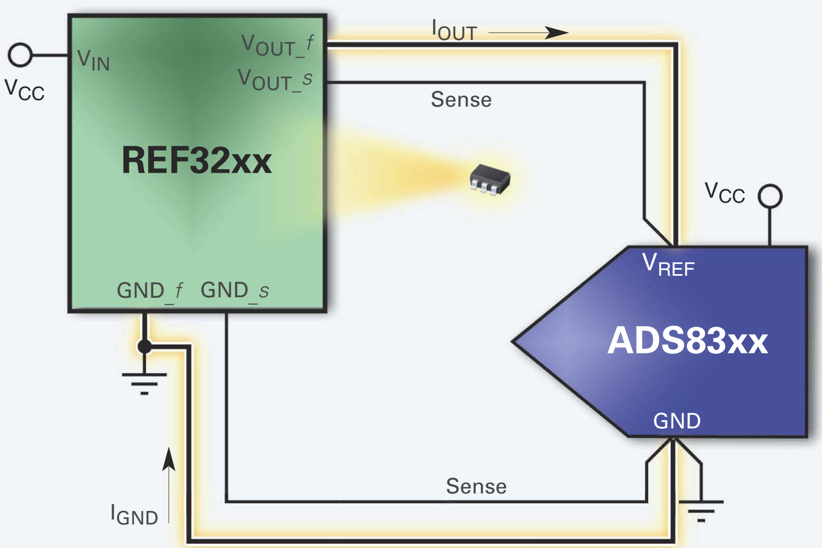
—by Bill Schweber

▶IRC Inc, TT Electronics PLC, www.irctt.com.



As your system gets hotter and hotter, you needn't worry about resistors drifting too far from their nominal specifications with these SMT voltage dividers, chip resistors, and SIP and DIP networks from IRC/TT Electronics.

Low-Drift 4ppm/°C Voltage Reference with 4-Wire Connection



▶ **Applications**

- Portable equipment
- Data acquisition systems
- Medical equipment
- Test equipment

▶ **Features**

- 7ppm/°C (max) at 0°C to +125°C
- 17ppm/°C (max) at –40°C to +125°C
- Supply current:
  –Typical 100µA
  –Shutdown 1µA
- High output current: ±10mA
- Low dropout: 5mV
- SOT23-6
- Pricing: $1.70 in 1,000s

The new **REF32xx** family of voltage references uses an innovative, industry-first, 4-wire technique, fast recovery (60µs) shutdown, improved accuracy, and is stable with any capacitive load. Small size and low power consumption (120µA max) make it ideal for portable and battery-powered applications.

Available Output Voltages

Device	Output Voltage (V) (typ)	Initial Accuracy (%) (max)	Temp. Coeff. (ppm/°C) (typ)	Temp. Coeff. (ppm/°C) (max)	Long-Term Stability (ppm/kHr) (typ)	Noise (0.1 to 10Hz) (μV_{pp}) (typ)	Reference Type	I_Q (µA) (max)	Package	Price Starts at 1k
REF02	5	0.2	4	10	50	4	Buried Zener	1,400	DIP-8, SO-8	$1.90
REF102	10	0.05	–	2.5	5	5	Buried Zener	1,400	DIP-8, SO-8	$1.75
REF1004x	1.235, 2.5	0.3	20	23	20	18	Shunt	0.01-20	SOIC-8	$1.30
REF29xx	1.25, 2.048, 2.5, 3, 3.3, 4.096	2	35	100	24	20 - 45	Bandgap	50	SOT23-3	$0.49
REF1112	1.25	0.2	10	30	60	25	Shunt	0.001-5	SOT23-3	$0.85
REF30xx	1.25, 2.048, 2.5, 3, 3.3, 4.096	0.2	20	50	24	14 - 45	Bandgap	50	SOT23-3	$0.60
REF31xx	1.25, 2.048, 2.5, 3, 3.3, 4.096	0.2	5	15	70	17 - 53	Bandgap	115	SOT23-3	$1.10
REF32xx	1.25, 2.048, 2.5, 3, 3.3, 4.096	0.2	4	7	55	17 - 53	Bandgap	1/135	SOT23-6	$1.70

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GLOBAL DESIGNER

Printed circuitry takes on a new meaning

Research organization QinetiQ will soon begin a research program focusing on printing complete electronic circuits, including both active and passive devices. With funding from both the United Kingdom's Ministry of Defense and Department of Trade and Industry, the program will explore the feasibility of applications in both consumer electronics and defense.

Earlier work in active-circuitry printing has focused largely on high-volume, low-cost applications, says project leader and QinetiQ Research Fellow Ian Sage, PhD. By contrast, his program will first develop materials and then examine ways of applying them to areas in which users might derive other benefits.

In the consumer area, a possible route is the development of production processes that could combine low manufacturing cost with the ability to produce short runs of products with different configurations and features. The research could also result in reductions in the size and cost of many electronic products and allow designers to add electronics in other ways, such as in fabrics or product packaging.

Possible defense applications include printing electronic circuitry onto substrates, including curved shapes, to add functions to an object without adding materially to its weight or volume. Examples might include adding features to a helmet or other items of clothing without impacting their primary functions.

Earlier work has also frequently centered on display technologies. For example, the ability to print the active transistors that every pixel of a TFT (thin-film-transistor) display requires, using deposited conductive polymers instead of etched amorphous silicon, could represent an economical route to mass-producing displays. Such an approach could also be more environmentally friendly than conventional technology, Sage points out. As an additive rather than subtractive process, it potentially dispenses with the need for large quantities of aggressive etching chemicals. For high-volume manufacturing, previous work envisaged production processes such as continuous printing on rolls of flexible substrates or on large sheets. The QinetiQ project will also look at the possibilities for large-screen displays for TV and advertising applications.

QinetiQ has demonstrated the ability to print fine metal lines with a feature size of approximately 1 micron, to build thin-film FETs. The process, "soft lithography," forms a relief mold of the required pattern in a polymer material, which in turn deposits the conductive elements by a pad-printing process. It deposits carefully engineered inks with high resolution. The ink then binds metal selectively onto the surface to form the complex structures that active devices need. In contrast, ink-jet techniques, which previous systems used, are limited to features no smaller than tens of microns. The QinetiQ process will use conventional digital printing techniques, such as ink jet, in the interconnect-deposited components.

Materials that designers can use to print semiconducting layers have typical electron mobilities of 0.1 cm^2/V-sec, Sage notes—a fraction of that of silicon. Nevertheless, with continuing progress in materials technology, he anticipates that designs should be able to achieve switching speeds into the megahertz region.

Observing an impetus in organic electronics in general, Sage says, "A lot more work is needed, but the technology also offers a huge opportunity to quickly add electronics to defense equipment at low cost. And we can expect to see products using printed electronics beginning to appear in stores by the end of the decade."

—by Graham Prophet, *EDN Europe*

▷**QinetiQ,** www.qinetiq.com.

Ecosystem supports collaborative product development

09.01.05

ADI's (Analog Devices Inc's) India development center is focusing on DSP design and application engineering and helping Indian companies develop products for domestic and international markets. MobiApps, a Bangalore-based provider of hybrid terrestrial and satellite technologies for commercial communications, has developed the m100D OEM transceiver for tracking and industrial remote communications. The m100D operates using the Orbcomm low-earth-orbit satellite network and targets fleet-tracking and remote asset-management applications.

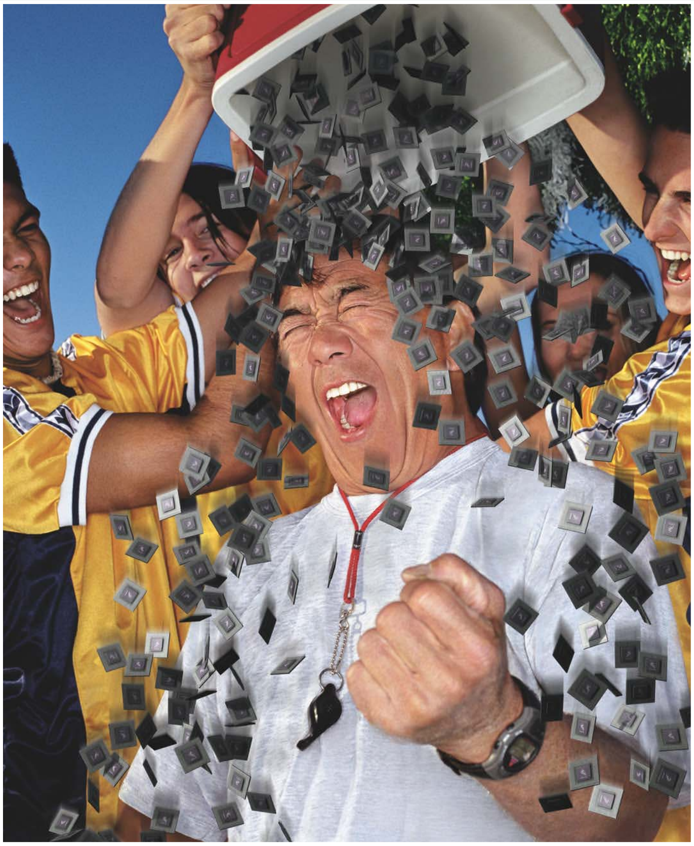
MobiApps based the m100D on the ADI Blackfin DSP, which handles Orbcomm baseband signals; an ADI GPS RF downconverter; and a MobiApps' discrete RF module. Commenting on the use of ADI embedded processors in the design, T Narayana Rao, program manager at ADI India, says, "By using the Blackfin DSP, MobiApps has been able to reduce the size of its product by 50%. A single Blackfin processor does the GPS baseband processing, Orbcomm satellite modem communication, and host processing. This [approach] eliminates the need for three processors." ADI developed Blackfin, a 16/32-bit embedded processor, at its Indian development center.

In addition to the processor, MobiApps also received software-system-engineering assistance from ADI. MobiApps, ADI, and other Indian strategic-development partners jointly developed the GPS engine and associated communications that the MobiApps application uses, explains Rao. The MobiApp transceiver also incorporates a proprietary memory architecture to support over-the-air reprogramming for simplified field logistics.

—by Chitra Giridhar, *EDN Asia*

▶**Analog Devices Inc,** www.analog.com.
▶**MobiApps,** www.mobiapps.com.

STILL THE DESIGN LEADER AND STILL KEEPING OUR COOL.



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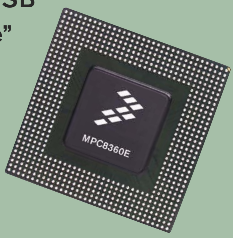

freescale™ semiconductor

Q&A

The MathWorks' Andy Grace on simulation

Andy Grace is vice president of engineering for design tools at The MathWorks. He is responsible for The MathWorks' family of model-based simulation, code-generation, and testing tools. He has more than 15 years of experience in software development and has been involved with a number of The MathWorks' product developments, including Simulink, Real-Time Workshop, Control System Design Toolbox, Optimization Toolbox, and Stateflow. He received his doctorate in computer-aided control-system design from the University of Wales in 1989.

What led you to becoming an engineer?

A I loved making little circuits that would flash lights or make sounds when I was a kid. Then, when my school bought a Z80-based computer back in 1980, I became hooked on programming. In graduate school, I got hooked on an early version of Matlab, wrote an add-on product, and that's how I ended up at The MathWorks.

What has been the impact of more powerful PCs?

A I think it goes without saying that more powerful computers have been tremendous enablers for engineers. Simulation, numerical optimization, and graphical programming are examples of technologies we work on that are much more widespread now that powerful machines are prevalent. The only bad impact I can think of is that, with these powerful numerical techniques, there is less reliance on theoretical or closed-form approaches—and my PC will be obsolete in six months' time!

Where do users of products such as yours have the greatest misunderstanding?

A If you've used Matlab and Simulink before, you know the real benefit is that they give you a playground in which to learn, explore, and innovate. When you enter new markets or address users who've never been exposed to these products, they often want canned functions, such as GUIs, and don't always fully appreciate the power of having two very powerful languages—one textual, Matlab, and one graphical, Simulink—in which to explore ideas.

How has the industry changed since the 1980s and 1990s? Who is now leading the R&D and product-development efforts?

A The MathWorks addresses all industries in which you find engineers and scientists, so it's hard to make a general statement. One common theme I've witnessed over the last 10 years is that companies have become more focused on the process. Quality-process-improvement initiatives, such as Six Sigma [a quality initiative that strives for 3.4 defects per million opportunities], are prevalent in many engineering organizations. We have benefited from this approach, because organizations are trying to tie together disparate parts of their organizations, such as R&D and production, and are looking for technologies such as model-based design to reduce cost and improve quality.

What is model-based design?

A "Model-based design" is a term we've coined to refer to the process of using models throughout a design process. It starts with the conceptual phase, in which you might try out an idea using a graphical model and simulation. You elaborate the model adding more detail at each design iteration—for example, adding data types as you near the implementation phase for an embedded system. You test at each design iteration using any combination of simulation, rapid-prototyping, hardware-in-the-loop, and model-coverage information. You automate the implementation through code generation, which eliminates hand-coding errors.

Enormous benefit comes by tying together all these steps, so all groups are using the same models and talking the same language. For example, this approach means that you can reuse plant or environment models, such as hardware-in-the-loop testing, that you've developed in the conceptual phase for testing of the implementation. And you eliminate a lot of waste by having an unambiguous executable specification, such as a simulatable model that is, using code generation, also the implementation.

Any comments on the state of engineering and science education?

A I believe that engineering education has improved because students and professors have greater access to the tools that they will use in industry. They are much more readily able to put into practice what they've learned in the classroom. With more than 3500 universities worldwide having adopted Matlab and Simulink, we are continuing to see broader use of our products in diverse technical curricula. Students are now entering the workforce with a greater understanding of how to solve today's complex R&D and engineering challenges. I am someone who learns best by discovery, so I have always found tools such as Matlab to be great learning vehicles.

—by Bill Schweber

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For an extended version of this interview, go to www.edn.com/050901/pq&a.

Interface Implementation

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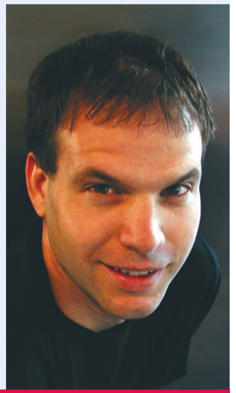
FPGA-Based Software-Defined Radio (SDR) Technology

FPGAs play a critical role in cost-effectively implementing software-defined radio (SDR) technology in real-world applications. Through SDR, developers can create flexible high-speed communications equipment, including radars that can shift operating modes and cellular base stations that can support various radio technologies.



To read this case study, go to **avnet.national.com**

Managing High-Speed Analog Signals for SDR Applications Using FPGAs

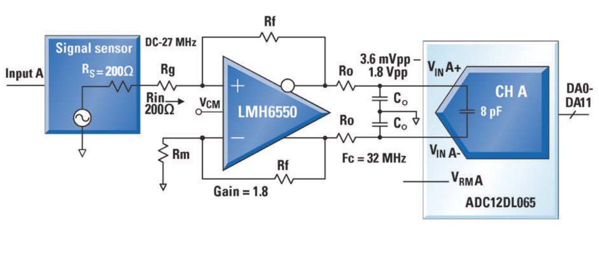
This month, industry expert Nicholas Cravotta explores the key issues behind managing high-speed analog signals in FPGA-based SDR systems, including:

- How to construct a flexible SDR that utilizes a single ADC/FPGA/DSP IF processing subsystem across multiple RF front-ends
- Effective means for handling multi-path distortion
- Implementing down conversion in the ADC to reduce signal and FPGA frequency
- Reducing overall power consumption by reducing operating frequency and managing IF data throughput

PRODUCT SPOTLIGHT:

PART #	DESCRIPTION	PACKAGE TYPE	OPERATING TEMPERATURE RANGE
ADC12DL065	Dual 12-Bit, 65 MSPS, 3.3 V, 360 mW A/D Converter	Evaluation Board, TQFP	-40˚ C to 85˚ C
ADC12DL066	Dual 12-Bit, 66 MSPS, 450 MHz Input Bandwidth A/D Converter with Internal Reference	Evaluation Board, TQFP	-40˚ C to 85˚ C
LMH6550	Differential, High-Speed Operational Amplifier	SOIC NARROW, MINI SOIC	-40˚ C to 85˚ C
LMH6551	Differential, High-Speed Operational Amplifier	SOIC NARROW, MINI SOIC	-40˚ C to 85˚ C
LMV227	Production RF Tested, RF Power Detector for CDMA and WCDMA	—	-40˚ C to 85˚ C
SCAN90CP02	1.5 Gbps 2x2 LVDS Crosspoint Switch with Pre-Emphasis and IEEE 1149.6	LLP, LQFP, Evaluation Board	-40˚ C to 85˚ C

Single-End-to-Differential Amplifier Configuration



BY BONNIE BAKER

Choose your watchdog timer with reliability in mind

Embedded-system applications use WDTs (watchdog timers) to identify error conditions that cause the controller or processor to default into an erroneous state. Stand-alone WDTs used to be quite popular. For a short time, they were more reliable than their counterpart, which was the internal WDT in the controller or processor. With the controller or processor option, if the processor failed to execute in a timely manner, the WDT would surely have problems, as well. But, the stand-alone WDT fell short with its lack of an adjustable clock—allowing the user to change the setting of this timer independently of the system clock. The stand-alone WDT was missing features, such as minimum and maximum trigger times. With multiple triggers built into the WDT, you can catch situations in which the application system is running too slow or too fast.

Once again, the integrated-controller option has effectively assimilated the stand-alone option and gained some sophistication in the process. Today, the design of integrated WDTs is a separate function on the same chip. The clock on today's controller WDT is many times separate and usually set to an independent clock, such as an on-chip, RC time constant. With this configuration, the WDT clock is essentially isolated from the controller's system clock or oscillator. This fact alone could point you toward using the integrated-WDT option for your application.

These integrated devices also provide the flexibility of programming the number of counts in the WDT counter with a ratio of 1-to-16,384 or more to program the counter for ranges of milliseconds to several seconds. Controller and processor manufacturers call this function the WDT prescaler. With this generation of microcontroller WDTs,

The stand-alone WDT has also evolved from having the integrated WDT's simple, primitive function to a more sophisticated version.

you can also program two or more triggers in the software. These triggers can catch erroneous code in noisy environments. The microcontroller WDT also continues to operate independently of the controller's sleep and idle modes. Other features, such as a double reset code, reduce the probability of false WDT resets in noisy environments.

So, does the stand-alone WDT provide functions that the integrated version does not? Essentially, the stand-alone WDT has also evolved from having the integrated WDT's simple, primitive function to a more sophisticated version. The functions of the stand-alone unit now include all of the features of the controller/processor version, except for on-the-fly programmability and double-reset-code capability. Some stand-alone WDTs also feature manual-reset pins to implement pushbuttons for the user. But you can easily implement this function with controller or processor interrupts or other designated controller pins, such as a master clear.

Both the integrated and the stand-alone options offer the possibility of EM (electromagnetic) interference or static discharge. If your layout is sensitive, the stand-alone WDT may be more susceptible to these disturbances, particularly if the alternative controller or processor WDT has double coding for the WDT reset. One issue may erroneously point you to a stand-alone version over the integrated microcontroller and microprocessor. When safety is critical, using an independent clock source may be preferable. For certain equipment, regulatory agencies recommend the use of independent WDTs. The controller-integrated-isolated version, as well as the stand-alone chip, effectively fit this bill. Additionally, many designers prefer the benefit of the other controller's power-control features, such as power-on reset or brownout reset.

The decision to use an integrated WDT or stand-alone WDT could go either way, depending on your application. But the truth about WDT challenges does not stop at hardware selection. The software plays an equal or larger role in ensuring that your system is robust and reliable on the way off the manufacturing floor. In your software, you can effectively program your WDT characteristics to fit the specifics of your application. EDN

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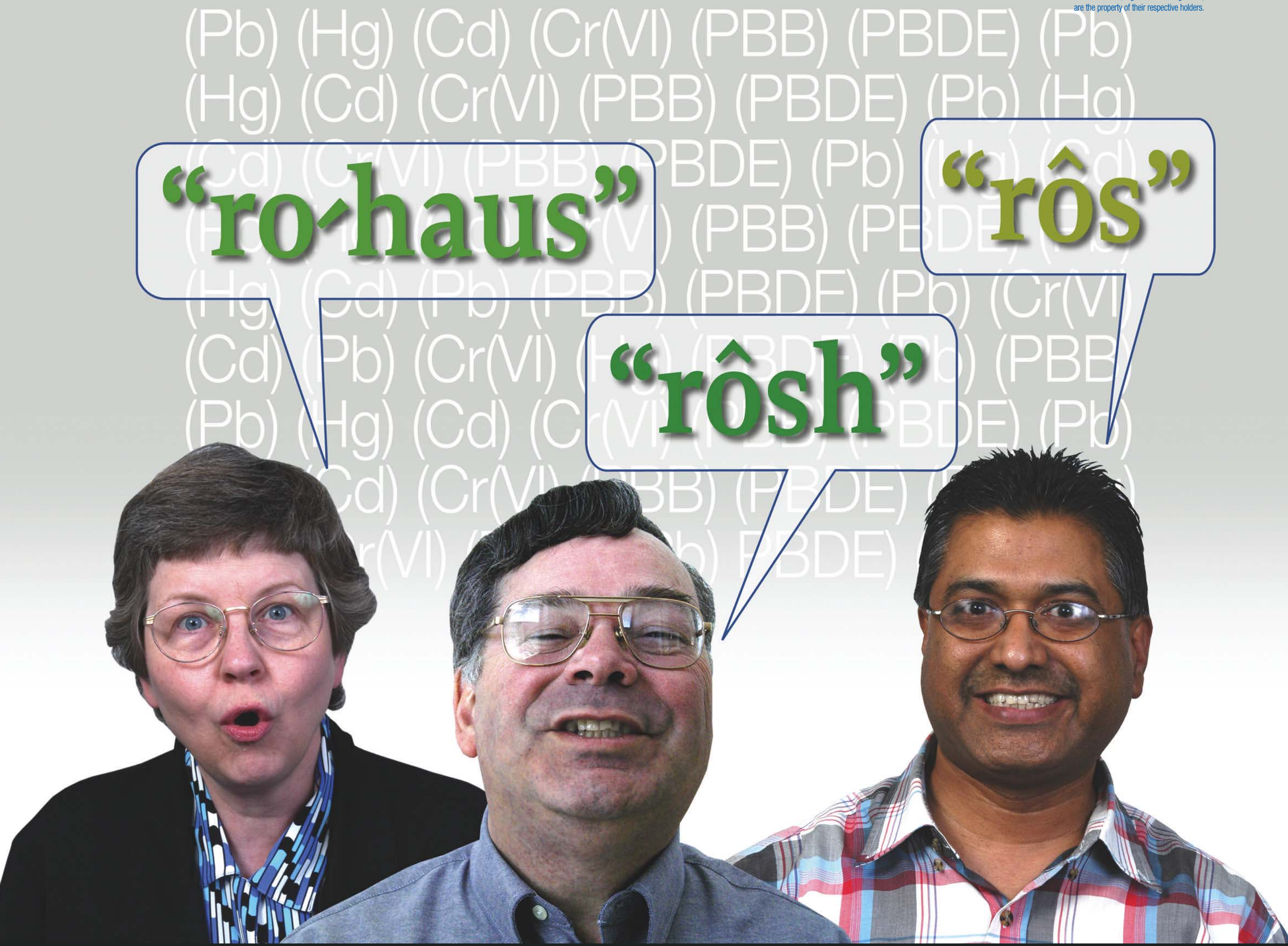
Bonnie Baker is the author of A Baker's Dozen: Real Analog Solutions for Digital Designers. *You can reach her at bonnie.baker@microchip.com.*



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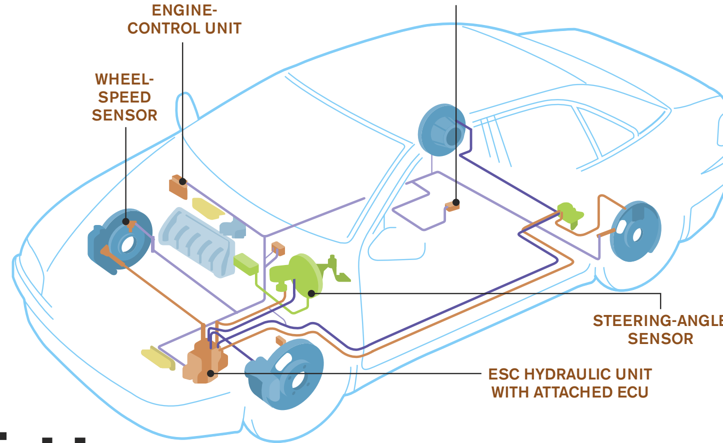
Engineers have found a way to keep vehicles stable while driving on slippery surfaces. Now they need to cut the technology's cost so they can convince the public to buy it.

It's all about μ



An electronic-stability-control system includes a lateral accelerometer, gyroscopic yaw-rate sensor, and steering-angle sensor, plus an electronics module and wiring harness.

In many cases, the fatal scenario is simple: Skid. Trip. Roll. Crash. Within seconds, the deadly chain of events is irreversible, and another life is lost on the highways. Now, however, that situation may be changing. After more than a decade of experience with ESC (electronic-stability-control) systems, automotive researchers are comprehending the value of this little-used technology. Stop the skid with ESC, they're saying, and you can head off the other events in the gruesome chain.

"When you consider that there are between 14,000 and 17,000 single-vehicle fatalities every year, and we can reduce those fatalities by 50%, you realize we're dealing with a huge number of lives that could be saved," says Rich Golitko, marketing director for ESC at Bosch Automotive.

An ESC system's primary components include a lateral accelerometer, gyroscopic yaw-rate sensor, and steering-angle sensor, as well as an electronics module and wiring harness. The system works by measuring yaw and lateral acceleration, then comparing that to the driver's desired path, as indicated by the steering-angle sensor. If a microcontroller determines that the difference between the desired path and actual path is too great, the system activates one or more of the wheel brakes by means of the ABS (antilock-braking system).

To fully comprehend the nature of what's happening, most stability-control systems also employ vehicle data, such as vehicle mass, wheel mass, center of gravity, drag coefficient, engine torque, pitch moment of inertia, roll moment of inertia, and more. A stability-control system uses that data to determine whether additional measures, such as pulling back on the throttle or braking another wheel, are necessary.

ESC also uses the sensor data to derive a rough estimate of the coefficient of friction (μ) on the driving surface. Knowing μ, as well as the vehicle's performance characteristics, helps ESC determine how much intervention is necessary and when the time has come for action.

To make ESC affordable, electronics vendors are working on lower cost sensors, as well as on electronic integration methods that would help reduce installation costs. Analog Devices, for example, has developed silicon-based yaw-rate sensors that could ultimately cost substantially less than the quartz-based, piezoelectric tuning fork "gyros" now used in most ESC systems. Unlike the quartz gyros, which use the frequency of the tuning fork to measure yaw, the silicon sensors employ a "vibrating mass," which produces a voltage signal that's proportional to the vehicle's angular rate of change. By employing silicon instead of quartz, Analog Devices engineers believe they can bring down sensor costs from their current levels of \$20 to \$30 apiece, to less than \$10.

Device integration could also be a key way to cut costs, engineers say. Analog Devices, among others, is working on integrating lateral accelerometers onto a single die with yaw-rate sensors. Such efforts go hand in hand with attempts to integrate ESC electronics into ABSs under the hood, instead of in their current location in the passenger compartment. Doing so would eliminate the need for costly wiring harnesses that must pass through firewalls between the passenger and engine compartments. Some automakers are also said to be looking at the possibility of leaving the ESC electronics in the passenger compartment, and instead cutting costs by integrating the ESC module with the air-bag module.

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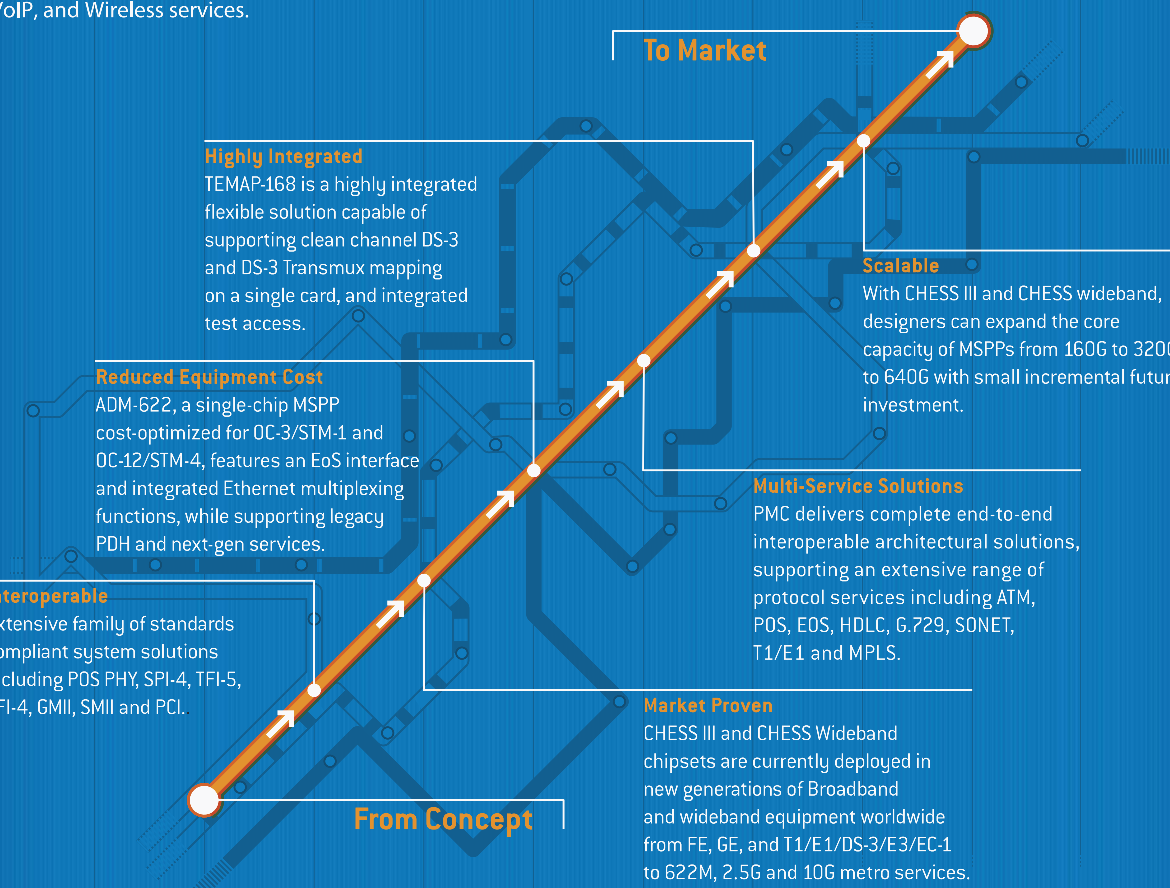

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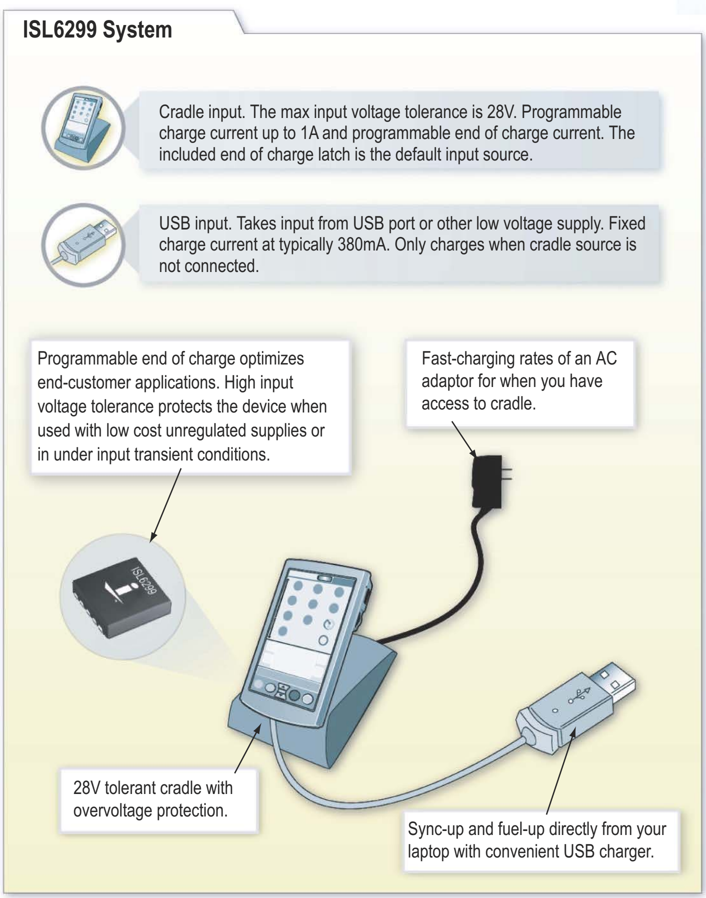

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VIDEO OVER THE INTERNET: Services and devices move closer to living-room convenience

EDN'S DIGITAL DENIZENS EVALUATE WHETHER SOME OF THE NEWEST DIGITAL-VIDEO APPLIANCES HAVE A FUTURE IN TOMORROW'S DIGITAL DEN.

You could argue that the Internet has long been used for video distribution, but such applications have been mostly computer-centric and the video of questionable quality. But recent Digital Den experiments with the Akimbo PVR (personal video recorder) and the Slingbox suggest that mainstream consumers can both receive quality video streams through the Internet and use the Internet to "place shift" their own content. And assuming some form of a home network, the products and services won't bust the bank. Remaining obstacles include distributing digital video in a home, the rather narrow choice of Internet content, and, of course, the business models involved. Still, our evaluation suggests that digital video is in the nascent stage and will still offer designers and entrepreneurs many opportunities in the future.

The Digital Den staff set out to look at three issues in this digital-video project. First, we'd evaluate how well video delivery over the Internet to an Akimbo PVR works (**Figure 1**). We'd also consider place shifting. For those who haven't heard of Slingbox, the diminutive box sits in the living room, encodes the video you receive using cable, antenna, or satellite, and streams that content to PCs connected via a home network or the Internet (**Figure 2**). The industry has begun to call this function "place shifting," as opposed to the time-shifting function that a PVR offers. Finally, we'd also set out to see how you might integrate such diverse functions into a workable whole-house A/V environment (see **sidebar** "Whole-house modulator works, but picture quality suffers").

A home network is the common element that both Akimbo and Slingbox require. And both Akimbo and Slingbox are typically living-room-resident devices. Akimbo would typically connect to your TV, and Slingbox to the same source that feeds your main TV. So, the first step in anyone evaluating these products may be a network upgrade.

Figure 1 It could pass as any other PVR, but the Akimbo allows users to specify what content it downloads using a standard Internet connection and buffers on the internal hard drive for later viewing.

LIVING-ROOM LAN REQUIRED

EDN's Digital Den has long been a wireless advocate, although it has correctly pointed out the potential weaknesses of wireless when it comes to video distribution. Still, you may get by with a wireless connection for one or both of the test products. You could certainly use

AT A GLANCE

- Devices such as Akimbo and Slingbox will require a robust home network.
- Users have to conceive a comprehensive A/V-distribution scheme to take advantage of new devices.
- Akimbo works well, but the content and business model are question marks.
- Slingbox delivers acceptable video even over cross-country Internet connections.

Figure 2 The stylish Slingbox states its case on its cover, promising “my video, my TiVo, my music ... ” and then delivering that content to PCs locally or remotely.

a wireless bridge to link a living-room Ethernet switch to the duo if you need to connect multiple devices in the living room—and realistically you will, in the future. Akimbo supports a Linksys USB-to-802.11 adapter that can link the PVR to a wireless network. But in our case, we wanted to evaluate the products in the best network environment possible. So we augmented our test living room with a new Cat5 cable drop and a Netgear five-port 10/100-Mbps switch. The switch cost only about $30. The sweat left in the attic was probably worth far more (see **sidebar** “Jacks ease installation”).

Once you solve the home-network problem, you have to find a way to work products such as Akimbo or Slingbox into your A/V system. For the tests in our Digital Den, we added the duo of new products into a system that already had analog cable, an HD DirecTV/terrestrial receiver, and a dual-tuner TiVo/DirecTV receiver as inputs. (See **sidebar** “Whole-house modulator works, but picture quality suffers” for details on the connections.) Indeed, our digital den was already woefully short on places to connect A/V inputs or outputs.

The Akimbo PVR is decidedly simple when it comes to connections. It has a single A/V output, a LAN connection, and two USB connectors. Most other PVRs have multiple outputs, but then again, Akimbo was at press time selling its Internet PVR for $100, including three free months of service (normally, $10 per month). Both the HD and TiVo receivers fed the multiroom modulator in our Digital Den before Akimbo arrived. But, it turns out, you have to configure the Hughes HD receiver to output only an SD (as opposed to an HD) signal for the receiver to drive its composite-video output. So, generally, that output stays inactive save the rare occasion when both TiVo tuners are busy and someone needs to access a DirecTV receiver from a remote TV. So Akimbo got the B input to the modulator that feeds the signal to every TV in the test house on channel 122.

The software setup on Akimbo was also amazingly simple. The PVR produces a pass phrase on screen and instructs you to enter that phrase through the company’s Web site. The Web site asks for pertinent information including a credit-card number. To get the three free months of service, you enter a promo code from the packing label. In minutes, you can be perusing the Akimbo channel guide.

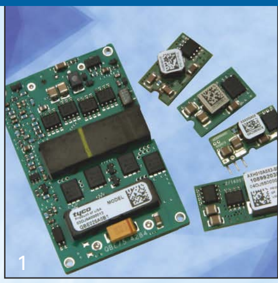
REQUEST NOW/VIEW LATER

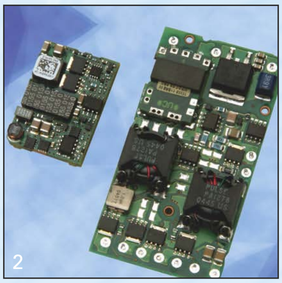
Unlike TiVo, which records from a broadcast source, Akimbo must download viewing choices. Subscribers instruct Akimbo to get the desired content, and then watch it later. Still, 30-minute shows take only a few minutes to arrive by means of a cable modem. Akimbo offers a broad mix of content. There’s easily recognizable programming from sources such as CNN, the Food Network, and Turner Classic Movies, along with specialty programming, such as The Billiard Network, Asiamoviechannel.com, and Best of California.

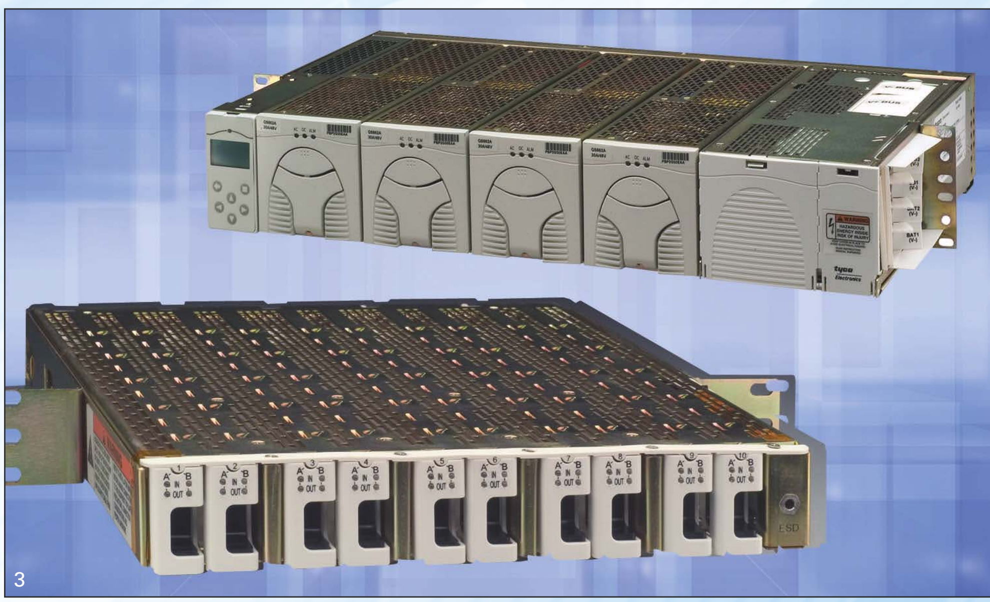
Indeed, content is arguably Akimbo’s near-term Achilles’ heel and perhaps in the long term its greatest strength. The company has gathered bits and pieces ranging from Turkish programming to golf instruction. But there’s probably not

JACKS EASE INSTALLATION

If you need to install Cat5 cable or, for that matter, phone cable, consider Leviton Quickport jacks, which allow you to gang multiple types of connections into a standard home faceplate. The company sells single-gang faceplates with one, three, or six square sockets that you can fill with Cat5, phone, coax, A/V, or other types of connections. Moreover, the Cat5 Quickport and phone jacks are color-coded, so you can easily wire the jacks without stripping the individual wires and without a schematic. Note that the Cat5 jacks offer two configuration choices–A or B–based on wire colors. It doesn’t matter which configuration you choose, but once you choose it, you must remain consistent.







enough of any category to satisfy a subscriber really interested in a niche. And there is not enough of the broadly applicable content, such as mainstream movies on Turner Classic Movies, to attract a huge subscriber base. In the long term, the company may benefit from being independent and may be able to keep building the available programming block by block. The company does not share the constraints placed on MSOs (multisystem operators) that own their own networks as to what programming they must carry.

Still, to survive, Akimbo may need to tweak its business model. It provides much of its content on a pay-per-view basis on top of the $10-per-month subscription fee. Perhaps an extra charge for adult content is legitimate if the company feels it must offer such programming. But subscribers interested in subjects from wine to golf are likely to feel that they are being nickel-and-dimed to death. For instance, the GolfSpan channel offers a series of one-minute instructional programs that cost 49 cents each for a 30-day viewing period. A golf enthusiast wouldn't have to buy many before a good instructional DVD would have been a better investment. Understand that the monthly fee includes substantial content, such as the Food Network and CNN programming. But much of it carries a tariff. Feel like paying 2FlyTV 49 cents to see a six-minute aerial fly-over of New York City? Check the Web site for a complete list of content.

FROM IN TO OUT

Akimbo is all about another way to bring content home, but the second new component in our Digital Den specializes in encoding and transmitting content. Consumers will surely find the Slingbox handy to distribute home video both on a home network and to remote locations using the Internet. In in-home applications, Slingbox can serve programming to, say, a home-office PC in a room not served by a typical home A/V system. Remotely, say, while traveling on business, some sick sports fans we know might choose to spend time in their hotel watching a baseball team, such as the Padres, lose another game. Such a game wouldn't likely be available to a business traveler, but Slingbox would let that traveler watch using the Internet and the Slingbox feed from home. No doubt, Slingbox will also allow grandparents to watch live video of grandkids, remote monitoring of security cameras, and who knows what else.

Slingbox sells for $250. At press time, the product was available in limited quantities at Best Buy and CompUSA. The approximately 10.5×3.5×1.75-in. device certainly consumes little shelf space. It offers both composite- and S-video input and output connectors, a coax input for the internal tuner, and a LAN connection. The video output is a pass-through connection that allows the buyer to place Slingbox between a source, such as a TiVo, and a TV. Making the hardware connections is a snap. Initially, we connected one of the local coax outputs of the multiroom modulator to the Slingbox in our digital den.

Installing the Slingmedia software and configuring Slingbox is a bit more complicated. Perhaps the company should have considered separating the configuration software from the Slingplayer application. Instead, a 70-Mbyte zipped download is the first step in installing Slingbox support on any PC. You must use a machine on the home LAN to initially configure the box. On local or remote PCs from which users want to watch only Slingbox content, the quick witted will realize that they need to check the box indicating that this is not the first time the Slingbox has been configured. A plain-English alternative might have offered the choice of installing and configuring the hardware or installing the Slingplayer application.

Users that want to watch Slingbox content only locally are spared many networking details. To make your Slingbox accessible by means of the Internet, however, you must open a TCP/IP in your router to the IP address that the router assigns to the Slingbox. Presumably, new Universal Plug & Play routers make the router configuration automatic. Manually configuring a router isn't difficult for computer enthusiasts but will surely stymie some consumers. Slingmedia attempts to solve the problem with help screens that it serves by means of the Internet. The system asks for the model number of the router on the network, and then attempts to deliver instructions specific to that model. We found it missed completely on a popular router, and bad help in this case may be worse than no help at all.

To run the Slingplayer, you need a Windows XP PC with Service Pack 2. You may have to disable PC-resident firewalls and VPN software to access the Slingbox for configuration or viewing. In the case of the standard Reed Business (*EDN*'s parent company) software load, the McAfee Desktop Firewall causes no problems, but the Nortel Contivity VPN prevents the Slingmedia software from finding the Slingbox.

Our initial installation of Slingbox took less than an hour, and that was with phone interruptions and other obstacles. The quick-start guide warns of the VPN and firewall problems. We didn't take the time to read about minimum system requirements. But we quickly had a video stream from our digital den playing on a PC in the home office. The initial test machine did experience pauses in the stream at what seemed like a repetitive interval.

Because the office PC is connected by means of an older 10-Mbps Ethernet switch, that slower switch stood out as the potential culprit. And upon installing the Slingplayer in the family room—on a PC connected to the Slingbox via a 10/100-Mbps switch, the stream played perfectly.

REMOTE ACCESS

Next, an East Coast-based member of the Digital Den team fired up a remote test on the other side of the country. During the initial configuration process, the Slingmedia software generated a 32-character "Finder ID" specific to our Slingbox. For remote access, a user needs that Finder ID along with a password established at initial configuration. It appears that Slingmedia is keeping a list of Finder IDs and linking them to local IP addresses. Presumably, you can also guide a remote user to your Slingbox as long as you know the

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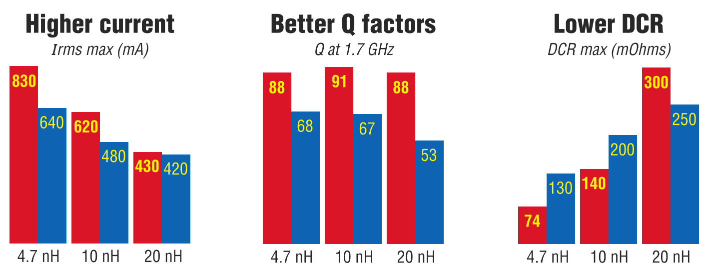

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We were smart enough to stop, capture, and store the Finder ID—after starting to record the onerous string on a message pad. After receiving the Finder ID and password by means of e-mail, our Eastern invader quickly had access to *EDN*'s West Coast-based digital den. Cox Communications handled the outbound feed in the San Diego area, and Comcast in Boston handled the inbound stream. Generally, the remote-viewing experience was perfectly acceptable—with the exception of the image size. When we changed channels remotely,

WHOLE-HOUSE MODULATOR WORKS, BUT PICTURE QUALITY SUFFERS

With the advent of cable or satellite set-top boxes, video games, DVD players, PVRs, and other devices, planning a living-room-wiring scheme is a challenge. Trying to devise a whole-house A/V-distribution system is a level tougher. Sure, DVD players are cheap enough to put one with each TV, and video games are typically used only in one room or, at worst, move along with the players. Still, consumers rightly want to view the content from that new TiVo box that lives in the living room on their family-room or other remote TVs. Products such as TiVo and DirecTV are both costly upfront and come with service fees on a per-box basis that make distribution attractive. For now, a modulator/amplifier is the only real option for whole-house distribution and is a simple addition to homes with a star-wired coax plant.

Consider a living room with the following video sources: basic analog cable, a dual-tuner TiVo/DirecTV receiver, and an HDTV-based terrestrial/DirecTV tuner.

The ChannelPlus Model 3025 Multi-room Video Distribution System is a perfect match for the sources described above (Figure A). The 3025 has two composite A/V inputs and a coax input. The box modulates the two A/V inputs to UHF channels 14 to 64 or cable channels 65 to 126. The user selects the actual channels used by means of a crude but effective sequence of button pushes. The system outputs the modulated channels, combined with the incoming signal, on five coax connectors. Two of the five are local outputs for the living room. The other three are amplified for remote distribution over coax to other rooms. The 3025 can also connect an IR emitter to allow remote control of living-room components from other rooms.

You can certainly build a much more complex modulation-driven distribution system. ChannelPlus, for example, sells a box with four A/V inputs and one output that's meant to be combined with an amplifier and distribution components. But that four-input box starts at approximately $300, and you still must buy the other needed components. Online retailer Parts Express, meanwhile, offers the 3025 for $135.

Video quality is the only real problem with a modulator-driven distribution screen. The quality of the video on remote TVs is essentially analog-cable quality. But the quality of the TiVo/DirecTV receiver connected directly to a living-room TV is essentially DVD-quality. The discrepancy will only worsen as more HD content enters the picture.

Figure A A multiroom modulator/amplifier, such as the ChannelPlus 3025, may not match the video quality of a source such as a DirecTV receiver or digital-cable box directly connected to a TV, but it allows consumers a simple way to view those sources remotely.

You can distribute higher quality video–if you have much deeper pockets and are willing to run more cable in your home. For instance, Cable Electronics offers a box that accepts a composite A/V signal and provides four outputs that you can drive over 150-ft cable runs. The amplifier costs only $120, but you need to combine multiple amplifiers and switching components to support multiple sources. The company offers a component-video version for $150. In either case, you need to install new, noncoax wiring to support the distribution system.

ChannelPlus also offers a line of components that can distribute either composite A/V or S-video signals over Cat5 cable. In a house with structured wiring and multiple Cat5 runs to each room, the Cat5 option may make sense. But realize that a single transmitter-receiver pair (the SVC-10) costs upward of $400, and you will need multiple transmitters and switching components to support multiple sources. The company's Video over Cat5 family really targets commercial installations.

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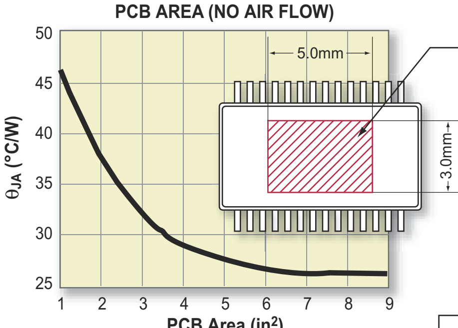

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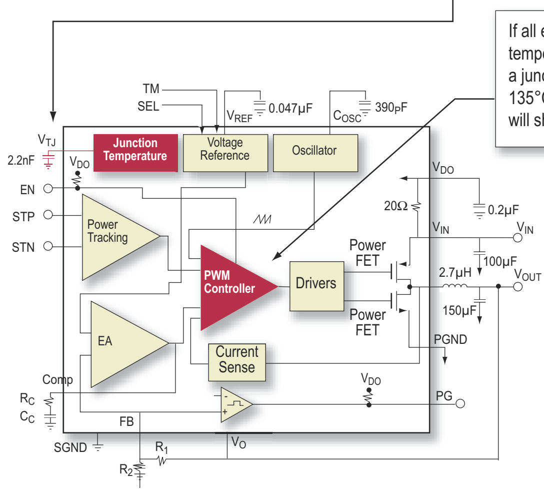

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the stream would take seconds and sometimes tens of seconds to stabilize. But once stable, the stream was solid.

Back on the West Coast, it was fairly obvious that a 10-Mbps switch was not causing pauses in the stream. It appears it was purely a lack of horsepower. Slingmedia specifies a 1-GHz Pentium IV or faster processor. Our initial test machine is based on a 1-GHz Mobile Pentium III CPU.

In all cases, it is best to view the video stream as a relatively small window. At one-quarter to one-third of a 19-in. display set to 1024×768-pixel resolution, the video quality looks good. When blown up to full screen, the stream shows artifacts—especially if there is a lot of movement in the content. Remember, an encoder is processing the stream in real time.

Overall, the Slingbox experience was positive, but the company could do so much more with just slightly better software—both the configuration software that runs on the PC and the embedded software that carries out the task in the Slingbox. For instance, you can have a coax input or a composite-video input, but not both. We're not suggesting that the Slingbox should simultaneously encode both, but we are suggesting that the software should be smart enough to let the user swap between inputs without reconfiguring the box. The device does come with IR emitters that let the unit control a TiVo or ReplayTV PVR. But, in our case, if TiVo is connected and active, a baseball fan wouldn't have access to a Padres game that is available only through Cox Channel 4 in San Diego.

At first, we thought our system-configuration problem was unique, because we actually have the TiVo/DirecTV receiver modulated onto channel 120 on the coax input to the Slingbox. It's understandable that the Slingbox engineers didn't anticipate such a connection and the potential need to use the IR emitter to control a source coming in through coax. But upon rerunning the configuration software, it became clear that the Slingmedia software deals with only one source—either coax or composite video—at any point in time. The company's tech support confirmed that limitation via e-mail.

Still, we're planning on keeping Slingbox—unless those guys on the Prying Eyes staff steal it away one night. We may decide to let them have Akimbo without a struggle. EDN

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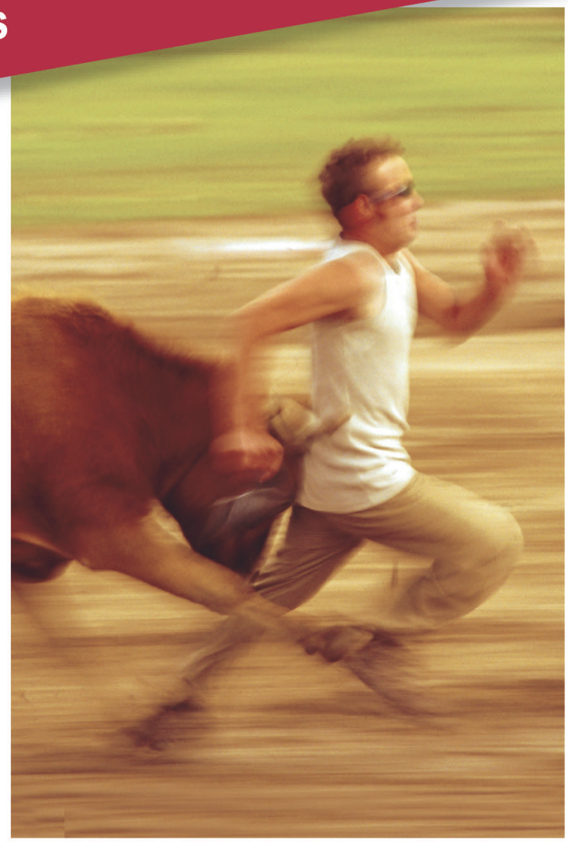

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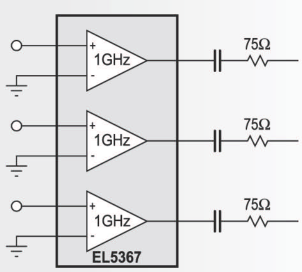

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EL5162/3	1	500	4000	1.5	1	100	±3.6	5
EL5164/5	1	600	4700	3.5	1	140	±3.8	3.5
EL5166/7	1	1400	6000	8.5	1	160	±3.8	5
EL5260/1	2	200	2000	0.75	1	70	±3.4	5
EL5262/3	2	500	2500	1.5	1	100	±3.6	5
EL5462	4	500	2500	1.5	1	100	±3.6	5

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EL5100/1	1	300	2200	10	2.6	100	±3.4	5
EL5102/3	1	400	2200	6	5.2	150	±3.7	5
EL5104/5	1	700	4500	14	9.5	160	±3.8	5
EL5202/3	2	400	2200	6	5.2	150	±3.9	5
EL5204/5	2	700	3000	10	9.5	160	±3.8	10
EL5300	3	200	2200	10	2.5	100	±3.4	4
EL5302	3	400	2200	6	5.2	150	±3.7	5
EL5304	3	700	3000	10	9.5	160	±3.8	10

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BY RICHARD A QUINNELL • CONTRIBUTING TECHNICAL EDITOR

DOUBLE-BARRELED

ADDING "WIRELESS" TO NETWORKING DOES MORE THAN CHANGE PHYSICAL-LAYER-TEST REQUIREMENTS; IT ADDS SYSTEM COMPLEXITY THAT NEEDS SIMULTANEOUS CONTROLLED TESTING OF MANY LAYERS.

Wireless networking based on the IEEE 802.11 standards is poised for substantial growth in both the numbers of units and the range of their applications. The mobility inherent in wireless networks, however, creates interactions between the physical and the protocol layers that—compared with wired networks—greatly increase the complexity and number of tests necessary to verify a design. Fortunately, tools are becoming available to streamline the process.

The 802.11a/b/g standards, collectively known as WiFi (Wireless Fidelity), have engendered a large and growing market among home users, who are finding wireless a simpler alternative to Ethernet for sharing resources such as printers and broadband connections in their homes. In addition, business users that need mobile-computing capability are adopting the technology in droves. Public WLANs (wireless local-area networks), or "hot spots," are also increasing in popularity with both business and home users. The result: worldwide WiFi-equipment revenues of $737.6 million in the first quarter of 2005 alone, a 15% increase over the first quarter of 2004, according to market-research company In-Stat.

Although the adoption of WiFi in homes and businesses for computer access is still rising, new markets for the technology are poised to emerge. In-Stat is tracking promising applications, such as VOWLAN (voice over WLAN), the use of WiFi as a means of consumer-electronics connectivity, and the combination of VOWLAN with cellular telephones. Each represents a market that could match or exceed that of computer access.

The rise of these major markets could result in many designers facing for the first time the challenges of WLAN test. The challenges are significant, and designers' experience with more traditional cabled networking is an insufficient background for meeting them. WLAN is more than traditional networking with a radio-based physical-layer interface.

COMPLEX PROTOCOLS COMPLICATE TESTING

For one thing, the protocols are more complex, says Thomas Alexander, PhD, chief technology officer at VeriWave. He notes that many extra features in WLAN protocols address three aspects of wireless LANs that cabled networks lack: dynamic configuration, a spatial nature, and mobility. These aspects add to the complexity of wireless testing. The dynamic-configuration aspect of WiFi allows endpoint stations to query APs (access points) to gain network access and has APs announce the services they support. Although cabled networking has comparable functions, they are typically present in higher layer protocols. WiFi implements them at the MAC (media-access-control) layer. WiFi stations must also use "association" to determine which AP to use when several are avail-

WiFi TEST

AT A GLANCE

- The WiFi market is large and expanding into new applications, such as entertainment electronics and voice communications.
- WiFi uses more complex protocols and thus requires more extensive testing than cabled networking.
- The mobile, dynamic, and spatial characteristics of a wireless network force testing with combined RF- and data-test tools.
- To ensure repeatability, tests need shielded enclosures or Faraday cages to eliminate outside interference.
- Specialized tools for RF testing and system-environment emulation are becoming available.

able, and the APs must use "authentication" to determine whether the station is a valid user before granting access. Physically secure cabled connections need no authentication. A radio connection could come from someone parked down the block trying to get free Internet access.

The spatial nature of WiFi creates situations, such as "hidden nodes," that you don't find in cabled networks. In such situations, two stations can be in range of an AP yet not in range of each other. As a result, the two can repeatedly clash when trying to send messages to the AP because neither can detect the collision. Similarly, in cabled networks, careful design and installation can control the noise levels in the physical layer, and switches can segment the network into manageable groups. Designers of wireless-network devices, however, cannot assume a controlled environment. WiFi shares its frequency band with Bluetooth, portable phones, and microwave ovens, among other RF sources. Designers also cannot control the number of stations that may be actively attempting to reach an AP. The protocols must allow the network to simply adapt to the environment it finds.

The mobility aspect of WiFi also imposes functions on equipment and protocols that cabled networks don't need. One added function is that battery-operated stations may need power management to optimize power dissipation, such as by turning down transmitting power when close to an AP to save energy. One added protocol function is the ability to dynamically switch a station between APs during a transmission, similar in nature to cell-phone roaming. Another added protocol function is rate adaptation, the ability to adjust the signaling data rate based on the received signal power to optimize the overall channel performance.

Figure 1 Agilent's N4010A consolidates WiFi's RF test needs in a single package that handles all transmitter and receiver measurements.

LAYERS NOT FULLY SEPARABLE

Another complication arises beyond the more complex protocols, however. With cabled networks, engineers can independently test system layers and then simply combine the tested components to assemble a working system. Following the traditional network-testing model, testing of wireless-networking-device designs would have two major tasks. One task would be for digital and software engineers to evaluate the device from the network side by using protocol and logic analyzers. The other component would have RF engineers evaluate the radio section using vector-signal and spectrum analyzers along with signal generators, oscilloscopes, and other RF equipment.

But, the old adage "the whole is greater than the sum of its parts" applies in spades to testing WiFi product designs. The physical and protocol layers need not only independent testing, but also simultaneous testing to verify the proper operation of higher layers. This situation leads to a requirement for many pieces of equipment, both RF and digital, working in concert to create the necessary test conditions and measure the results.

Fortunately, RF-test-equipment vendors have been working to consolidate and automate some of the necessary

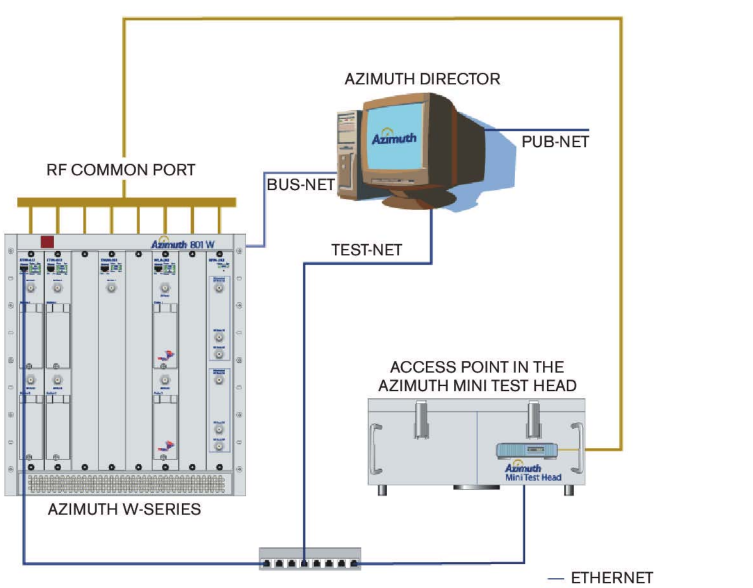

Figure 2 To emulate an entire WiFi network, the Azimuth Systems W-series test equipment provides a mix of WiFi signals under program control to the device under test.


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equipment, and many such products emerged in mid-2004 to late 2004. Agilent Technologies created the N4010A wireless-connectivity test set, which uses software modules to implement signal- and vector-analysis functions, as well as signal generation, and to form a more self-contained RF-test package (**Figure 1**). Similarly, Anritsu Corp offers software for its spectrum analyzers to combine several WLAN RF-test abilities in one instrument. LitePoint Corp has IQView for testing WiFi transmitter and receiver functions. The company also offers IQWave software for creating custom signal waveforms with the instruments to test response to impaired waveforms. Most recently, National Instruments has entered the market with a PXI-based instrument package with its LabView development software and a software package from SeaSolve Software that runs physical-layer-compliance tests on WiFi-radio units.

Figure 3 VeriWave's TestPoint products simulate WiFi stations and access points with the option of conducting cabled or open-air testing.

Having covered the testing of the physical-layer components, it would seem that testing the higher layers would simply require digital pattern generators and protocol analyzers. But WiFi's complex protocols must handle the network's dynamic, spatial, and mobile natures, and equipment cannot simulate those parameters with a purely digital pattern. Engineers must test them using the RF link to exercise functions such as rate adaptation, hidden-node detection, and other signal-strength-dependent conditions.

The difficulty of WiFi testing emerges most strongly in this area. To provide repeatable tests, the DUT (device under test) needs a controlled stimulus. This requirement means at least testing the unit in a shielded enclosure to isolate the unit from stray signals. In addition, the stimulus signals must have controllable strengths, which involves the use of programmable attenuation. In addition, to simulate a full network configuration, multiple stimulus signals from independent sources must be present.

PROTOCOL TEST

Unfortunately, most of the RF-test instruments available directly stimulate the DUT with a single signal. Testing the device in a multisignal environment has required the use of many instruments. Coordinating the signals from these multiple instruments to create repeatable test conditions using a home-brewed test setup has been difficult at best. The test setup requires either using a complicated cabling scheme with manual calibration of each source to feed the DUT in a shielded enclosure or placing the entire test configuration in a Faraday cage, a metallic enclosure that prevents the entry or escape of an EM field, to gain repeatability.

Further complicating the test setup, however, is the mobile aspect of WiFi. The tests must somehow replicate the movement of the DUT or the stimulus signals to fully exercise the unit. "The whole idea behind WiFi is mobility," says Ray Cronin, chief executive officer of Azimuth Systems. "You have to have a system that will test the effect of mobility on the quality of service."

Providing the means to generate multiple controlled stimulus signals, along with simulating the effects of mobility by using programmable attenuation, has been the focus of companies such as Azimuth, Ixia, and VeriWave. All of these companies have products that provide protocol analysis as well as allow the coordinated generation of multiple test signals for evaluating WLAN devices under a wide range of conditions.

The companies have different approaches to the testing, however. The Azimuth W-series test platform provides a shielded enclosure for the DUT, feeding it controlled signals through a cable system (**Figure 2**). The test signals come from a bank of generator modules under the common control of a computer system that specifies the function of each module, coordinates signal activity, and manages the combination of the RF outputs using programmable attenuators. This approach allows the system to mimic a variety of traffic patterns and signal conditions, including roaming, in a repeatable configuration without the need for a shielded room.

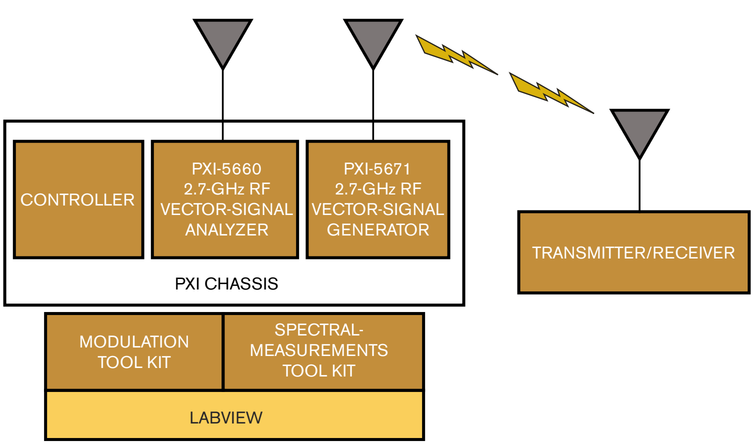

Figure 4 National Instruments has developed a PXI-based WiFi RF-test platform with software-controlled conformance testing.

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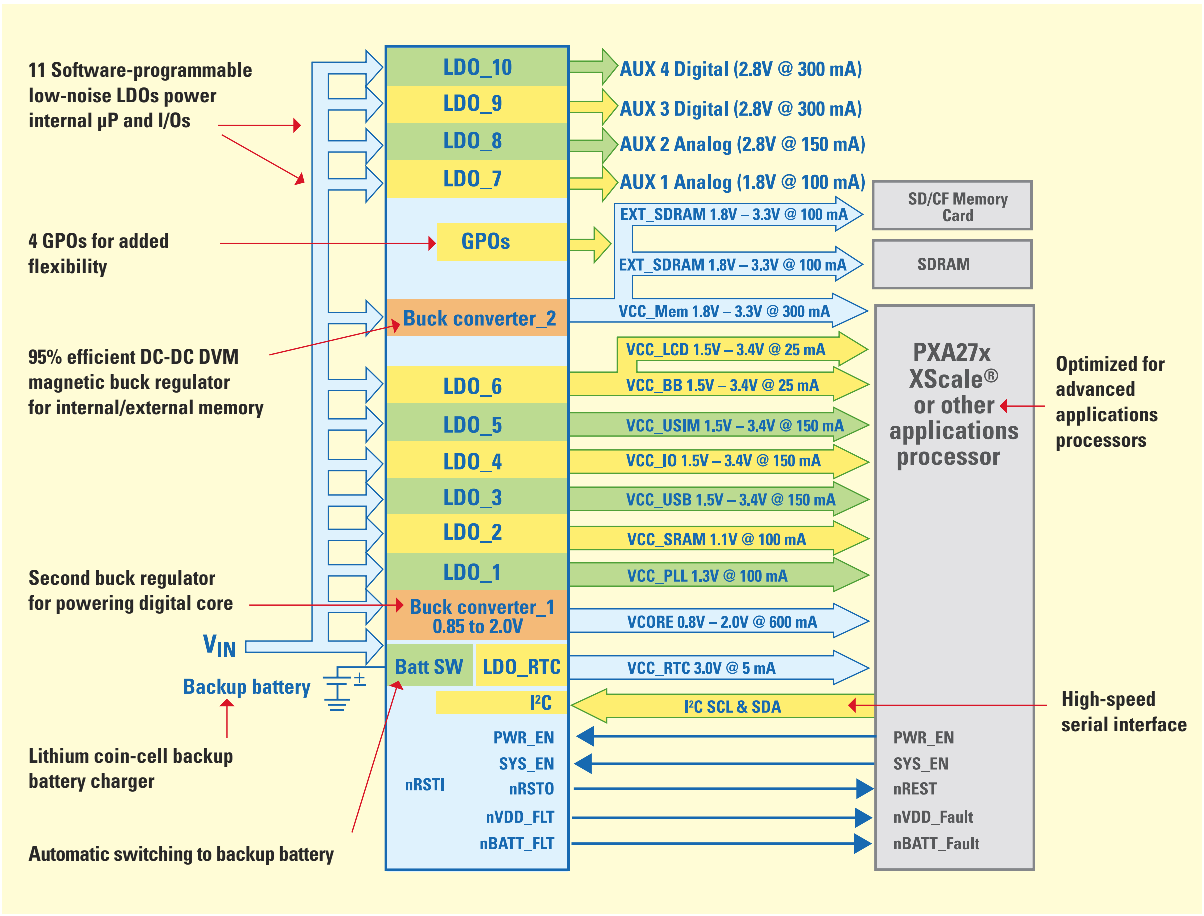

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The Sight & Sound of Information

Testing a WiFi design requires a combination of RF- and data-level test equipment that designers must use together to fully exercise the protocols (courtesy Agilent Technologies).

The Ixia IxWLAN and VeriWave WaveTest systems allow both a cabled and an open-air approach (**Figure 3**). The systems feature synchronized control of numerous test-stimulus devices to generate the network signals and offer control of both the transmitting power and receiver thresholds of the test-stimulus devices to handle spatial relationships. The systems can work in a cabled configuration, in a Faraday cage, or in an open-air field environment. The VeriWave system can also capture signals in the field for later playback under laboratory conditions.

A key attribute of all three systems is their scalability. They allow the creation of test setups that can mimic dozens of access points with hundreds of stations, all under automated control. This approach allows for testing of designs against the crowded conditions users are likely to find in actual installations as well as the measurement of system performance under such conditions. The tests can thus help system administrators plan their installations to optimize throughput.

Another key attribute of these systems is the level of automation they provide. Development teams can outfit these systems with vendor-provided software that implements a complete compliance-test suite using the system. Running these test suites does not provide design certification but does assure development teams that their designs will achieve certification.

Such protocol test systems help round out the testing of WiFi devices by addressing network issues during the test. They do not, however, provide measurement of the RF parameters, although the WaveTest system can generate triggering signals to RF-test equipment to coordinate such measurements. Test engineers must test the RF portion and the data portions separately. WiFi testing may be consolidating its tools, but some two-step procedures still occur.

TEST SYSTEMS LAG

That two-step dance is likely to continue for some time. As Azimuth's Cronin points out, "A new technology evolves ahead of the test technology to support it." In the case of WiFi, the technology is still evolving. In addition to versions a, b, and g, new versions of the 802.11 standard are in development. The 802.11q standard, for instance, allows the mapping of virtual LANs onto the wireless network. The 802.11i version adds new security protocols to the network to bolster the privacy of wireless connections. Another trend adds voice to the wireless networks, requiring controlled quality of service and timing.

To meet the ever-changing needs of WiFi designs is WiFi testing's ultimate

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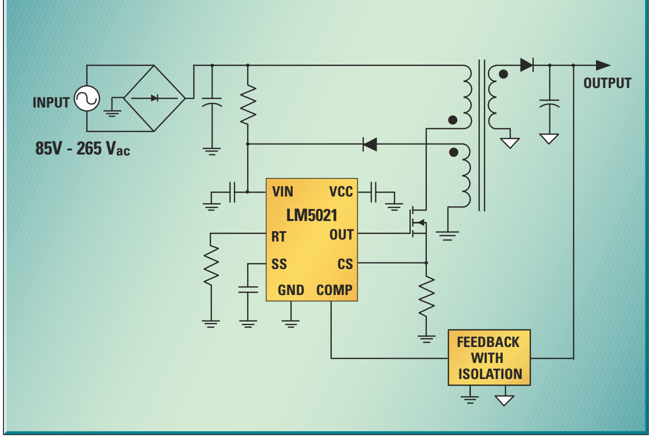

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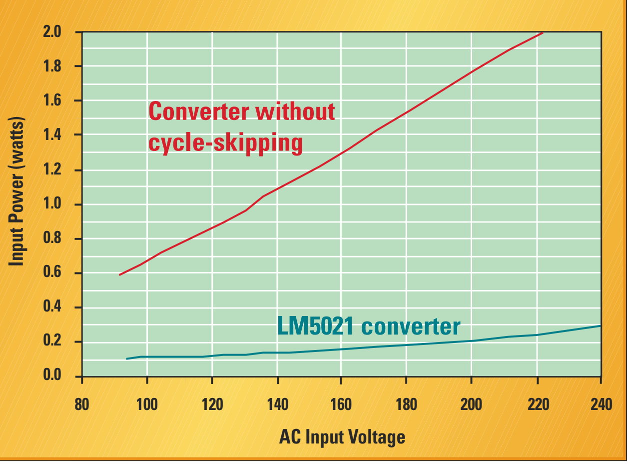

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challenge. Traditional hard-wired products are too slow to adapt to the rapidly changing technology. Today's wireless test equipment must be adaptable through software if there is to be any hope of keeping pace.

National Instruments is taking the programmability approach in its RF-test system (**Figure 4**), according to modular-instrument product manager Darcy Dement. "As technology evolves, so must the test," says Dement. "When the equipment is software-driven, it lets designers keep their tools in line with the changing standards. Having an open architecture, such as Matlab, also allows designers to get into the test parameters to customize them for their unique needs." Azimuth's Cronin agrees that programmability is key to test's keeping pace with changing standards. "Without the programmability built into tools such as ours, changes in the standards would put the onus on the developers to create their own ad hoc tools," says Cronin.

With complete system-test tools now available, automated RF testing, and tool programmability providing a path for tracking changes in the standards, developers are in a good position to embrace WiFi in their next designs. The test tools to exercise and validate designs are becoming more available—whether for game systems to talk with broadband connections, music players to send data to sound systems, or cell phones to switch from WANs to LANs. The presence of these standardized test tools can mean only more innovation and faster growth in wireless networking with less designer frustration. EDN

AUTHOR'S BIOGRAPHY

Contributing Technical Editor Rich Quinnell has been covering technology for more than 15 years. He has been a practicing engineer in embedded systems and has degrees in engineering and applied physics.

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BY MARGERY CONNER • TECHNICAL EDITOR

Get the message:

Power-management protocol rides on industry bus

THE PMBUS—BASED ON THE TRIED AND TRUE I^2C HARDWARE INTERFACE—OFFERS A POWER-MANAGEMENT COMMUNICATIONS PROTOCOL FOR POWER-CONVERSION SUBSYSTEMS.

As system power requirements have increased in complexity for telecom and datacom applications, so have the communication requirements between the system host and its power subsystems. Power-supply and power-management-IC vendors initially responded by developing proprietary communication and control schemes. However, an SIG (Special Interest Group) comprising power-management-IC and power-supply vendors, after about 18 months of planning, this year released the first version of the PMBus, an open standard for communication between host systems and the power subsystems. The PMBus Implementers Forum, which the System Management Interface Forum has now absorbed, originally developed the standard.

Communication between the system host and power subsystems has been relatively simple, often comprising one line indicating that power is either on or off. In complex telecom and datacom applications, such an indicator is woefully inadequate. The PMBus SIG members believed the time was right for an industry-backed open standard.

Why does a system need to communicate with its power subsystem beyond a simple on/off response? The host must be able to tell the power subsystem what the system's power needs are or will be and to get status information from the subsystem. Don Alfano, director of power products for Silicon Labs, gives an example: "Let's say that you have a large system with a lot of high-current ASICs. And let's say that system doesn't necessarily have all of these high-current ICs on at any one time, because it's switching them in and out to conserve power whenever possible. When these ASICs turn on, there is an enormous inrush of current. It would be nice to give the power subsystem some warning that the massive current needs of an ASIC will shortly need to be met. The power subsystem can begin to position itself for a large current load or to limit the inrush current. Either way, the subsystem can react as an integral part of the system, rather than something that just sits there and tries to hold the voltage constant."

The PMBus' physical interface is based on the simple and popular I^2C (Inter-IC Bus), a serial bus that Philips developed for communication between large ICs, typically within a single backplane. As Alfano puts it, "It's a little LAN for chips. With only two wires, an almost unlimited number of talkers and listeners can be on the network. And many microcontrollers already have an I^2C port."

The PMBus is not the only intersystem-communication bus based on I^2C: SMBus, which Intel developed for system management, is also I^2C-based. Howev-

AT A GLANCE

- The PMBus applies to relatively complex systems, such as telecom and datacom applications.
- The PMBus developers based its physical layer on the popular I^{2}C bus.
- Designers can implement the protocol in a power converter's digital controller.

er, PMBus is more robust than its precursors in that if a chip stops talking on an I^{2}C bus or the SMBus, the bus hangs up, whereas the PMBus times out and boots the chip off the network.

Building on the I^{2}C hardware interface, the PMBus SIG next developed a protocol for handling power-management information. The protocol covers manufacturing information, power-supervision and -monitoring commands, and power-supply-control commands. Manufacturing information can include information such as serial numbers, lot numbers, codes, and manufacturer-specific information. Power-supervision and -monitoring commands provide a framework for the system to communicate with the power subsystem's controller, an important feature because each power-microcontroller vendor has developed its own protocol. Dave Freeman, system-power-products engineering manager at Texas Instruments and TI's representative on the PMBus SIG, says, "A lot of power-management ICs are out there, and they all manage and sequence supplies with their proprietary interfaces. One of the goals of the SIG was to develop a protocol that would make it simpler for the host software to deal with these various microcontrollers."

Power-supply-control commands allow the system to set power-supply parameters, such as frequency, duty-cycle limits, compensation, and values for closing the power-control loop. Freeman explains how TI plans to implement the PMBus control protocol in its power-controller ICs: "The PMBus will configure and set limits and set operational policies for the digital controller. The digital controller will be responsible for closing the loop and operating within the bounds set by the PMBus. The PMBus is too slow for real-time control as far as closing a control loop, but it can set power policy," he says. For example, it can define compensation values for loop closure in sleep mode versus the values that the supply would use when it is awake. Says Freeman, "The PMBus overhead is small compared to the bandwidth necessary for the digital controller."

Alfano of Silicon Labs agrees and points out that, because of the low overhead the bus protocol incurs, designers can implement the PMBus almost free in parts costs and count for subsystems that have digital controllers. And he believes that most subsystems within the next few years will have a digital controller. "Since you've already got the microcontroller to close your digital-control loop, running a PMBus protocol is easy and cheap."

He underscores the importance of using a microcontroller with onboard ADCs: You can use the ADC to replace analog circuits that provide circuit protection such as overvoltage protection, current shutdown, and overtemperature protection. If you use the additional bandwidth in your mixed-signal microcontroller to monitor these conditions, you can replace several analog components (**Figure 1**). Other advantages include increased reliability from the reduced parts count and the added flexibility of programmable parameters.

The specification comprises 115 commands, such as power-supply temperature status and history, output voltage, current, and switching offline and online. However, a device neither needs nor is likely to implement all 115 commands. To comply, all a power subsystem must do is obey the physical specification, including the electrical and timing specification, and implement one standard command. Additionally, if you implement commands that have the same effect, you must implement the command according to the specification, and, if the system doesn't implement a command, it must send a nonacknowledgment and not execute it. Keith Curtis, principal applications engineer for the security, microcontroller, and technology-development division for Microchip, says the SIG insisted that any device claiming PMBus compatibility must be able to operate stand-alone with no bus connection.

Having access to a GUI (graphical user interface) to develop your application is just as important as having the right digital controller to interface to the PMBus. Curtis, who is chairman of the PMBus Reference GUI subcommittee, explains the importance of a powerful GUI: "The intent of the whole GUI effort is to make

(continued on pg 60)

COMPETITION FOR A POWER-MANAGEMENT PROTOCOL

Before the formation of the PMBus SIG (Special Interest Group), Power-One developed the Z-One power-control structure, which provides an approach to communications between the host and the power subsystem. In December 2004, the company formed the Z-One Alliance, which has since added power-supply vendor C&D Technologies and semiconductor vendor Atmel to its ranks. The alliance is skeptical about the capabilities of the PMBus, such as the need to individually address each POL (point of load) and the lack of a core set of commands that must be supported to comply with the standard.

As with most standards, the market will have the ultimate say on each standard's acceptance (references A, B, and C).

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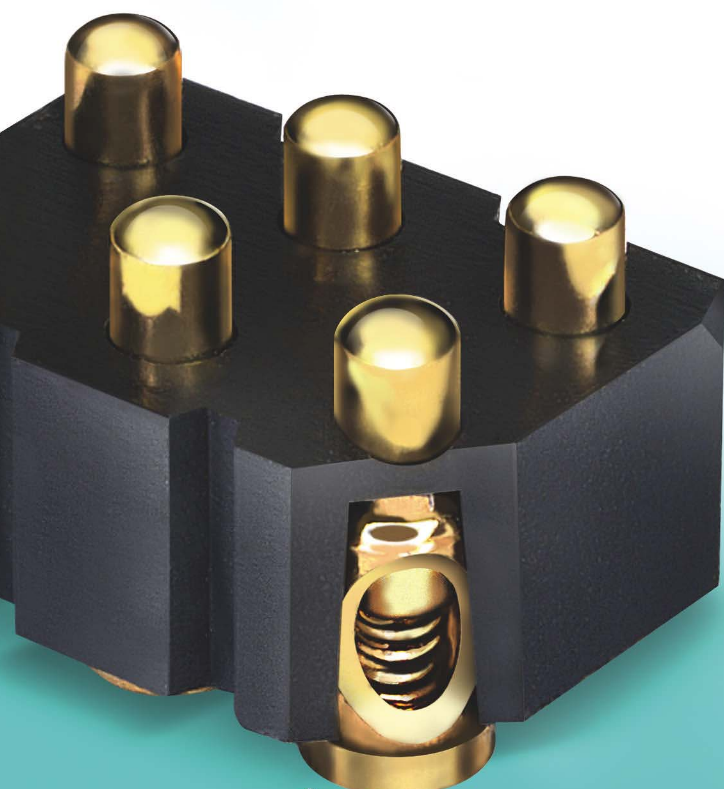


MAXI

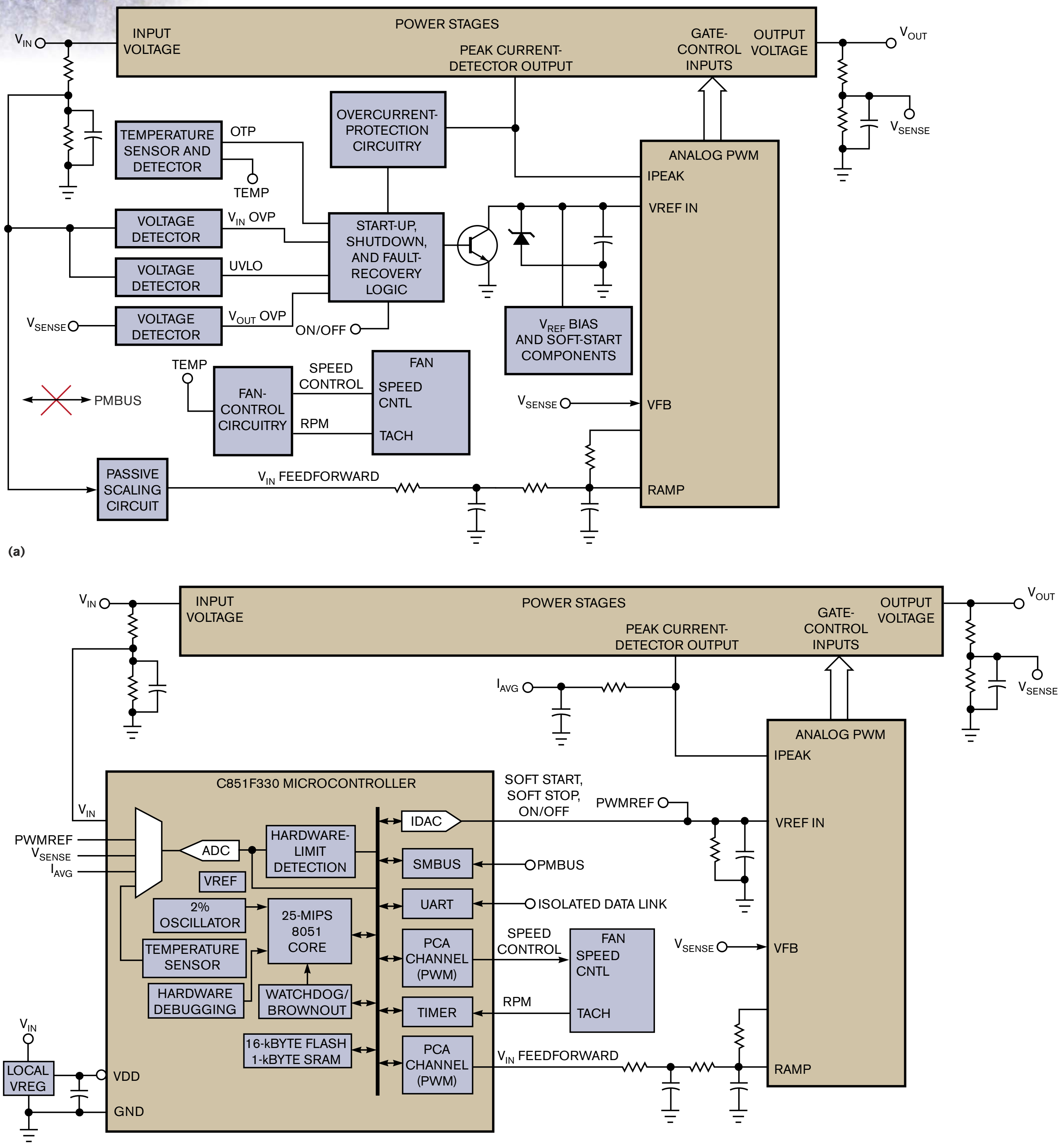

Figure 1 In an analog power supply with analog circuit protection, the circuit-protection elements are fixed, and both add cost and decrease reliability. You can replace all the pale-blue components with a mixed-signal microcontroller, such as the C851F330 from Silicon Labs (a). In an analog power supply with a microcontroller, the microcontroller closes the power-supply-control loop, has additional bandwidth to run the PMBus protocol, and can monitor the circuit-protection points through an onboard ADC, thus replacing the need for external analog monitoring and protection circuits (b).

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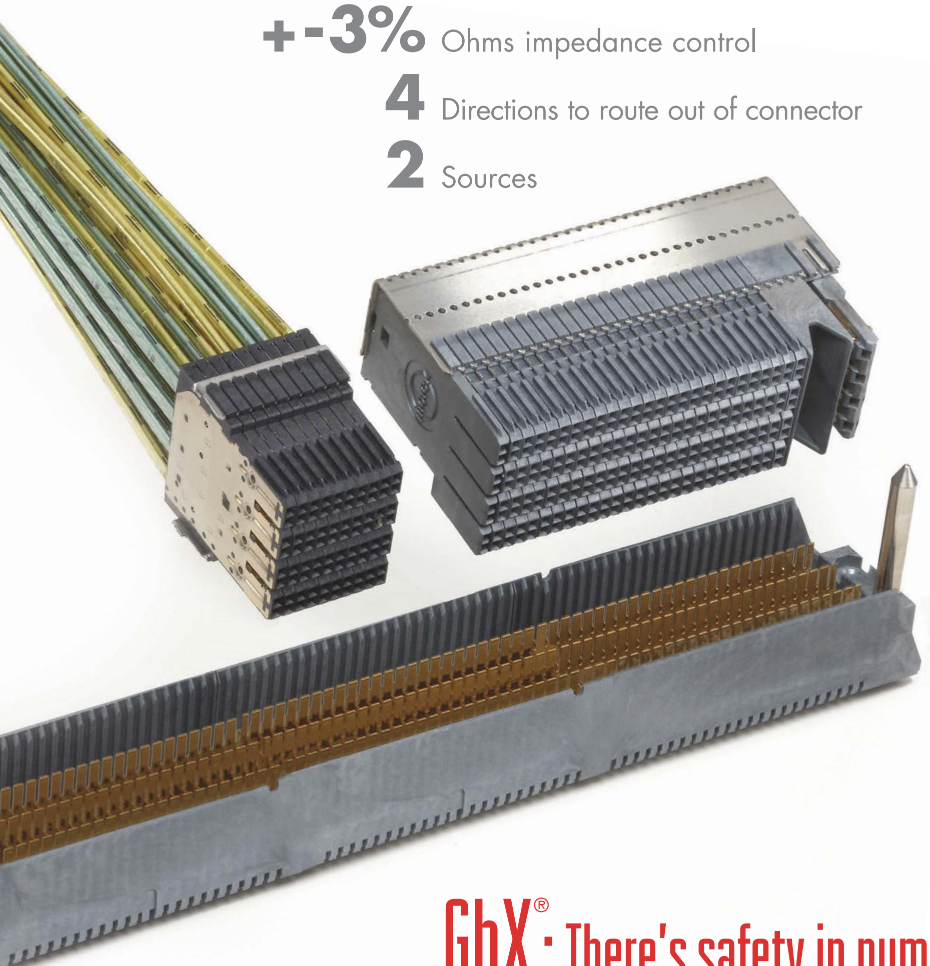

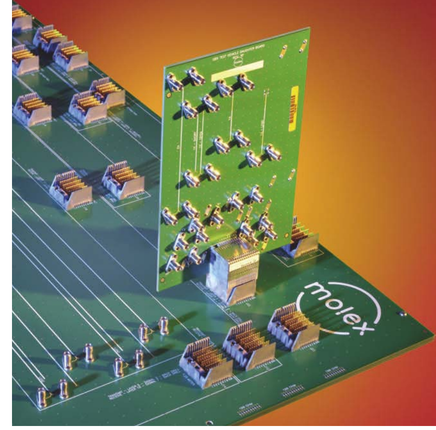

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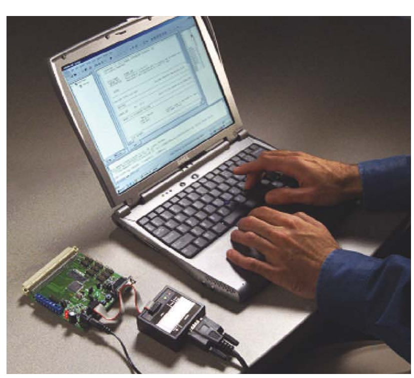
it easy for people to get started with an upfront configuration. I would expect people to take this as a starting point and then build their own in-house systems." Curtis expects developers to also control the PMBus from environments such as LabView, Virtual Basic, or C, depending on their expertise.

In addition to running on a variety of platforms, the GUI must support a variety of microcontrollers. "The GUI has to be able to run on something as simple as a PIC16F785 with an I^2C interface, up through the dsPIC," says Curtis. "The GUI must have the kind of range that allows it to support a small low-dropout point-of-load regulator on a board up through the ac/dc converter that's supplying a rack." Microchip has released the PIC16F685/687/689/690, the company's first offering that supports the PMBus.

The SIG will by year-end release a GUI that will support debugging, multiple command strings, demonstration functions, and manufacturer-specific commands. The debugging function allows designers to manually enter commands and debug initial communications routines. The multiple command strings include a macro function, and the demonstration function takes advantage of all the capabilities of the PMBus, displaying voltages as real numbers rather than as hexadecimal values. With the manufacturer-specific commands, you can change the GUI's front end and have it run with your company's name and format. You also can use the built-in PMBus functions for communication.



Silicon Labs' $199 development kit includes an Si8250-based half-bridge dc/dc target board; a real-time firmware kernel; and automated development tools.

Not all vendors have immediately and wholeheartedly embraced the PMBus (see **sidebar** "Competition for a power-management protocol"). Semtech recently announced its SC900 I^2C power-management IC, which offers the I^2C interface but no PMBus support. Tom Karpus, handheld-systems manager for portable power products at Semtech, says the company is looking at the PMBus, but stayed with the I^2C interface for the SC900. "The I^2C interface offers substantial benefits to a small, multiregulator device like the SC900. I^2C also involves having an address assigned to the device, so there is no need to have external pins to set the device address, an important consideration for a miniature device without the room for these address-assignment pins," says Karpus. He adds that Semtech is monitoring the evolution of PMBus for future designs.

Even the staunchest supporters of the bus don't claim it excels in all applications. Because the designers of the original I^2C bus developed it for inter-IC communication, the bus is best for short-haul applications, such as within a single board or server blade. For intercabinet runs, you're better off with a more robust bus. The European CANBus, whose developers targeted automotive applications that are similarly noisy environments, is the most likely choice. EDN

You can reach Technical Editor Margery Conner at 1-805-461-8242 and mconner@connerbase.com.

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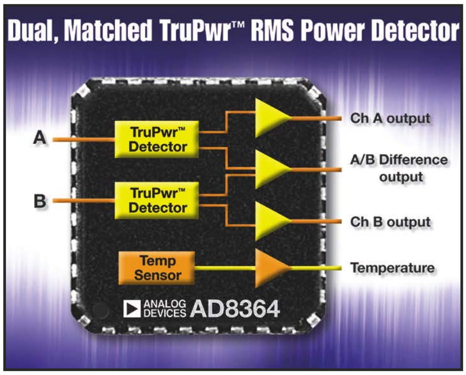
Summer 2005

Industry's First Dual-Channel RMS Power Detector



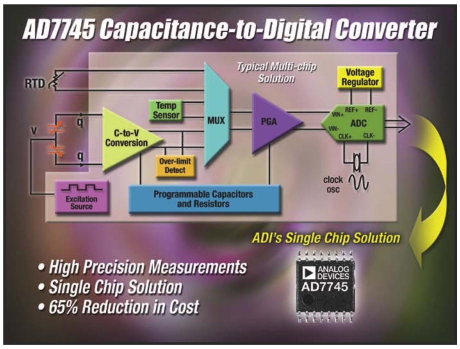
The AD8364 is the industry's only power detector that measures two complex input signals simultaneously, enabling cellular base station system designers to solve one of their biggest challenges—the accurate measurement of RF signals. The AD8364 is ideally suited for next-generation cellular infrastructure equipment using complex signals with constantly varying peak-to-average ratios, such as CDMA2000, WCDMA, and TD-SCDMA. Specific applications include PA (power amplifier) control and linearization, antenna VSWR (voltage standing wave ratio) monitoring, transmitter power control, and automatic gain control circuits.

AD8364	$7.85

www.analog.com/AD8364

World's First Single-Chip High Precision Capacitance-to-Digital Converter

Analog Devices' single-chip, high precision capacitance-to-digital converter (CDC) family (AD7745/AD7746/AD7747) leverages ADI's expertise in high precision Σ-Δ technology and system integration by combining 24-bit resolution, superior accuracy of 4 fF, and low power (700 μA max). In addition to being the industry's highest precision solution for interfacing with capacitive sensors, the CDC offers enhanced on-chip functionality by integrating a number of analog functions (ADC, clock, multiplexer, temp sensor, I²C® Interface, and voltage reference) that result in a cost savings of up to 65% over alternative multichip solutions. The AD7745/AD7746/AD7747 are available in a 16-lead TSSOP package.

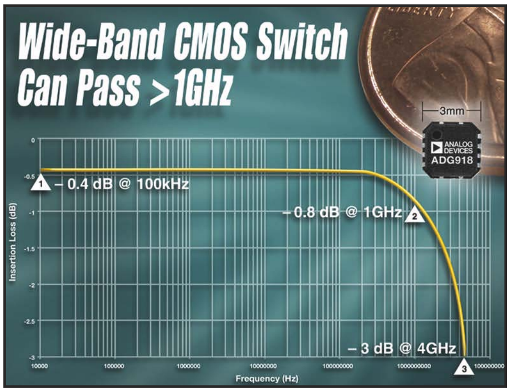


AD7745	$4.60
AD7746	$4.95
AD7747	$4.60

www.analog.com/CDC

Bulk CMOS Switch Delivers 3 dB Bandwidth in Excess of 4 MHz

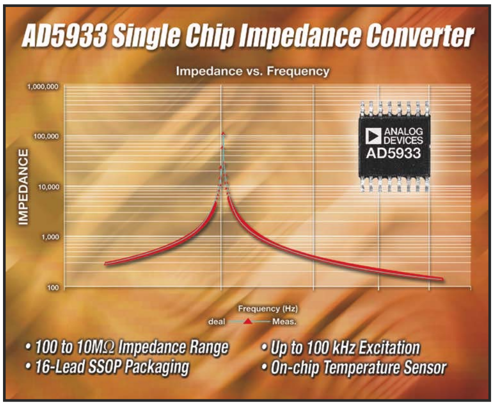
The ADG901 family of high frequency switches is the first family of bulk CMOS switches to provide 3 dB bandwidths in excess of 4 GHz. It has many advantages over traditional RF switching solutions that offer PIN diodes, GaAs, pHEMT, and MESFET switches. The ADG901 family of wideband switches is also designed to meet the demands of devices transmitting at frequencies ranging from dc to ISM band frequencies and higher. Its low insertion loss, high isolation between ports, low distortion, and low current consumption provide excellent solutions for many high frequency applications that require low power consumption and transmitted power up to 16 dBm.



ADG901 $1.03
www.analog.com/ADG901

Single-Chip Impedance-to-Digital Converter Delivering Superior Accuracy and Integration

The AD5933 and AD5934 single-chip impedance-to-digital converters combine state-of-the-art digital and analog signal processing techniques in a compact integrated solution for impedance measurement. Using a direct digital synthesizer (DDS) to provide a fine-frequency sweep capability combined with an analog-to-digital converter and sophisticated digital signal processing these devices allow an external complex impedance (range 100 Ω to 10 MΩ) to be excited with a known frequency of up to approximately 100 kHz. The response signal from the impedance is sampled by the on-board ADC and discrete Fourier transform (DFT) processed by an on-board DSP engine. The DFT algorithm returns a real (R) and imaginary (I) data-word at each frequency point (in the case of a sweep) allowing impedance to be conveniently calculated based on an initial calibration. The AD5933/AD5934 are available in a 16-lead SSOP package.



AD5933	$6.65
AD5934	$4.35

www.analog.com/IDC

ADI's Lens Driver Chip Provides Industry's Smallest, Lowest Cost Solution for Autofocus Applications

AD5398 $1.51
www.analog.com/lensdriver

The AD5398 lens driver features a fully integrated and optimized lens motor and actuator driver design that is 80% smaller and one-half the cost of existing discrete solutions. Targeted for the mainstream camera phone market and modules with image resolution greater than 1 MP (megapixel), the AD5398 features 120 mA output current sink capability and 10-bit resolution, exceeding the typical performance requirements of the application. These performance levels enable fine focus without compromising image quality. The device is highly integrated to provide a complete solution requiring no external components. In addition to a 10-bit DAC, included on-chip are a current sensing resistor and inductive protection diodes—components that typically consume large amounts of board space and introduce unreliability to the system—and an internal reference. The AD5398 is available in a small 8-lead 3 mm × 3 mm LFCSP (lead frame chip scale package) and is priced at less than $1.00 per unit in volume quantities.

Class-D Amplifiers that Boast the "Best-in-Class" Performance and EMI Reduction

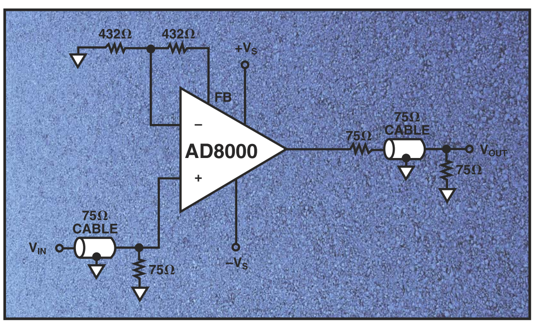
The AD199x amplifiers deliver audiophile sound quality (THD<0.005%; SNR>101 dB; PSRR>65 dB) with 50% lower heat dissipation than traditional linear amplifiers. The devices' breakthrough performance is achieved through Analog Devices' closed-loop, mixed-signal integration of 7th-order Σ-Δ modulator technology with high power output drive circuitry and bridge circuitry. Radiated and conducted out-of-band RF emissions are minimized with Analog Devices' advanced modulation techniques and closed-loop, Σ-Δ architecture to enable a significant reduction in EMI.

The AD199x amplifiers, including the AD1990, AD1992, AD1994, and AD1996, are single-chip devices containing an integrated stereo modulator and stereo "bridge-tied" load (BTL) power stage. Power levels range from Stereo 5 W (Mono 10 W) to Stereo 40 W (Mono 80 W). The AD1990/AD1992/ AD1994 are available in a 64-lead LFCSP package while the AD1996 is available in a 32-lead PSOP form factor.

AD1990	$2.90
AD1992	$3.28
AD1994	$4.42
AD1996	$6.99

www.analog.com/AD1990

Ultra High Speed Op Amp with Power-Down



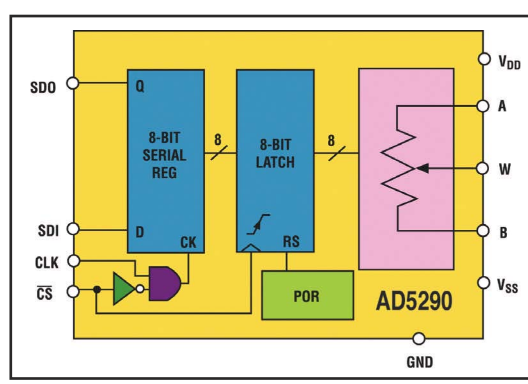
High speed video applications such as video signal routing require a high level of performance to maintain excellent fidelity. The AD8000 current feedback amplifier offers excellent video specifications including a 0.1 dB flatness out to 170 MHz, fast settling of 12 ns to 0.1%, and differential gain and phase of 0.02% and 0.01°. The AD8000 power-down mode reduces the supply current to 1.3 mA. It is available in both 8-lead LFCSP and 8-lead SOIC.

AD8000	$1.68

www.analog.com/AD8000

New 256-Position Digital Potentiometer Combines Terminal Voltage Range, Package Size, and Price

The AD5290 is our new 8-bit digital potentiometer that delivers an unbeatable combination of features and performance in an ultrasmall package size. This device performs the same electronic adjustment function as the traditional mechanical potentiometers or variable resistors, but with the enhanced resolution needed for high voltage designs and the benefits of complete digital control. The AD5290 also provides superior temperature coefficient performance and solid-state reliability—something that mechanical potentiometers can't claim. This package of digital potentiometer performance and features is comfortably within the budget of your design.

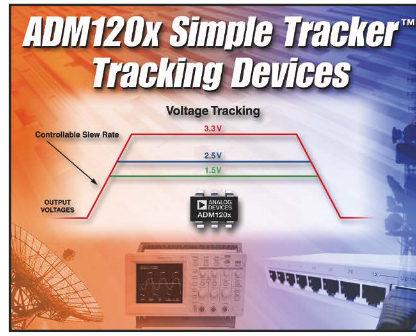


AD5290	$1.95

www.analog.com/AD5290

ADM120x Family of Cascading Tracking Devices Provide ±100 mV Accuracy for Multisupply Systems

The ADM120x family of Simple Tracker tracking devices consists of tiny 6-lead and 8-lead devices that provide accurate control over the slew rate of voltage rails at power-up and power-down. An on-board charge pump generates a voltage to control the gate of an N-channel FET. An external capacitor accurately sets the slew rate of the gate turn-on and turn-off. The devices can be cascaded to provide a voltage tracking solution for multisupply systems. In the standard tracking configuration, the voltages will not be more than ±100 mV apart when ramping up and down. The ADM1200 is available in 6-lead SOT-23 while the rest of the family is available in an 8-lead TSOT.



ADM1200/1201/1203	$1.75
ADM1204	$1.90

www.analog.com/ADM120x

Video Amps Offer 97% Lower Standby Power for Portable Consumer Video Applications

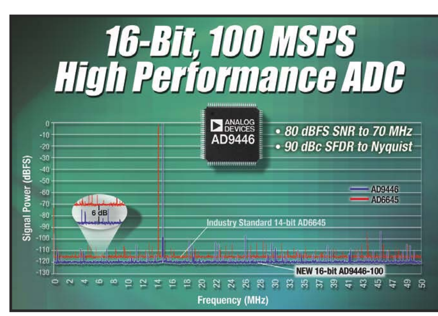
The ADA4850 family of low power amplifiers is designed to enable battery-powered video devices to efficiently play back high quality video on televisions. When video display is not needed, the amplifiers have a patent-pending low power standby mechanism that significantly reduces power consumption—consuming 97% less power than the closest comparable devices. The ADA4850 video amplifiers minimize operating current to 2.7 mA maximum and have the industry's lowest standby current at less than 1 μA. This energy consumption breakthrough is achieved using a patent-pending internal shutdown mechanism. The devices also include rail-to-rail outputs that allow driving line-terminated video lines on single-supply voltages as low as 2.7 V. The amplifiers have excellent differential gain and phase of 0.12% and 0.09°, respectively. Priced to save as much as 50% compared to bipolar and CMOS amplifiers that have higher standby power, these amplifiers save space and component costs by integrating the low power standby feature in a 3 mm × 3 mm chip LFCSP package.

ADA4850-1 (100k)	$0.45
ADA4850-2 (100k)	$0.59

www.analog.com/ADA4850-1
www.analog.com/ADA4850-2

16-Bit ADC Achieves Industry's Best Noise Performance at 100 MSPS

As part of a family of high speed converters optimized to deliver higher sample rates and improved dynamic performance at competitive prices, the new AD9446 achieves a 10x increase in sample rates over competing ADCs while offering 90 dBc SFDR and 80 dBFS SNR at baseband—a full 6 dB better than the SNR achieved by the closest competing ADC. The AD9446 is also available in an 80 MSPS speed-grade option that achieves industry-leading 85 dBc SFDR, while improving the signal-to-noise ratio by another 2 dB to 82 dBFS SNR. The AD9446 enables developers of instrumentation and automated test and measurement equipment, data acquisition systems, medical imaging devices, and advanced military/aerospace communication subsystems to build more performance overhead into their designs by capturing a better representation of the input signal while using fewer samples.



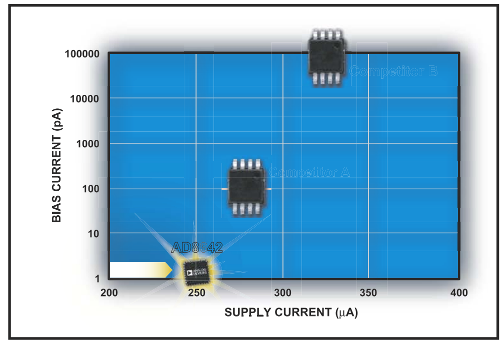
AD9446-100	$79.90
AD9446-80	$72.25

www.analog.com/AD9446

Best Precision, Low Power JFET Amps in the Market

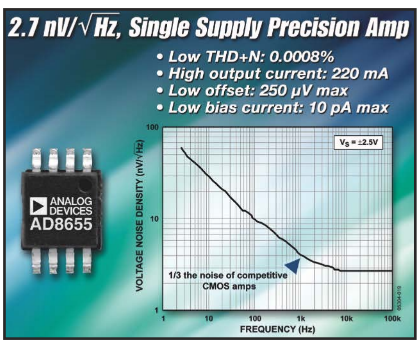
Designers continue to face power consumption and board space constraints in their system designs. The AD8642 and AD8643 are low power, precision, dual and quad JFET amplifiers that feature rail-to-rail output, high source impedance, low bias current, and low supply current. These amplifiers are ideal for ECG/EKG, blood analyzers, and fluid condition monitors as well as those applications using multichannel boards and requiring low power to manage heat.

The AD8642 and AD8643 operate from 5 V to 26 V (+2.5 V to +13 V) and are specified at –40°C to +125°C. The device features low input bias current (1 pA max), low supply current (250 µA max), and offset voltage of 750 µV max. The AD8642 is available in 8-lead MSOP and 8-lead SOIC Pb-free packages. The AD8643 is available in 3 mm × 3 mm 16-lead LFCSP and 14-lead SOIC Pb-free packages.



AD8642 $2.32
AD8643 $3.80
www.analog.com/AD8642

Low Noise, Precision Amp for Low Voltage Applications

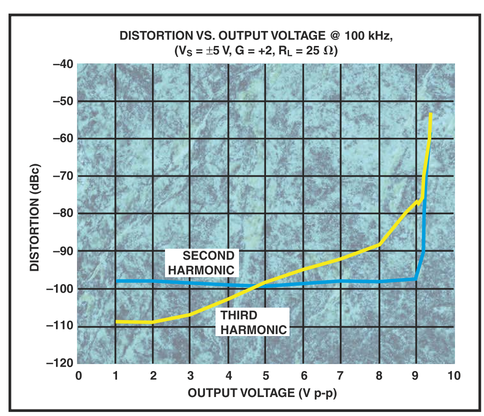


AD8655 $0.70
www.analog.com/AD8655

The AD8655's low noise and low distortion performance eliminate the need for external transistors or the use of multiple amps to lower system level noise in low voltage applications. These features along with low offset and offset drift, and rail-to-rail input/output are attractive for communications and audio applications as well as data acquisition and process controls. The low noise and distortion improves SNR and accuracy for driving high resolution ADCs. The AD8655 operates from 2.7 V to 5.5 V and is specified from –40°C to 125°C. The device features R-R input/output, low noise (2.7 nV/ $\sqrt{\text{Hz}}$), 0.0008% THD+N, and an output current of 220 mA. The AD8655 is available in 8-lead MSOP and SOIC Pb-free packages.

Rail-to-Rail Op Amp Offers High Output Current and Low Distortion

When designers seek op amps that provide a large dynamic range to drive light loads, they typically seek a rail-to-rail output amplifier that has a wide supply range and high output current with good distortion performance. The AD8397 can offer this performance without compromising output current. The AD8397 has excellent differential linearity with 310 mA peak output current making it ideal for a variety of applications including active filters and twisted pair line driving. The device can be used over a wide supply range of 3 V to 24 V. The AD8397 is available in a standard 8-lead SOIC package and, for higher power applications, a thermally enhanced 8-lead SOIC EPAD package. It operates over a temperature range of –40°C to +85°C.



AD8397 $2.29
www.analog.com/AD8397

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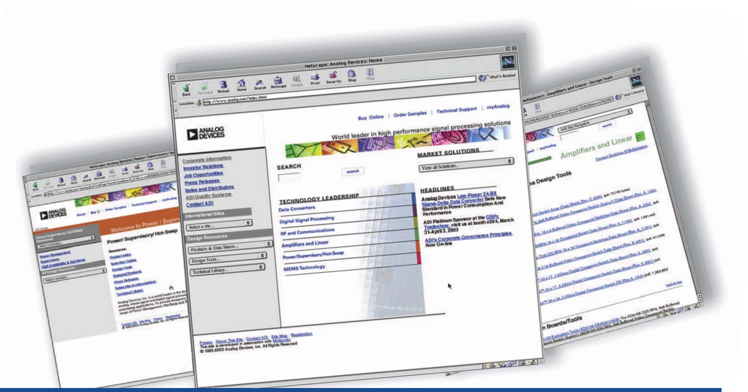


For a complete list of products released this quarter and to order samples, please go to *www.analog.com/currents*.

New Class of Integrated Video Filters for Consumer Applications

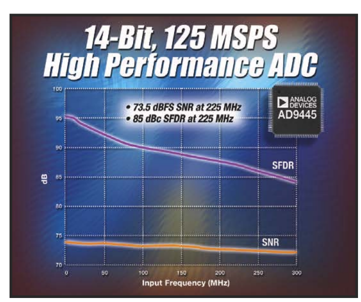
ADA4410-6	$2.49
ADA4411-3	$1.89
ADA4412-3	$1.59

www.analog.com/ADA4410

The ADA441x family of integrated filtering products provides consistent, high quality video images for consumer applications including set-top boxes, HDTV, and DVD players and recorders. The parts are designed to filter and drive many types of analog video signals, including HD, SD, S-Video, and composite video. The products are ideal as reconstruction filters at the DAC outputs of video encoders, but can also be used as antialias filters. The ADA441x offers R-R output, 2:1 mux on all inputs, selectable gain X2 or X4, and a wide supply range of +4.5 V to ±5 V. The ADA4410-6 is available in 32-lead LFCSP. Both the ADA4411-3 (available in 24-lead QSOP) and the ADA4412-3 (available in 24-lead QSOP) products release in July 2005.

New 14-Bit ADC Increases Cell Coverage and Reduces Dropped Calls in Base Stations

The AD9445 is the first 14-bit, 125 MSPS (megasamples per second) ADC to achieve a spurious-free dynamic range (SFDR) above 80 dBc and a signal-to-noise ratio (SNR) of 72.5 dBFS at input frequencies up to 300 MHz, better than competing solutions by a full 10 dB and 4 dB, respectively. A converter with high SFDR can capture weak signals in the frequency band of interest, despite the presence of strong, interfering signals. The industry-leading SNR characteristics of the AD9445 enable wireless infrastructure equipment designers to improve cellular base station receivers by offering lower overall system noise at higher intermediate frequencies, which translates to expanded cellular coverage and fewer dropped calls. A 105 MSPS version of the AD9445 is also available at a reduced cost.



AD9445-125	$59.50
AD9445-105	$49.30

www.analog.com/AD9445

**Analog Devices, Inc.
Worldwide Headquarters**
Analog Devices, Inc
One Technology Way
P.O. Box 9106
Norwood, MA 02062-9106
U.S.A.
Tel: 781.329.4700
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**Analog Devices, Inc.
Europe Headquarters**
Analog Devices SA
17-19 rue Georges Besse
Antony, 92160
France
Tel: 33.1.46.74.45.00
Fax: 33.1.46.74.45.01

**Analog Devices, Inc.
Japan Headquarters**
Analog Devices, KK
New Pier Takeshiba
South Tower Building
1-16-1 Kaigan, Minato-ku,
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Japan
Tel: 813.5402.8210
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**Analog Devices, Inc.
Southeast Asia
Headquarters**
Analog Devices
22/F One Corporate
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Designing offline power supplies using power-factor correction

BY REDUCING AC-LINE CURRENT, SWITCHED-MODE POWER SUPPLIES THAT INCORPORATE PFC ARE CUTTING THE COST OF INSTALLING AND OPERATING AC-POWERED EQUIPMENT. INCREASINGLY, REGULATORY BODIES ARE REQUIRING PFC.

To develop offline power supplies that use PFC (power-factor correction), you must first understand the meaning of PFC and the regulations that surround the design of offline power supplies.

PFC aligns the current waveform with the voltage waveform. If the voltage and current waveforms are not aligned, the PF (power factor) is less than 1 (**Figure 1**); otherwise, the PF is equal to 1 (**Figure 2**). In most cases, PF-corrected designs have PFs of 0.95 to 0.98. Most supplies that are not PF-corrected have PFs of approximately 0.6. In a three-phase system, if the voltage and current waveforms are not aligned, nonsinusoidal currents at three times the line frequency flow in the neutral line, requiring companies that supply ac power to use larger neutral conductors than would otherwise be necessary and to install more capacity to produce the required number of kilovolt-amperes. These harmonics are tough on power systems and can lead to overload and overheating of transformers, capacitor banks, and other power-system elements, sometimes tripping circuit breakers.

With this basic understanding of PFC, your next step is to determine when to use the PFC technique to comply with regulations in the regions where the product you are designing will be used. In 2001, the European Union put into effect EN 61000-3-2 to establish limits on harmonics as high as the 40th of ac-line-powered equipment's input current. Amendment A14, which took effect on January 1, 2001, has eased the impact of power-harmonics requirements in Class D, a group of equipment now defined far more narrowly than in the original standard: PCs, PC monitors, and television sets (**Table 1**).

WHAT CAUSES THE PROBLEM?

On a circuit level, the main cause of PFs of less than 1 in SMPSs (switch-mode power supplies) is that the main capacitor, C_{IN} (**Figure 3**), charges only when V_{IN} is close to V_{PEAK} or

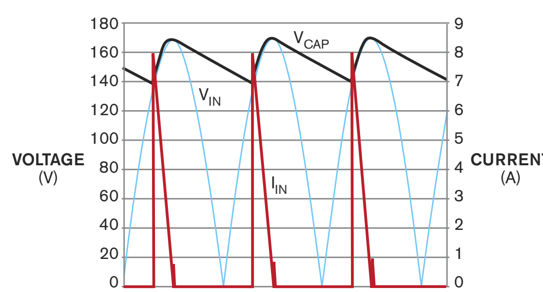

Figure 1 PFC aligns the current waveform with the voltage waveform. If the voltage and current waveforms are not aligned, the PF (power factor) is significantly less than 1.

TABLE 1 EN 61000-3-2 AND AMENDMENT A14 FOR PFC

EN 61000-3-2 Classification Scheme	Amendment A14 Classifications
Class A: balanced three-phase equipment, single-phase equipment not in other classes	Class A: balanced three-phase equipment; household appliances, excluding equipment identified as Class D; tools except portable tools; dimmers for incandescent lamps but not other lighting equipment; audio equipment; anything not otherwise classified
Class B: portable power tools	Class B: no change
Class C: lighting equipment with power requirements greater than 25W	Class C: all lighting equipment except incandescent-lamp dimmers
Class D: not Class B or C, single-phase, not motor driven, requiring less than 600W, and possessing a special waveshape	Class D: single-phase, requiring 75 to 600W, PCs, PC monitors, TV receivers

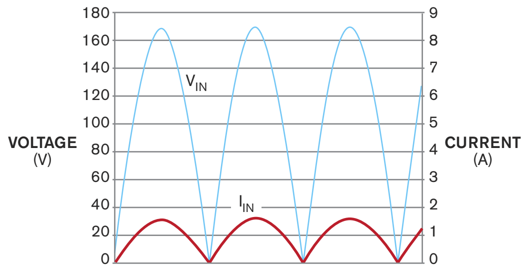

Figure 2 If the voltage and current waveforms are aligned, PF is 1.

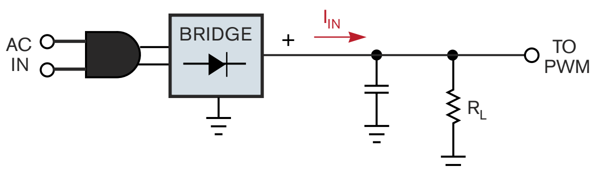

Figure 3 The input to a non-power-factor-corrected SMPS is typically a rectified sine wave.

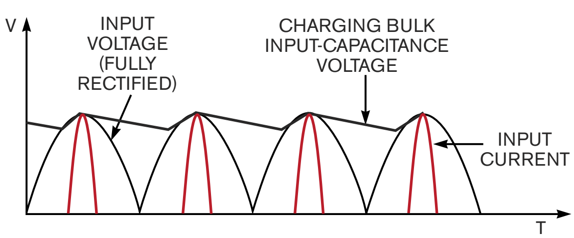

Figure 4 The bulk capacitor charges during the relatively brief portion of the ac-line cycle when the rectified voltage exceeds the bulk-capacitor voltage.

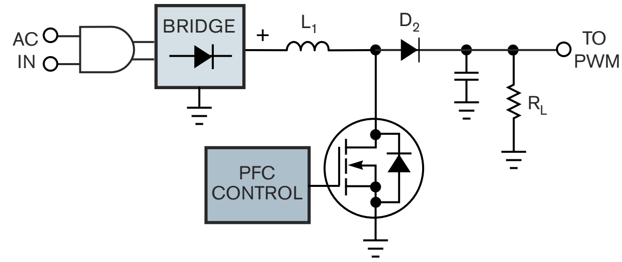

Figure 5 The boost converter adds a series inductor and MOSFET switch to the circuit of Figure 3.

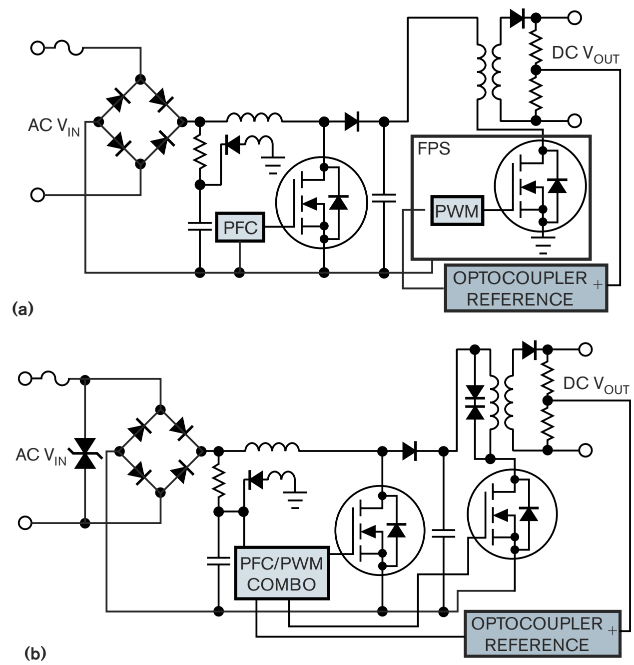

Figure 6 You can design an SMPS with a stand-alone PFC controller (a) or with a combined PFC/PWM-combo controller (b).

when V_{IN} is greater than the capacitor voltage, V_{CIN} (**Figure 4**). To achieve a PF-corrected power output, designers often use a boost converter to maintain a voltage higher than the line voltage's peak value. The boost topology maintains this increased voltage; the PFC controller makes the average inductor current proportional to the input-voltage waveform. The boost topology also allows the average inductor to charge the input capacitor, C_{IN}, now on the output side of the boost controller rather than after the bridge-diode device (**Figure 5**).

Several IC manufacturers provide PFC boost converters. For example, Fairchild offers discontinuous- and continuous-mode devices. Some of these, such as the FAN7527B, are stand-alone PFC controllers (**Figure 6a**). Others, such as the FAN4803, integrate PFC and PWM operation into one packaged device that supplies more than 500W (**Figure 6b**). This variety allows designers to develop offline power supplies that use fewer components and require less space. These combo devices not only achieve PFC control, but also use flyback, forward, or other types of voltage-conversion topology to convert from large dc voltages, such as 385V dc, to 12V dc.

DISCONTINUOUS OR TRANSITION MODE

Discontinuous-mode controllers, such as the FAN7527B, offer PFC control at output-power levels up to and including 200W. Such devices operate in the discontinuous mode in which the boost converter's MOSFET turns on at zero inductor current and turns off when the current meets the desired input-reference voltage (**Figure 7**). In this way, the input-current waveform follows that of the input voltage and achieves an average inductor current that is in phase with the input voltage.

Compared with continuous-mode devices, discontinuous-mode units have higher I^2R and skin-effect losses, use larger magnetic cores, and require larger input filters because of the larg-

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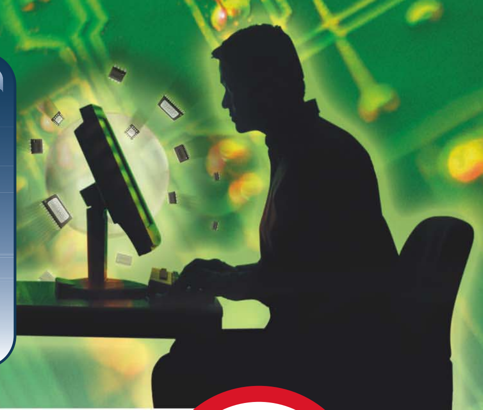

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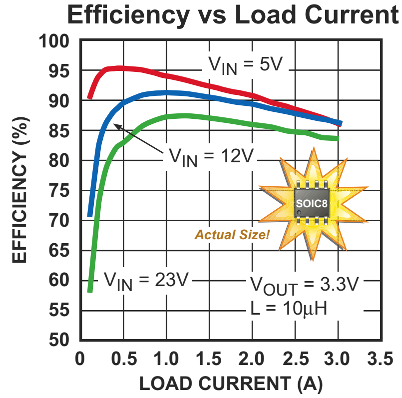

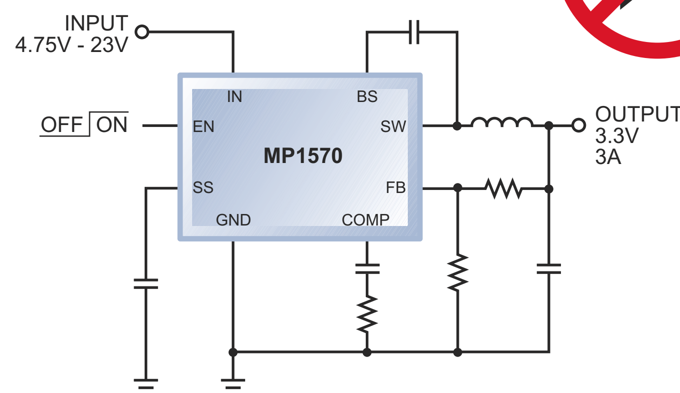

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Part	Frequency	V_{IN} (V)	I_{OUT} (A)	Package
Featured Synchronous Bucks				
MP2104	1.7MHz	2.5 - 6	0.6	TSOT23-5
MP2109*	1.0MHz	2.5 - 6	2x 0.8	QFN10 (3x3)
MP2106	800kHz	2.6 - 13.5	1.5	QFN10 (3x3)
MP2305	340kHz	4.75 - 23	2.0	SOIC8
MP1570	340kHz	4.75 - 23	3.0	SOIC8
Featured Non-Synchronous Bucks				
MP2361	1.4MHz	4.75 - 23	1.5	QFN10 (3x3)
MP2364*	1.4MHz	4.75 - 23	2x 1.5	TSSOP20
MP2354	380kHz	4.75 - 23	2	SOIC8
MP1593	385kHz	4.75 - 28	3	SOIC8

** Dual Output*

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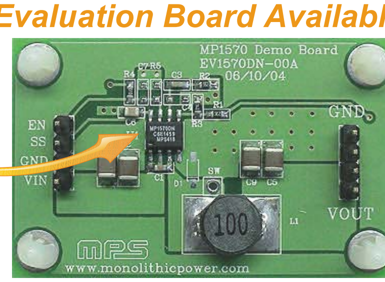

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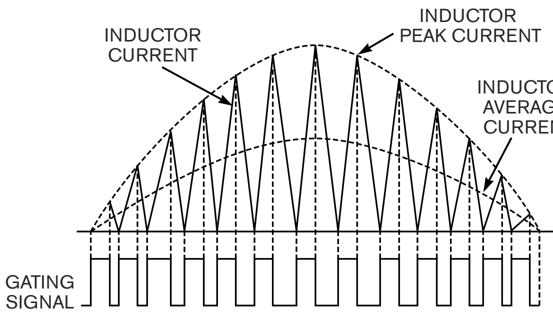

Figure 7 In the discontinuous mode, the boost converter's MOSFET turns on at zero inductor current and turns off when the current meets the desired input-reference voltage.

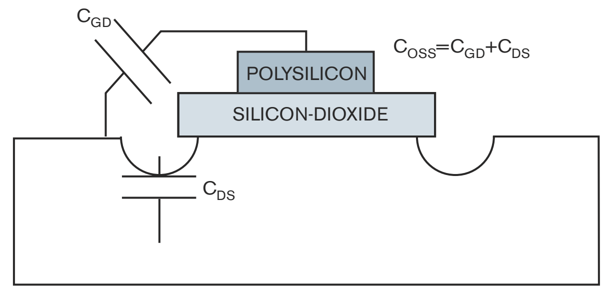

Figure 9 Continuous-mode zero-voltage switching uses an LC-resonant tank circuit to discharge the MOSFET's C_{OSS} (output capacitance).

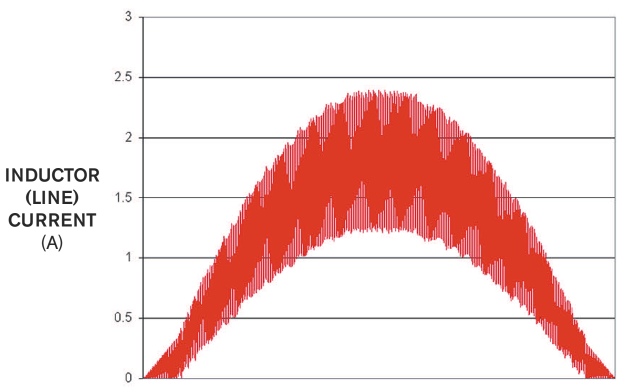

Figure 8 In the continuous mode, the current in the energy-transfer inductor never reaches zero during the switching cycle.

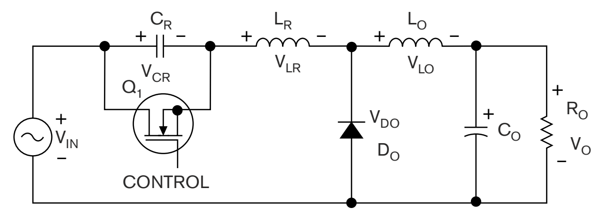

Figure 10 In this ZVS buck converter, when Q_1 turns on, $V_{CR}=V_{DS}=V_{DO}=0$. When Q_1 turns off, the voltage across C_R increases linearly and works with L_R to dissipate the charge stored in C_{OSS}.

er inductor-current swings. On the positive side, use of these devices is less complex because they switch the boost MOSFET on when the inductor current is zero, so the boost diode needs no reverse-recovery-current specification, which allows the use of a less expensive diode. Also, the use of variable switching frequencies spreads the spectrum of the EMI (electromagnetic-interference) signature that results from the boost switch's zero-current turn-on.

Continuous- or hard-switcher modes typically suit SMPS power levels greater than 200W. In this mode, the boost converter's MOSFET does not switch on when the boost inductor is at zero current. Instead, the current in the energy-transfer inductor never reaches zero during the switching cycle (**Figure 8**).

In consequence, the current swing is less than in the discontinuous mode, resulting in lower I^2R losses, lower inductor-core losses, and reduced EMI, which allows the use of a smaller input filter. However, because the MOSFET turns on when the inductor and diode currents are nonzero, a fast reverse-recovery diode is necessary to minimize losses.

CONTINUOUS MODE USING ZVS

Designers can use various techniques to reduce the hard transition of a continuous-mode PFC controller. Fairchild's FAN4822 implements one such technique, ZVS (zero-voltage switching). The primary purpose of using ZVS is to reduce the power loss or power dissipation in the PWM switch during turn-on. More losses occur in the external MOSFET with the increase in switching frequency. This technique uses an LC-resonant tank circuit to discharge the MOSFET's C_{OSS} (output capacitance, **Figure 9**). This capacitance is the sum of the C_{DS} (drain-to-substrate capacitance) and C_{GD} (gate-to-drain capacitance). ZVS works well with power supplies that switch at frequencies greater than 100 kHz. It also reduces the MOSFET's gate-drive requirements because the C_{GD} charge does not exist when the V_{DS} (drain-to-source voltage) equals zero.

When the switch is off, you have a charge, E, on C_{OSS} of $E=1/2C_{OSS}V_{DS}^2$ with $V_{GS}=0V$. Once the switch turns on, this energy dissipates and can become a limiting factor in SMPS topologies. As the switching frequency increases, so does the power dissipation:

$$P_D = E \times f_S,$$

where P_D is the power dissipation, E is the energy stored within C_{OSS}, and f_S is the switching frequency.

In its basic form, ZVS works as follows (**Figure 10**): When switch Q_1 turns on, $V_{CR}=V_{DS}=0$, and $V_{DO}=0$. When switch Q_1 turns off, the voltage across the C_R (resonant capacitor) increases linearly and works with the L_R (resonant inductor) to dissipate the charge stored in C_{OSS}. Note: $L_O>>>L_R$. The voltage

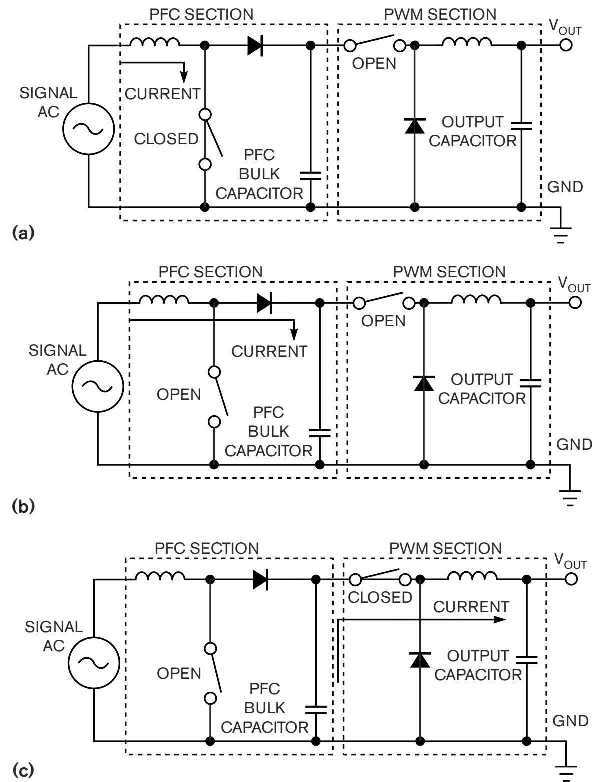

Figure 11 The major steps in the operation of this TEM/TEM converter are energizing the PFC inductor (a), charging the PFC bulk capacitor (b), and powering the output (c).

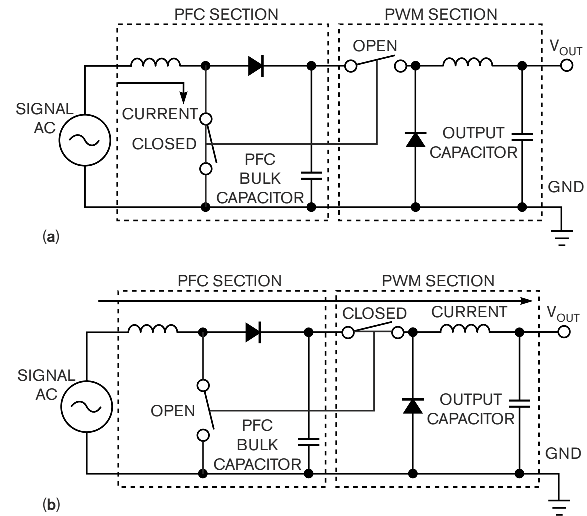

Figure 12 To perform the function of the converter in Figure 11, this LEM/TEM converter needs only two steps: energizing the PFC inductor (a) and charging the PFC bulk capacitor and powering the output (b).

across L_O then reverses polarity, and D_0 begins to conduct, thereby expending the energy stored in L_O. The resonant inductance-capacitance network components, C_R and L_R, are selected based on the maximum input voltage V_{INMAX} and minimum output current I_{OMIN} for the circuit to remain resonant over all operating conditions of line and load.

$$C_R = \frac{1}{Z_R \times \omega_R}; \quad C_R = \frac{I_{OMIN}}{V_{INMAX} \times \omega_R}.$$

$$L_R = \frac{Z_R}{\omega_R}; \quad L_R = \frac{V_{INMAX}}{I_{OMIN} \times \omega_R}.$$

LEM/TEM VERSUS TEM/TEM

In its combo mode (PFC/PWM) devices, Fairchild uses a patented LEM/TEM (leading-edge modulation/trailing-edge modulation) technique, in which the PFC and PWM switches are synchronized so that the PFC switch turns off just as the boost switch turns on. This technique allows the PFC bulk capacitor to be smaller than normal because it does not power the output all by itself; the PFC inductor helps out. Typically, PFC/PWM controllers use TEM/TEM, which results in an additional step as well as a larger PFC bulk capacitor (**Figure 11**).

Figure 11a shows the energizing of the PFC inductor. **Figure 11b** shows the energy from the inductor transferring into the PFC bulk capacitor. When you close the PWM switch, the energy within the PFC bulk capacitor drives the load (**Figure 11c**). Every time this cycle repeats, the PFC bulk capacitor has to be fully charged because it is fully discharged when the PWM switch closes.

In LEM/TEM, the PFC and PWM switches are tied together such that, when one is opening, the other is closing, so when the PFC switch is open, the PWM switch is closed, and vice versa. Initially, when the PFC switch is closed, the PFC inductor is energized. Once the PWM switch is closed, both the output and the PFC bulk capacitor are energized. **Figures 12a** and **12b** show that upon repetition of this cycle, the PFC bulk capacitor does not have to be as large as that in TEM/TEM because it does not power the output all by itself; the PFC inductor helps out.

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The potential for reducing operating costs by minimizing wasted power explains why device-side PFC has become important in so many products' power systems and is expected to increase the PFC-controller market to $175 million in 2006. Many standards (for example, EN 61000-3-2) are driving PFs toward 1 and are requiring minimum total-harmonic distortion in systems that consume ever-smaller amounts of power. EDN

AUTHOR'S BIOGRAPHY

Philip Zuk is a staff applications engineer at Fairchild Semiconductor. He has a diploma in electronic engineering technology from Red River College (Winnipeg, MB, Canada) and a bachelor's degree in electrical engineering and a master's in business from the University of Manitoba (Winnipeg). Visit www.fairchildsemi.com/pfc for additional information.

BY ALEXANDER SCHMITT • AGILENT TECHNOLOGIES

Testing serial gigahertz-speed buses

REPLACING DIGITAL PARALLEL BUSES IN COMPUTER AND DATACOM APPLICATIONS WITH SERIAL HIGH-SPEED BUSES HAS SIGNIFICANT IMPLICATIONS. SIGNAL-INTEGRITY EFFECTS MAY EMERGE AS ISSUES. ENGINEERS CAN USE STANDARD STIMULUS/RESPONSE TEST EQUIPMENT TO PERFORM DEMANDING PHYSICAL-LAYER TESTS.

Engineers have for many years used wide parallel digital buses, such as PCI, SCSI, and parallel ATA, for interconnects in the computer and datacom industry. Over time, the clock speeds of these buses increased to several hundred megahertz. Although the pace may have slowed a little bit, the ever-increasing demand for more bandwidth naturally has led to ever-higher processor clock speeds. At clock rates of approximately 1 GHz, however, parallel buses have become roadblocks on the data highway. Currently, engineers could overcome these challenges, such as synchronizing parallel data lanes at rates greater than 1 GHz, only with massive, probably unjustified technical effort. This scenario is especially true if you consider that, all of a sudden, digital designers are in the realm of "digital microwave." Thus, they are often unprepared to cope with nasty effects, such as EMI and jitter (phase noise). Traditionally, such effects occur only in RF designs, and engineers could ignore them at lower data rates.

To overcome the physical limitations of the legacy buses and to cope with the new challenges, the trend is to migrate to serial, differential high-speed buses, such as PCI Express, SAS (serial-attached SCSI), or serial ATA (SATA). **Figure 1** illustrates an example of computers using high-speed buses. Other examples include using PCI Express, RapidIO, and InfiniBand for chip-to-chip interconnects and on the bus and backplane level and using SATA on the system level.

In addition to overcoming the 1-GHz barrier, serial-bus implementations, such as PCI Express, offer significant advantages, including scalable performance, hot-plug and -swap capability, peer-to-peer communication without involving the processor, and low power consumption.

Clock speeds exceeding 1 GHz—for example, 1.5 GHz for SATA and 2.5 GHz for PCI Express—edge rates of less than 1 nsec, crosstalk, impedance mismatches, EMI, and jitter require careful modeling of the transmission channel. Coping with the effects of digital microwave requires innovative approaches. As an example, PCI Express uses spread-spectrum clocking to prevent EMI.

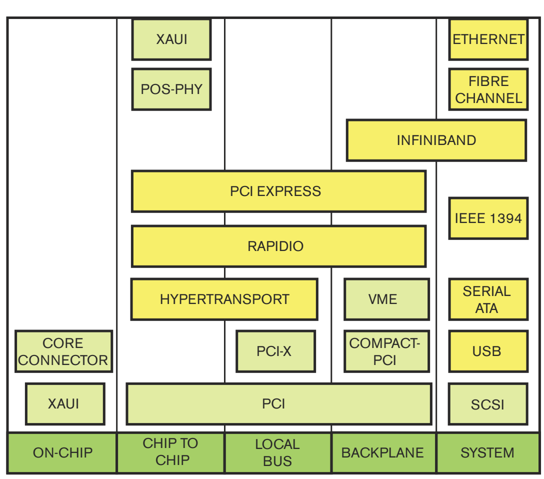

Figure 1 Computers can use high-speed buses.

You need complementary, innovative test equipment to assist the design phase and for the verification and manufacturing test of the OSI (open-systems-interconnect) layers. The low-level PHY (physical layer) defines the physical characteristics of the signal—for example, the voltage levels and timing—to ensure the reliable transmission of the raw bits.

The following two examples provide state-of-the-art PHY testing with digital stimulus/response test equipment. On the stimulus side, this equipment typically comprises a pulse-pattern generator for generating flexible, high-quality test signals. A function generator might complement this digital workhorse by inserting jitter into the pulse generator's output signal. The response side typically uses oscilloscopes, sometimes with complementary logic analyzers. This article focuses on the requirements and capabilities of advanced pulse-pattern-generator and oscilloscope options using two examples: PCI Express receiver-design-validation test and SATA PHY-compliance test.

PCI EXPRESS RECEIVER-DESIGN VALIDATION

PCI Express, a third-generation I/O architecture, addresses the ever-increasing need for I/O bandwidth by providing a point-to-point, high-speed, low-pin-count option. As with each new architecture, you must resolve new interoperability and compliance design challenges. Various test-equipment vendors' tool sets help to quickly and efficiently resolve these new challenges.

You need to validate the proper operation of PCI Express transceivers. Validating the transmitter is straightforward. It simply connects to a logic analyzer or an oscilloscope, and you directly measure the waveform or eye pattern. The validation test of the receiver is more challenging, as you can only indirectly derive it. The basic idea is to apply a known test pattern to the receiver and to measure the transmitter's response.

The test consists of a suitable pulse-pattern generator that generates the stimulus signal, training sequence TS_1. As sequences such as TS_1 may contain multiple megabytes of data, consider employing a straightforward-to-use pattern editor. For specific tests, a function generator complements the stimulus part to insert jitter—sinusoidal, for instance—into the pulse generator's output signal. To that end, you want a wide jitter-insertion bandwidth. On the response side, you can use either an oscilloscope or a logic analyzer. Alternatively, you could choose a bit-error-rate tester.

You conduct the stimulating training sequence under nominal conditions for the functional tests and superimpose stress for the stress tests (**Figure 2**). You apply stress to the DUT (device under test) by using various levels and swing, adding noise to the levels in common and differential mode, or adding jitter to reduce the eye opening.

The receiver-compliance tests that the PCI Express standard specifies comprise receiver-voltage, jitter-tolerance, common-mode, and crosstalk tests. You conduct the basic receiver-voltage test by applying a defined training sequence (pulse-generator output) to the PCI Express receiver and measuring the response of the transmitter with a logic analyzer or an oscilloscope. The test generates the signals both with the minimum specified voltage swing and then again with the maximum allowed voltage swing. The system achieves compliance when the DUT responds with the expected sequence in both cases.

The definition of "jitter" is the short-term variation on the zero-crossing time from the ideal position in the time domain. A reference clock that you recover from the data stream gives the ideal position. The reference has to track the spread-spectrum clock and wander, but not jitter. You perform reference-clock extraction using either hardware or a software phase-locked loop. For the jitter-tolerance test, you basically conduct the receiver-voltage test with random noise, sinusoidal jitter, or both, superimposed on the training sequence. You achieve the jitter injection by appropriately combining the output signals of a function generator and a pulse generator. To that end, you apply a standard function-generator waveform, such as a sine, triangle, or square, to the pulse-pattern generator's jitter-insertion port (delay-control input). The bandwidth of the pulse-pattern generator's jitter-input port needs to be adequate. You determine the receiver's jitter budget by adjusting the jitter amplitude until the device no longer generates the expected response.

The common-mode compliance test again comprises a pulse generator, a function generator, and an oscilloscope. This test adds common-mode noise to the nominal stimulus signal of the pulse-pattern generator by again using a function (noise) generator and the help of a power combiner. You achieve compliance in case the DUT responds with the expected data output.

Finally, the crosstalk-on-idle test requires the same instruments as in the other tests. This test, however, applies only single-ended noise on a transmission line adjacent to the tested one.

For more details on PCI Express receiver-design-validation tests, such as those on the generation of pre- and de-emphasized signals, see **Reference 1**. You can also find information on jitter measurements at **Reference 2**. For further information on advanced jitter analysis with wide-bandwidth sampling oscilloscopes (communication analyzers), see **Reference 3**. These references also cover total-jitter measurement as well as the separation of jitter into random and deterministic jitter.

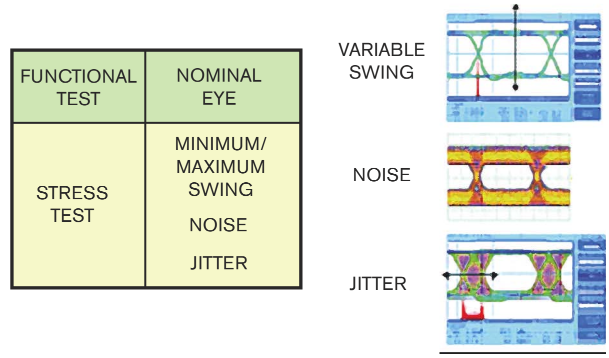

Figure 2 For functional tests, you conduct the stimulating training sequence under nominal conditions; stress tests superimpose stress.

SATA PHY-COMPLIANCE TEST

Engineers use SATA for connecting disk drives to motherboards or host adapters. The data-transfer rate of first-generation SATA (Generation I or SATA-I) is 1.5 Gbps. The equivalent data rate is 150 Mbytes/sec. SATA-II runs at twice that speed: 3 Gbps and 300 Mbytes/sec. The first devices recently became commercially available. SATA-III will run at 6 Gbps (600 Mbytes/sec).

You use compliance tests to guarantee the signal quality (eye pattern, jitter), out-of-band signaling, ac/dc common-mode volt-

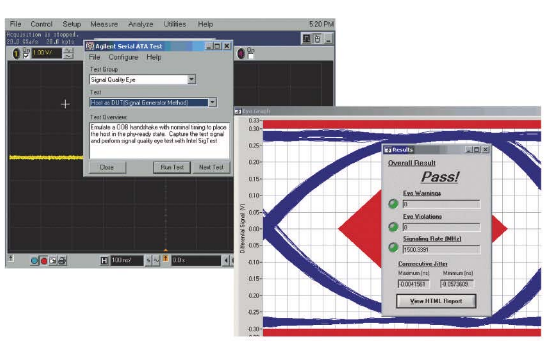

Figure 3 In this SATA-signal-quality-compliance-test example, screen shots show commercially available SATA-test software running on a high-speed, real-time oscilloscope after a transmitter-compliance test.

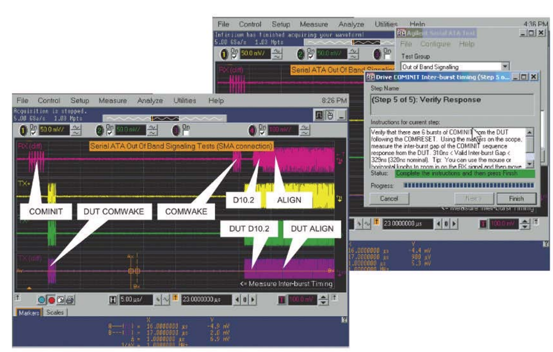

Figure 4 In this SATA out-of-band compliance test, the top signal trace displays the pulse generator's stimulus signal. The lower traces show the DUT's response in a single-ended and in a differential display. Here, the DUT properly responds to an initialization sequence that is in line with the specification.

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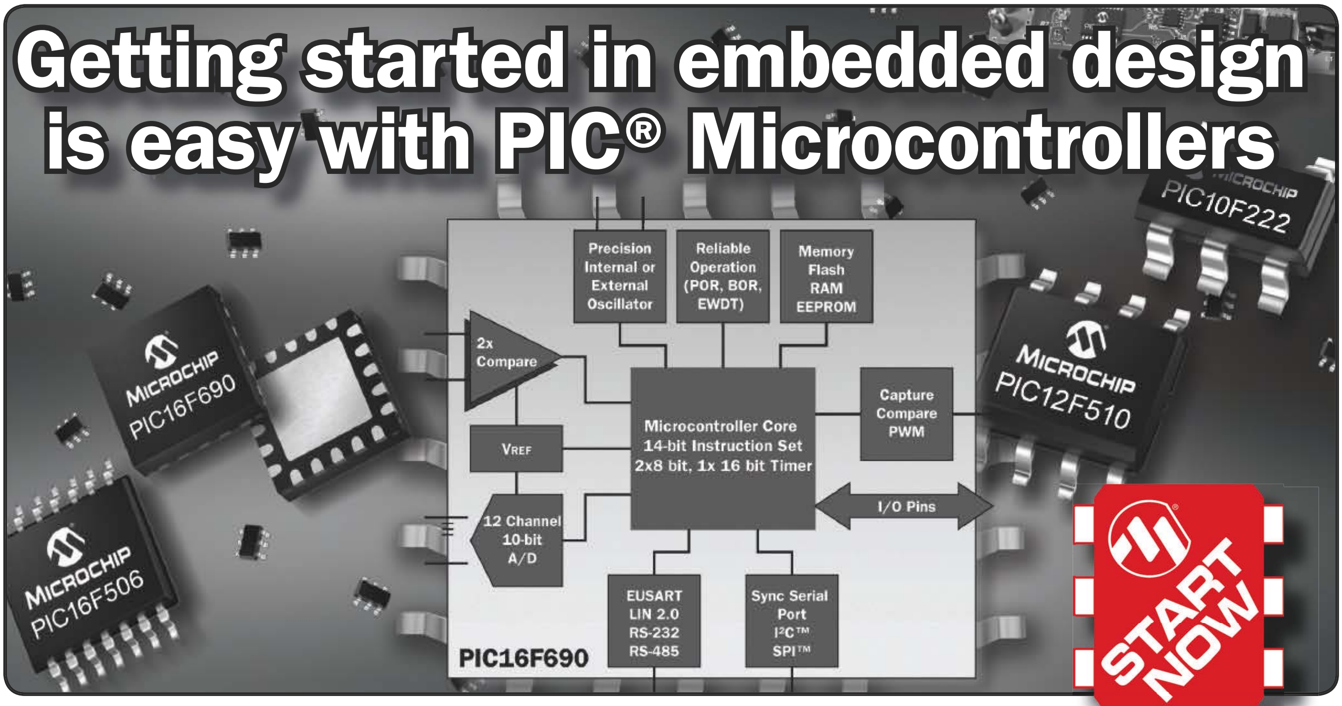

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	PIC12F	12-bit	8	768 to 1536	4 to 8 MHz	8-bit	⊙			
	PIC16F	12-bit	14 to 40	768 to 2048	4 to 8 MHz	8-bit	⊙			
Peripheral-Rich Mid-Range PIC Microcontroller	PIC12F	14-bit	8	1792 to 2048	32 kHz to 8 MHz	10-bit	⊙	⊙	⊙	⊙
	PIC16F	14-bit	14 to 64	1792 to 14336	32 kHz to 8 MHz	10-bit	⊙	⊙	⊙	⊙

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age, and receiver sensitivity (squelch test). The tests are similar to the PCI Express ones; therefore, the test-equipment requirements are similar. The recommended equipment again comprises a pulse-pattern generator, a function generator, and an oscilloscope. Test-equipment vendors offer comprehensive—sometimes free—SATA-compliance-test software. The software can run on the oscilloscope and can control the pulse-pattern generator.

Figure 3 provides an example for a specific SATA-compliance test. The **figure** shows screen shots of commercially available SATA-test software running on a high-speed, real-time oscilloscope after a successful transmitter-compliance test. The system passes the test if the transmitted test pattern does not violate the given mask. For the SATA protocol, out-of-band signaling is particularly important. You conduct out-of-band-signaling tests to ensure that the host and the device properly establish communication. You use so-called beacon signals to initialize the link between a host (the PC) and its client (the hard-disk drive) for this test. This test sends multiple data bursts to the DUT for different device states. The bursts always contain the same data. The bursts differ only in their signal-to-pause ratio, and user-friendly pattern editors can easily generate them. The compliance tests send all possible out-of-band signals to the DUT with the beacon-to-pause ratio set to both the maximum and the minimum allowed ratio for each state. In addition, this test checks the behavior of a DUT for a ratio outside the specified range.

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As in the PCI Express tests, this test monitors the reply data of the DUT's transmitter to determine whether it properly received the stimulus signal.

Figure 4 depicts an example of an out-of-band-signaling test. The top signal trace displays the pulse generator's stimulus signal. The traces below show the response of the DUT in single-ended and differential displays. In this example, the DUT properly responds to an initialization sequence that is in line with the specification. **EDN**

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2. Measuring jitter in digital systems, Application Note 1448-1, 5988-9109EN.
3. Advanced jitter generation and analysis, 5989-1650ENDE.
4. USB 2.0 compliance testing with Agilent Infiniium, Application Note 1400, 5988-6219EN.

AUTHOR'S BIOGRAPHY

Alexander Schmitt is the pulse-pattern-generator marketing manager at Agilent Technologies. He has a doctorate in mechanical engineering and enjoys jogging, biking, and reading the works of contemporary authors.

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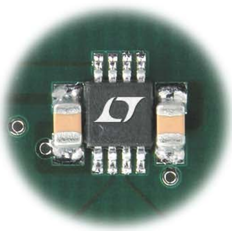

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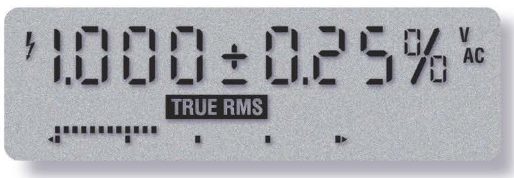

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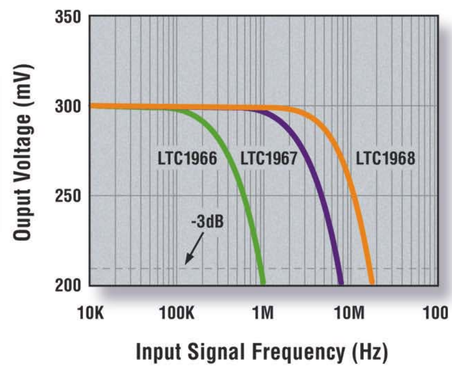

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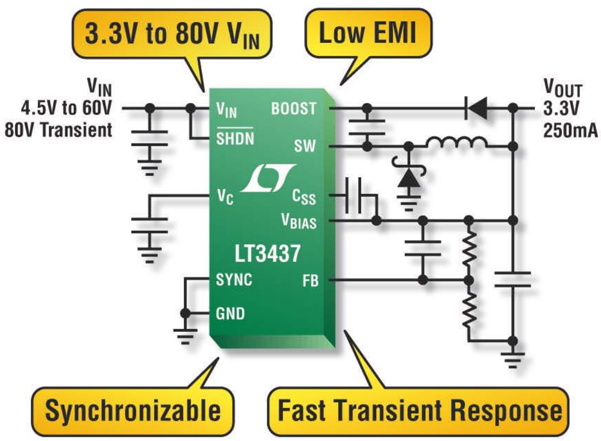

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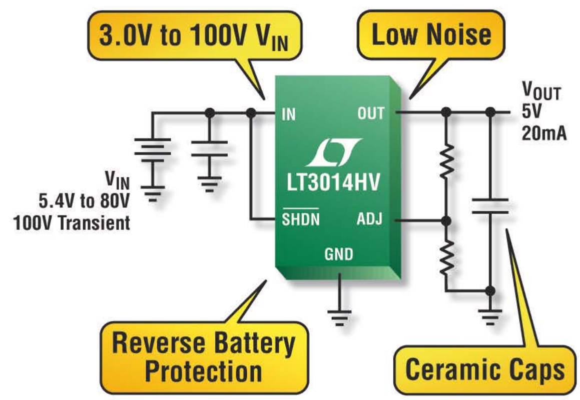

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LT3014/HV	High Voltage LDO	3.0V to 80V/100V**	0.02†	N/A	7µA	DFN, ThinSOT™
LT3012/13	High Voltage LDO	4.0V to 80V	0.25†	N/A	55/65µA	DFN, TSSOP-16E
LT3433	Buck-Boost Regulator	4V to 60V	0.50	200kHz	100µA	TSSOP-16E
LT3437	Step-Down Regulator	3.3V to 60V/80V**	0.50	200kHz	100µA	DFN, TSSOP-16E
LT1976/77	Step-Down Regulator	3.3V to 60V	1.50	200/500kHz	100µA	TSSOP-16E
LT3434/35	Step-Down Regulator	3.3V to 60V	3.00	200/500kHz	100µA	TSSOP-16E
LT3800/LT3724	Step-Down Controller	4.0V to 60V	10.00*	200kHz	100µA	TSSOP-16E
LTC3703/-5	Synch. Step-Down Controller	4.1V to 100V	20.00*	600kHz	1.5mA	SSOP-16E

*Depends on MOSFET Selection, **Transient Capable, †I$_{OUT}$ for LDO

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Precision full-wave signal rectifier needs no diodes

José M Blanes and José A Carrasco,
University Miguel Hernández, Elche, Spain

Rectifier circuits based on semiconductor diodes typically handle voltage levels that greatly exceed the diodes' forward-voltage drops, which generally don't affect the accuracy of the rectification process. However, the rectified signal's accuracy suffers when the diode's voltage drop exceeds the applied voltage. Precision rectifier circuits combine diodes and operational amplifiers to eliminate the effects of diode voltage drops and enable high-accuracy, small-signal rectification. By taking advantage of modern operational amplifiers that can handle rail-to-rail inputs and outputs, the circuit in **Figure 1** dispenses with diodes altogether, provides full-wave rectification, and operates from a single power supply.

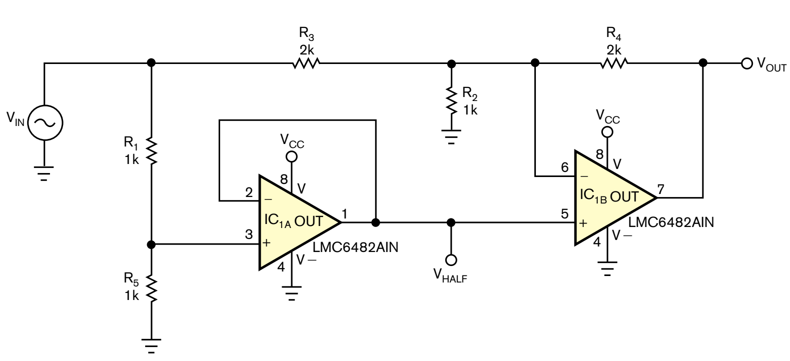


Figure 1 This precision full-wave-rectifier circuit uses two op amps and no diodes. When altering the basic design, note that resistors R_3 and R_4 are both twice the value of R_2 and that R_1 and R_5 are equal.

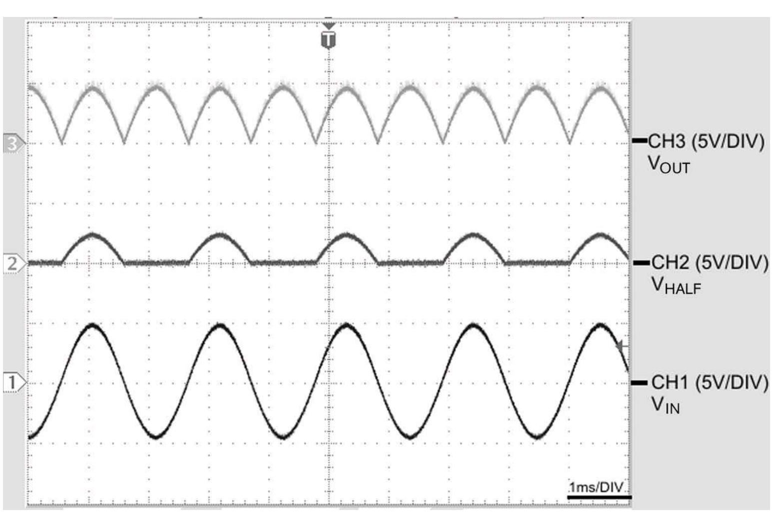


Figure 2 From bottom to top, the waveforms show V_{IN} (CH1), V_{HALF} (CH2), and V_{OUT} (CH3).

The circuit operates as follows: If $V_{IN}>0V$, then IC_{1A}'s output, V_{HALF}, equals $V_{IN}/2$, and IC_{1B} operates as a subtracter, delivering an output voltage, V_{OUT}, equals V_{IN}. In effect, the circuit operates as a unity-gain follower. If $V_{IN}<0V$, then $V_{HALF}=0V$, and the circuit behaves as a unity-gain inverter and delivers an output of $V_{OUT}=-V_{IN}$. **Figure 2** shows the circuit's input signal at V_{IN}; its intermediate voltage, V_{HALF}; and its output voltage, V_{OUT}.

The circuit uses a single National Semiconductor LMC6482 chip and operates in the linear regions of both operational amplifiers. Suggested applications include low-cost rectification for automatic gain control, signal demodulation, and process instrumentation. The circuit relies on only one device-dependent property: The amplifiers must not introduce phase inversion when the input voltage exceeds the negative power supply; the LMC6482 meets this requirement. EDN

DIs Inside

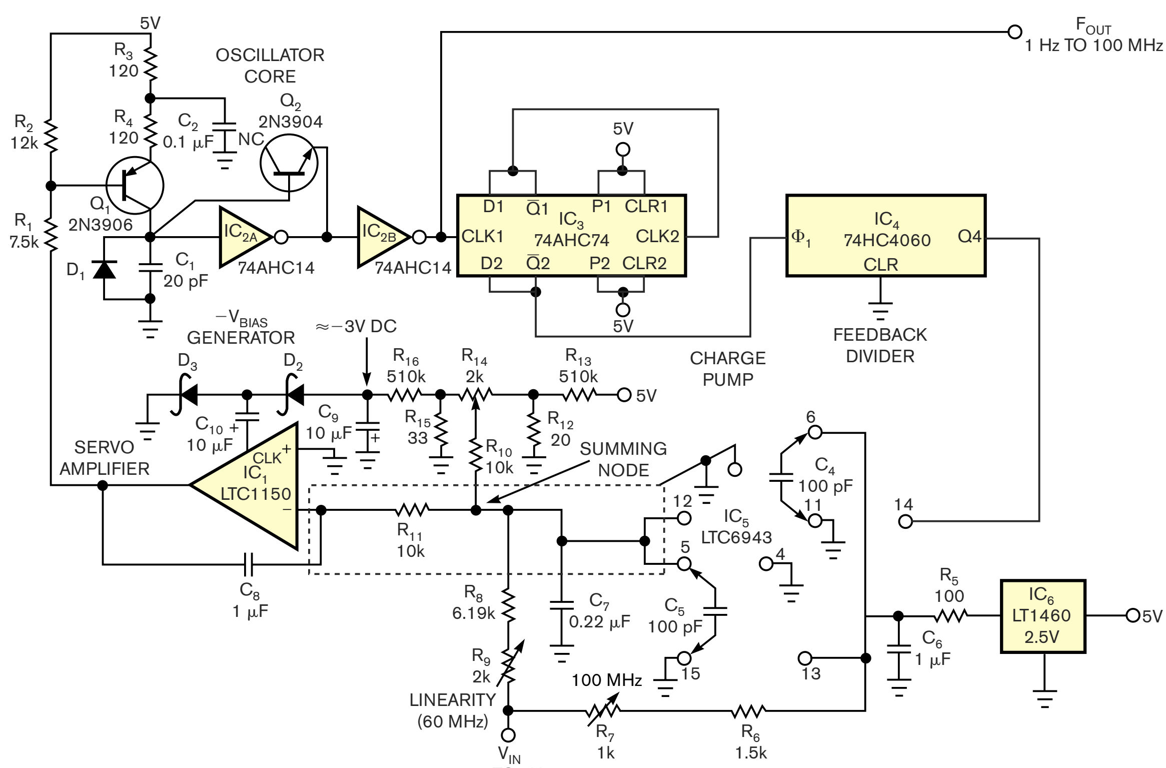
1-Hz to 100-MHz VFC features 160-dB dynamic range

Jim Williams, Linear Technology Corp

The VFC (voltage-to-frequency-converter) circuit in **Figure 1** achieves a wider dynamic range and a higher full-scale output frequency—100 MHz with 10% overrange to 110 MHz—by a factor of 10 over any commercially available converter. The circuit's 160-dB dynamic range spans eight decades for a 0 to 5V input range and allows continuous operation down to 1 Hz. Additional specifications include 0.1% linearity, a 250-ppm/°C gain/temperature coefficient, a 1-Hz/°C zero-point shift, and a 0.1% frequency shift for a 10% power-supply-voltage variation. A single 5V supply powers the circuit.

Chopper-stabilized amplifier IC_1, an LTC-1150, controls a crude but wide-range oscillator core comprising bipolar transistors Q_1 and Q_2 and inverters IC_{2A} and IC_{2B}. In addition to delivering a logic-level output, the oscillator core clocks divide-by-four counter IC_3, which in turn drives IC_4, a 74HC4060 configured as a divide-by-16 counter.

After undergoing a total division by 64 in IC_3 and IC_4, the oscillator core's output drives a charge pump comprising IC_5, an LTC6943, and its associated components. The averaged difference between the charge pump's output and the applied input voltage appears at the summing node and biases IC_1, thereby closing the control loop around the wide-range oscillator core.



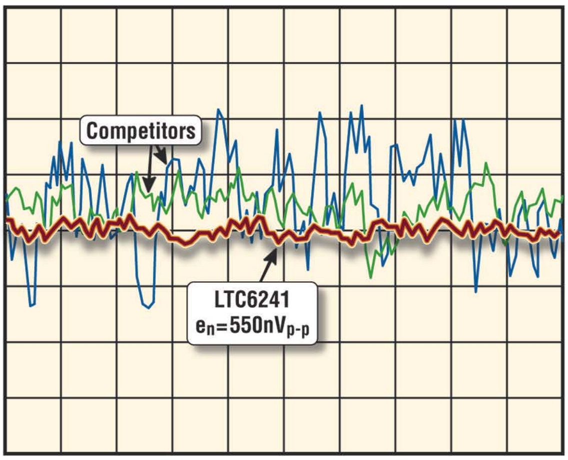
NOTES:

1. D_1: JPAD-500, D_2, D_3: BAT-85, R_5, R_6, R_8: TRW-IRC TYPE MAR-6, 1% METAL-FILM, C_4, C_5: WIMA TYPE FKP-2 CAPACITORS, AND C_7, C_8: WIMA TYPE MKS-2 CAPACITORS.
2. CONNECT ALL COMPONENTS AT Q_1'S COLLECTOR WITH A MINIMUM-AREA AIR-INSULATED "FLOATING" JUNCTION OVER A RELIEVED AREA OF GROUND TO MINIMIZE STRAY CAPACITANCE.
3. ENCLOSE R_{11} AND ITS CONNECTIONS TO R_9, R_{10}, IC_1'S INVERTING INPUT, C_7, AND PINS 5 AND 12 OF IC_5 WITHIN SOLDER- AND COMPONENT-SIDE GUARD TRACES TO INTERCEPT ANY BOARD-SURFACE LEAKAGE CURRENTS. (NOTE THAT THE DASHED LINE DEFINES THE GUARD TRACE.)
4. CONNECT IC_2'S UNUSED INPUTS TO GROUND. THE SCHEMATIC OMITS POWER-SUPPLY CONNECTIONS TO MOST ICS FOR CLARITY

Figure 1 Featuring a 160-dB dynamic range corresponding to a 1-Hz- to 100-MHz-frequency span, this voltage-to-frequency converter operates from a single 5V power supply.

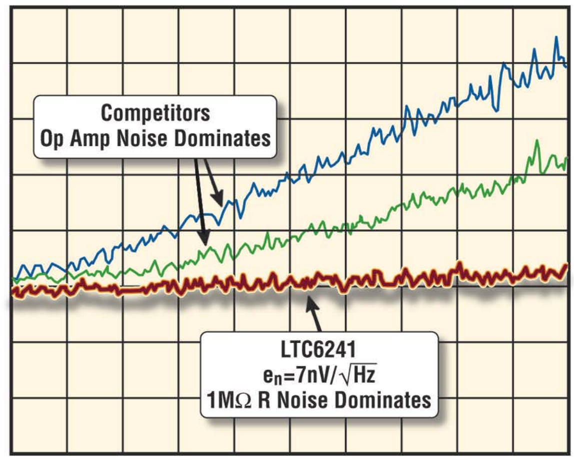
Low Noise CMOS

Low Frequency Noise

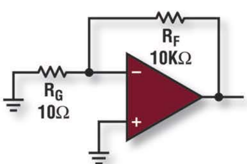


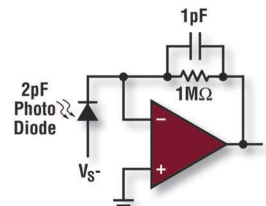
0.1Hz to 10Hz Input Referred Noise

High Frequency Noise



1kHz to 100kHz Noise Voltage Density





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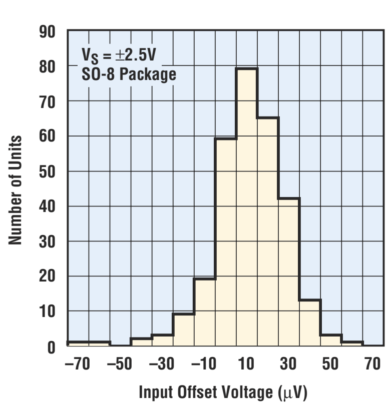

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LINEAR TECHNOLOGY

The circuit's extraordinary dynamic range and high speed derive from the oscillator core's characteristics, the divider/charge-pump-based feedback loop, and IC_1's low dc input errors. Both IC_1 and IC_5 help stabilize the circuit's operating point by contributing to overall linearity and stability. In addition, IC_1's low offset drift ensures the circuit's 50-nV/Hz gain-versus-frequency characteristic slope and permits operation as low as 1 Hz at 25°C.

Applying a positive input voltage causes IC_1's output to go negative and alter Q_1's bias. In turn, Q_1's collector current produces a voltage ramp on C_1 (upper trace in **Figure 2**). The ramp's amplitude increases until Schmitt trigger inverter IC_{2A}'s output (lower trace in **Figure 2**) goes low, discharging C_1 through Q_2 (connected as a low-leakage diode). Discharging C_1 resets IC_{1A}'s output to its high state, and the ramp-and-reset action continues.

The leakage current of diode D_1, a Linear Systems JPAD-500, dominates all other parasitic currents in the oscillator core, but its 500-pA maximum leakage ensures operation as low as 1 Hz. The two sections of charge pump IC_5 operate out of phase and transfer charge at each clock transition. Components critical to the charge pump's stability include a 2.5V LT-1460 voltage reference, IC_6; two Wima FKP-2 polypropylene film/foils; 100-pF capacitors, C_4 and C_5; and the low charge-injection characteristics of IC_5's internal switches.

The 0.22-μF capacitor, C_7, averages the difference signal between the input-derived current and the charge pump's output and applies the smoothed dc signal to amplifier IC_1, which in turn controls the bias applied to Q_1 and thus the circuit's operating point. As noted, the circuit's closed-loop-servo action reduces the oscillator's drift and enhances its high linearity. A 1-μF Wima MKS-2 metallized-film-construction capacitor, C_8, compensates the servo loop's frequency response and ensures stability. **Figure 3** illustrates the loop's well-behaved response (lower trace) to an input-voltage step (upper trace).

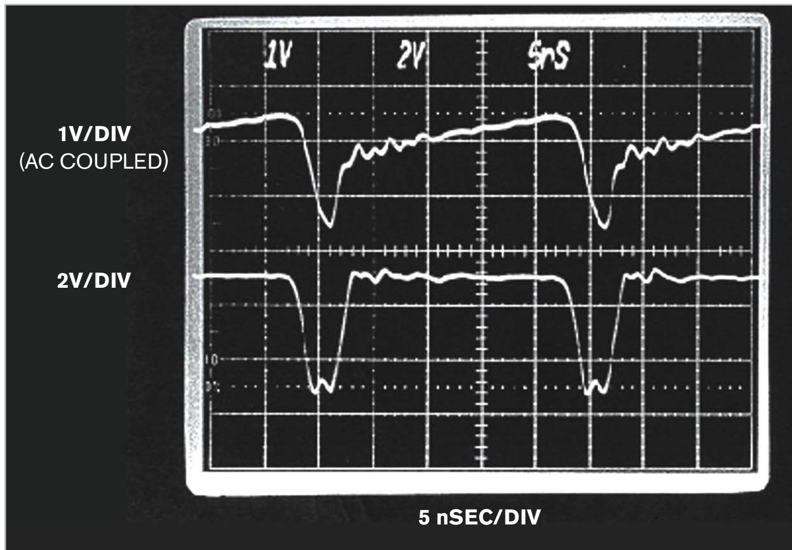

Figure 2 On a 700-MHz real-time oscilloscope, the oscillator-core waveforms at a 40-MHz operating frequency show the ramp-and-reset waveform at Q_1's collector (upper trace) and Q_2's emitter (lower trace).

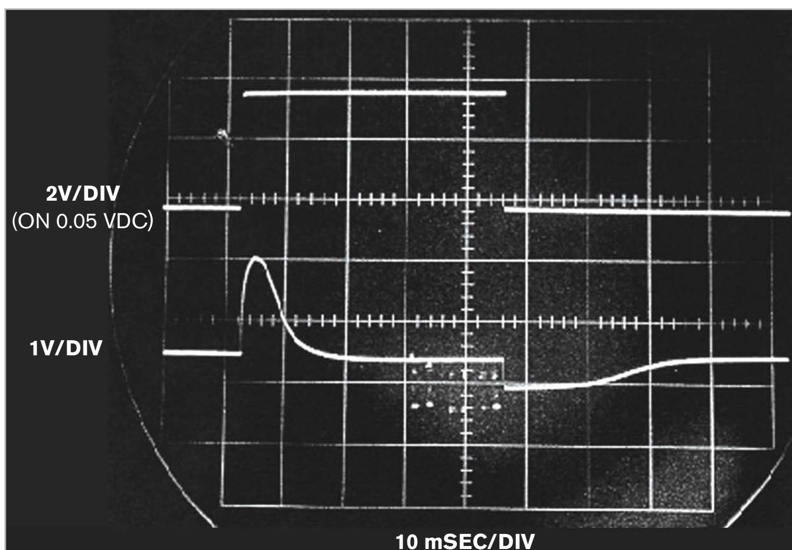

Figure 3 In response to an input-voltage step (upper trace), the voltage at the circuit's summing junction shows a 30-msec settling time.

For the circuit to achieve its design goals, certain special techniques and considerations apply. Diode D_1's leakage current dominates all other parasitic leakage currents at IC_{2A}'s input, and thus Q_1 must always supply sufficient source current to sustain oscillation and ensure operation as low as 1 Hz.

The circuit's 100-MHz full-scale upper frequency limit forces stringent restrictions on the oscillator core's cycle time, and only 10 nsec is available for a complete ramp-and-reset sequence. The reset interval imposes an ultimate speed limit on the circuit, but the upper trace in **Figure 2** shows a 6-nsec reset interval that falls comfortably within the 10-nsec limit. A path from the cir-

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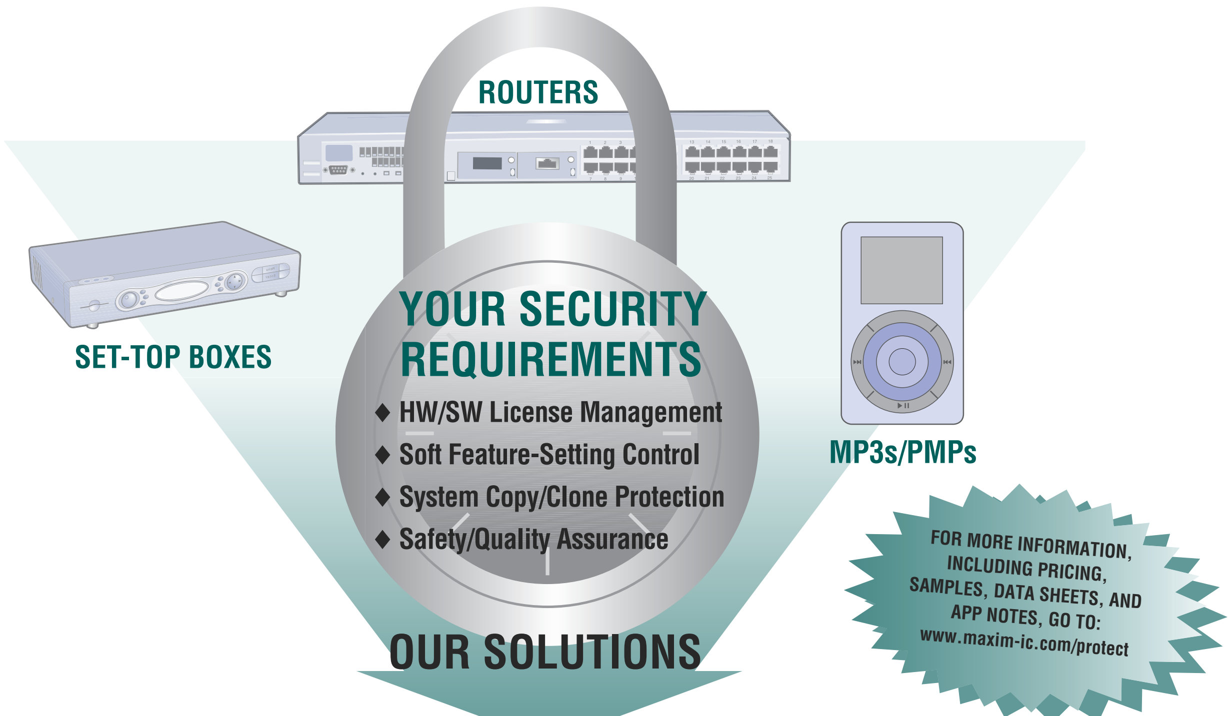

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cuit's input to the charge pump's output allows for correction of small nonlinearities due to residual charge injection. This input-derived correction is effective because the charge injection's effects vary directly with the oscillation frequency, which the input voltage determines.

Although you can use the component values given in **Figure 1** to assemble prototypes and small production quantities of the circuit, you need to consider component selection for optimum manufacturability and high-volume production. **Table 1** lists certain components' target values and estimated selection yields. The notes in **Figure 1** list the key components that the design uses.

To calibrate the circuit, apply 5V to the input and adjust the 100-MHz trimmer, R_7 for a 100-MHz output. Next, connect the input to ground and adjust trimmer R_{13} for a 1-Hz output. Allow for an extended settling interval because, at this frequency, the charge-pump update occurs once every 32 sec. Note that R_{13}'s adjustment range accommodates either a positive or a negative offset voltage because IC_1's clock output generates a negative bias voltage for R_{13}. Next, apply 3V to the input and adjust R_9 for a 60-MHz output. A certain amount of interaction occurs among the adjustments, so repeat the process until you arrive at optimum values for the three calibration frequencies. EDN

TABLE 1 SELECTION CRITERIA FOR COMPONENTS

Component	Selection parameter at 25°C	Typical yield (%)
Q_1	I_{CER}<20 pA at 3V	90
Q_2	I_{EBO}<20 pA at 3V	90
D_1	75 pA at 3V; I_{REV}<500 pA	80
IC_{2A}	I_{IN}<25 pA	80
IC_1	I_B<5 pA at V_{CC}=5V	90
IC_{2A}, IC_{2B}	Must toggle with 3.6-nsec-wide (at-50%-level) input pulse	80

Cascode MOSFET increases boost regulator's input- and output-voltage ranges

Scot Lester, Texas Instruments, Dallas, TX

Targeting use in portable-system applications that require raising a battery's voltage to a higher level, IC boost regulators often include output transistors that can drive storage inductors. However, most boost regulators' absolute-maximum input-voltage rating typically doesn't exceed 6V, an adequate level for battery operation. In addition, breakdown voltage of the regulator's output transistor limits the regulator's absolute-maximum output voltage to 25 to 30V, which may be too low for some applications.

You can extend a boost regulator's output-voltage range by adding an external transistor that has a higher breakdown voltage than the regulator. However, the internal design of a typical boost regulator's control circuitry often prevents direct drive of an external transistor's base or gate. As an alternative, you can add an external higher voltage transistor by connecting it in a cascode configuration.

Most boost regulators feature a peak-current-control method that reduces the number of external components and thus shrinks the overall pc-board area of the converter circuit. **Figure 1** shows a boost regulator based on a TPS61040 boost controller, IC_1, which uses peak-current control.

Applying input voltage V_{IN} to IC_1's V_{CC} pin and to one leg of inductor L_1 turns on IC_1's internal MOSFET switch, Q_1, allowing a gradually increasing amount of current to flow from V_{IN} through L_1, Q_1, and internal current-sense resistor R_1. The circuit's internal controller monitors the volt-

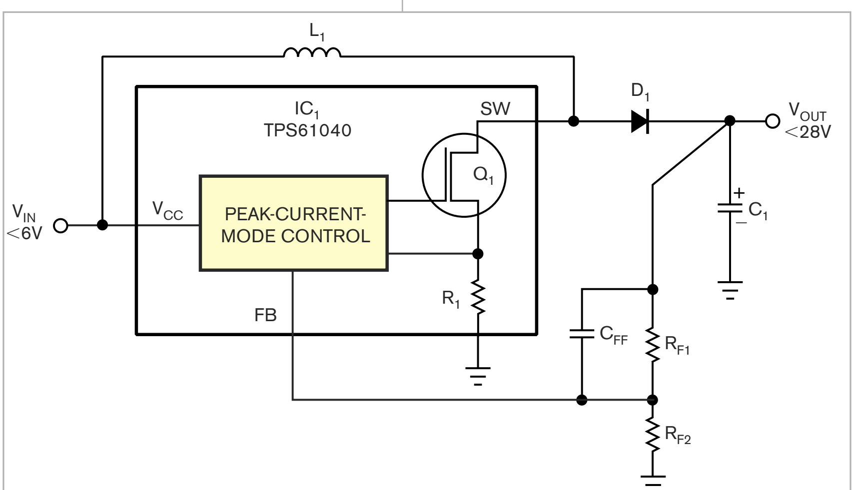

Figure 1 Based on the "barefoot" TPS61040, this dc/dc boost converter delivers output voltages only within IC_1's ratings.

age across sense resistor R_1 and, upon reaching a predetermined current limit, turns off Q_1.

Interrupting the current through L_1 raises the voltage across the inductor and applies forward bias to diode D_1, which conducts and charges output capacitor C_1 to a higher voltage than would be available from the input voltage alone. The input voltage, L_1's inductance, and the preset peak current through R_1 all affect Q_1's on-time, and the output voltage sensed by IC_1's FB (feedback) pin and its external components determines Q_1's off-time. To maintain operation and set Q_1's off-time, IC_1's internal controller must monitor current through L_1 using Q_1 and R_1.

You can add a higher voltage MOSFET transistor, Q_2 (**Figure 2**), for applications that require an output voltage higher than the internal transistor's breakdown voltage. To maintain the circuit's current-flow path through L_1 and IC_1's SW pin, you connect the external transistor in a cascode, or common-gate, configuration.

Q_2 comprises a low-on-resistance, low-gate-voltage-threshold MOSFET with the addition of diode D_2 between Q_2's gate and source. To ensure the circuit's proper operation, V_{CC}—5V in this example—must exceed Q_2's gate-threshold turn-on voltage. In operation, IC_1's internal control circuit turns on Q_1, which pulls Q_2's source close to ground level and turns on Q_2 with almost 5V of gate-to-source potential.

Current flows through inductor L_1, external transistor Q_2, internal transistor Q_1, and sense resistor R_1, and IC_1's control circuit "sees" no difference with the installation of Q_2. Once the inductor current reaches its preset limit, Q_1 turns off, leaving Q_2 with no path for current to flow from its source. The voltage on Q_2's drain rises rapidly to the desired output voltage plus the voltage drop across D_1. As the drain voltage rises, Q_2's drain-to-source capacitance attempts to pull the MOSFET's floating source above 5V, which forward-biases D_2, connects IC_1's SW pin voltage to 5V plus one diode drop, and clamps Q_2's source to the same voltage.

A boost converter delivers a 180V output at 4 mA (V_{OUT}) to bias a laser circuit from a 9V power supply (V+). In this application, the 5V input supply need provide only enough current—typically, a few milliamperes—to drive IC_1's internal logic and the gate of cascode MOSFET Q_2. You can use a dropping resistor and zener-diode voltage regulator (not shown) to supply the 5V requirement from the 9V supply. You can drive the inductor and IC_1 from a common power supply or from a separate source that's within Q_2's breakdown-voltage rating. The cascode circuit also can produce any output voltage that's within Q_2's drain-to-source breakdown-voltage rating. Specify other components with an appropriate voltage rating—for example, breakdown-voltage ratings of inductor L_1 and capacitor C_1 should safely exceed the desired output voltage. **EDN**

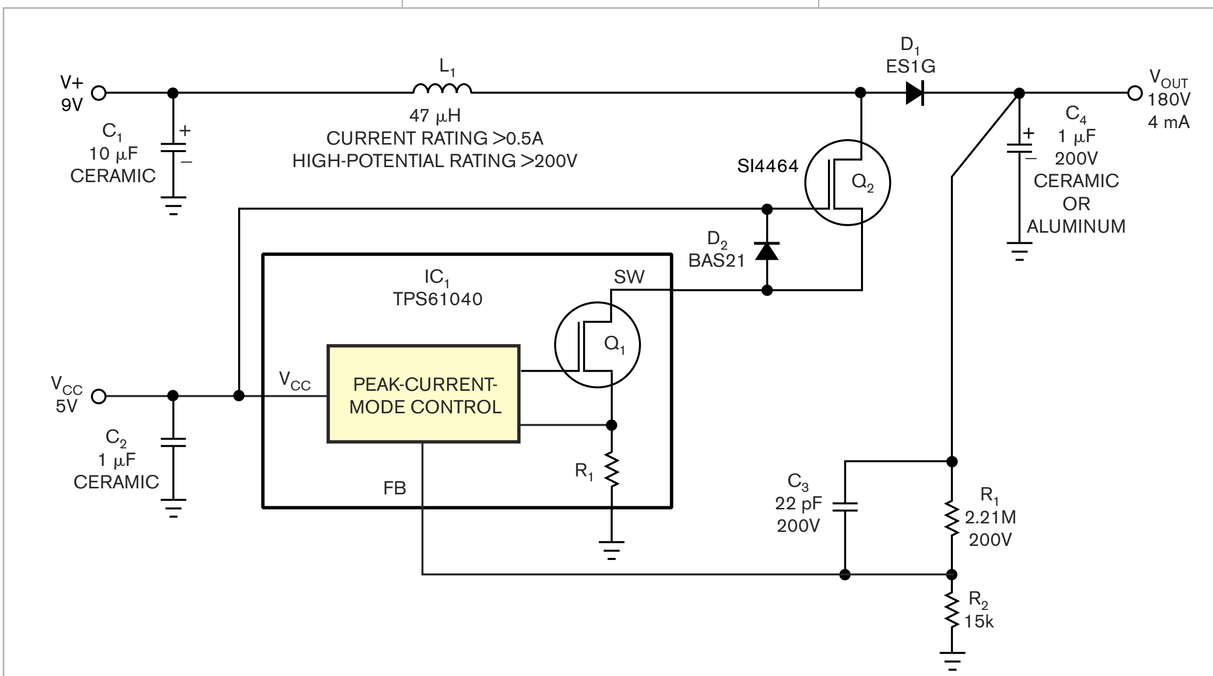

Figure 2 Adding an external cascode-connected MOSFET transistor, Q_2, with higher breakdown-voltage ratings, enables the circuit to produce higher output voltages.

DESIGN NOTES

Buck or Boost: Rugged, Fast 60V Synchronous Controller Does Both – Design Note 370

Greg Dittmer

Introduction

Automotive, telecom and industrial systems are harsh, unforgiving environments that demand robust electronic systems. For example, an automotive battery system may be a nominal 12V, 24V or 42V, but load dump conditions can generate transients up to 60V. The LTC®3703-5 is a synchronous switching regulator controller that can directly step down input voltages up to 60V and withstand transients up to 80V, making it ideal for harsh environments. The ability to step down the high input voltage directly allows a simple single inductor topology, resulting in a compact high performance power supply—in contrast to the low side drive topologies that require bulky, expensive transformers.

Feature Rich Controller

The LTC3703-5 drives external logic-level N-channel MOSFETs using a constant frequency, voltage mode architecture. A high bandwidth error amplifier and patented line feed forward compensation provide very fast line and load transient response. Strong 1Ω gate drivers minimize switching losses—often the dominant loss component in high voltage supplies—even when multiple MOSFETs are used for high current applications. Other features include:

- Low minimum on-time (200ns) for low duty cycle applications
- Precise 0.8V ±1% reference
- Programmable current limit utilizing the voltage drop across the synchronous MOSFET to eliminate the need for a current sense resistor
- Programmable operating frequency (100kHz to 600kHz)
- Low shutdown current (25μA), external clock synchronization input and selectable pulse skip mode operation
- Packaged in a 16-pin narrow SSOP or a 28-pin SSOP if high voltage pin spacing is desired.

High Efficiency 48V to 3.3V/6A Power Supply

The circuit shown in Figure 1 provides direct step-down conversion of a typical 48V telecom input rail to 3.3V at 6A. The circuit can handle input transients up to 60V

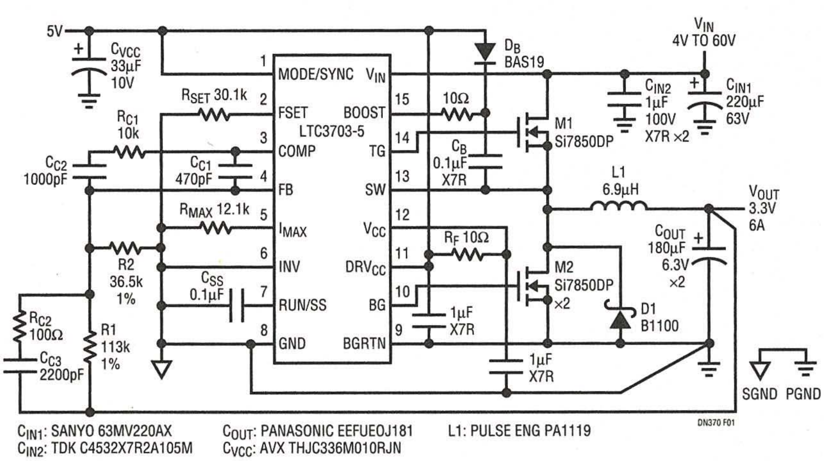

Figure 1. Buck: 48V to 3.3V/6A Synchronous Step-Down Converter

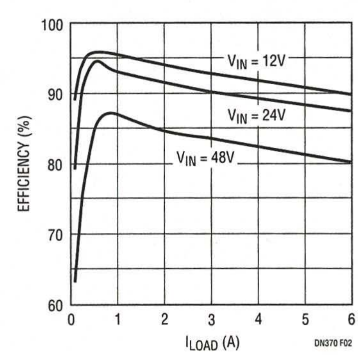

Figure 2. Efficiency of Figure 1's Circuit

without requiring protection devices or 80V if appropriate MOSFETs are used. The frequency is set to 250kHz to optimize efficiency and output ripple. Figure 2 shows a mid-range efficiency of over 90% at 24V input and 83.5% at 48V input. The loop is compensated for a 50kHz crossover frequency which provides 20μs response time to load transients (see Figure 3). The outstanding line transient performance is shown in Figure 4. The 12.1k R_{MAX} resistor value is chosen to limit the inductor current to about 12A during a short-circuit condition.

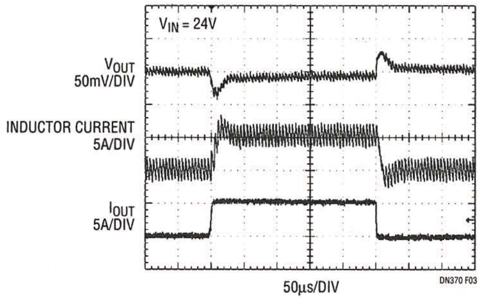

Figure 3. Load Transient Performance of Figure 1 Circuit Shows 20μs Response Time to 5A Load Step

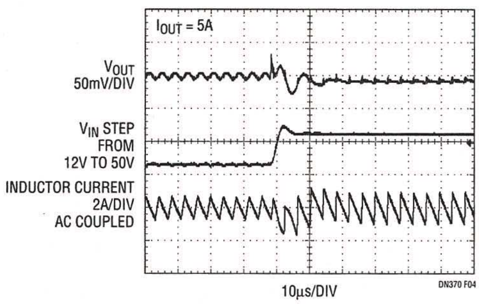

Figure 4. Line Transient Performance of Figure 1 Circuit Shows Almost Complete Rejection of 12V to 50V Supply Transient

High Efficiency 12V to 24V/5A Synchronous Step-Up Fan Power Supply

Synchronous boost converters have a significant advantage over non-synchronous boost converters in higher current applications due to the low power dissipation of the synchronous MOSFET compared to that of the diode in a non-synchronous converter. The high power dissipation in the diode requires a much larger package (e.g. D^2PAK) than the small S8-size package required for the synchronous MOSFET for the same output current.

Figure 5 shows the LTC3703-5 implemented as a synchronous step-up converter for generating 24V/5A from 12V—a common voltage for driving fans. This supply achieves a peak efficiency over 96% (see Figure 6). The LTC3703-5 is set to operate as a synchronous boost converter by simply connecting the INV pin to greater than 2V. In boost mode, the BG pin becomes the main switch and TG becomes the synchronous switch. Aside from this phase inversion, boost mode operation is similar to buck mode. In boost mode, the LTC3703-5 can produce output voltages as high as 60V.

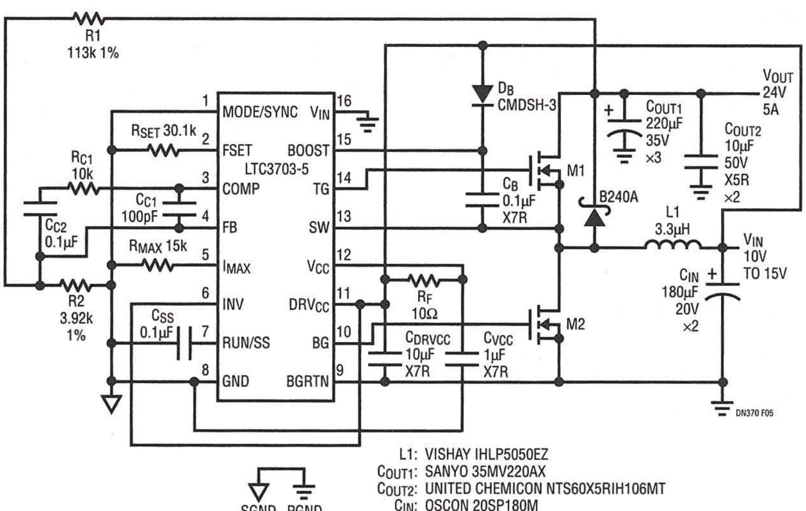

Figure 5. Boost: 12V to 24V/5A Synchronous Step-Up for Fan Power Supply

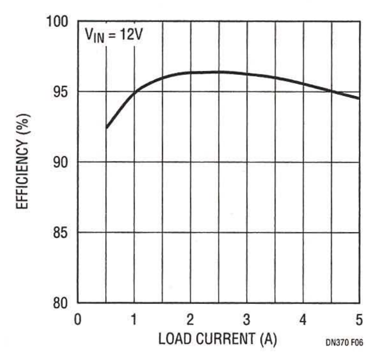

Figure 6. Efficiency of Figure 5's Circuit

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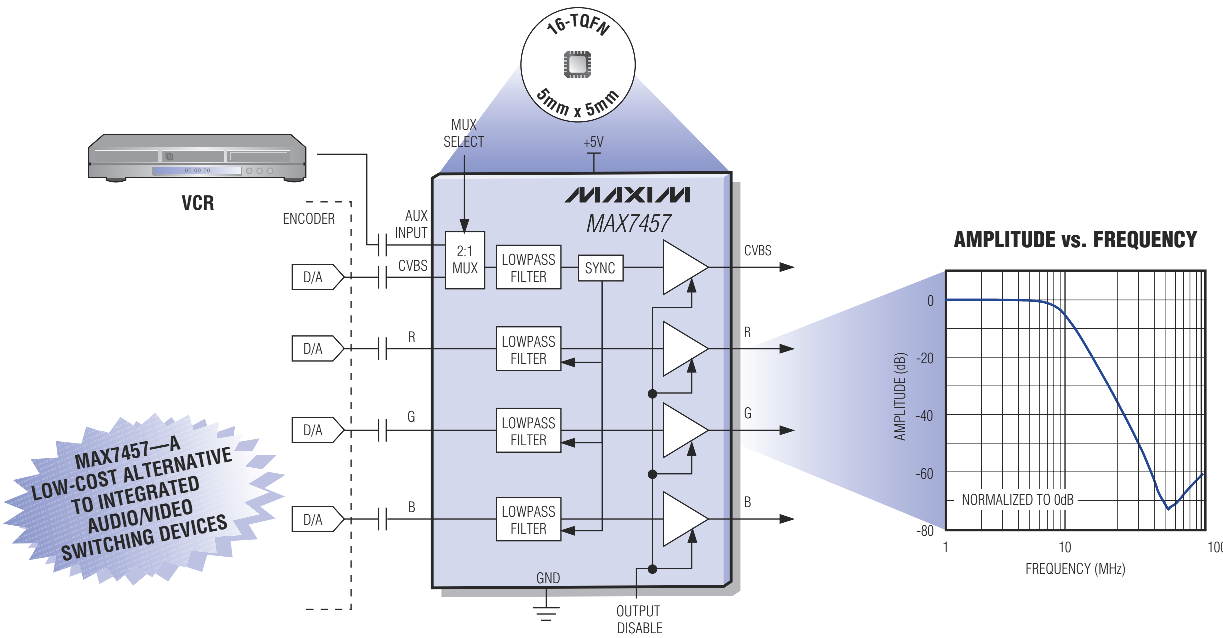

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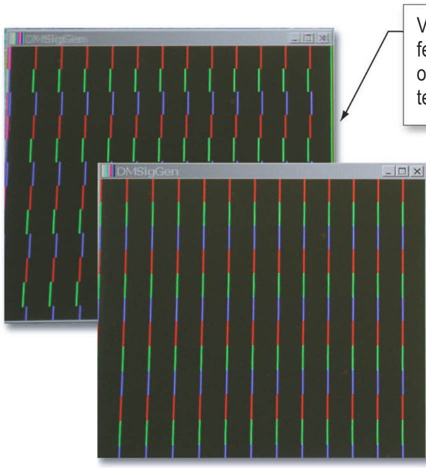

Video transmitted over 1000 feet of CAT-5. Note the lack of alignment on the RGB test pattern.

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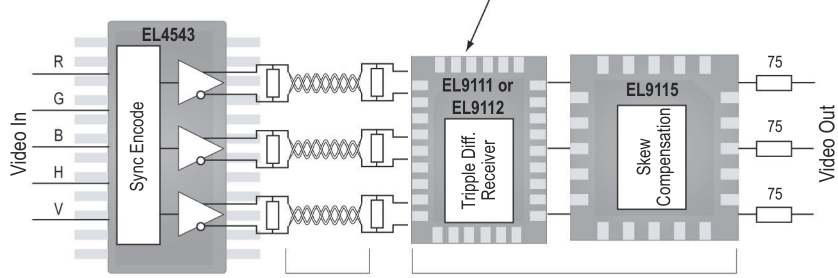

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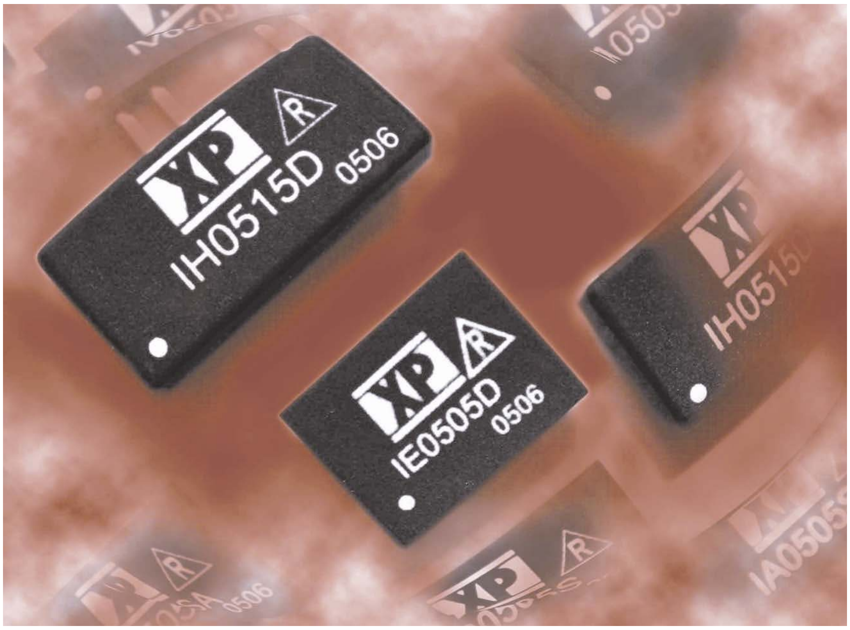


DC/DC converters come in more than 175 models

RoHS-compliant, 1 and 2W isolated dc/dc I-series converters comprise more than 175 models. Input and output voltages range from 3.3 to 48V dc, with an 80% efficiency at full load. Ripple and noise are 75 to 150 mV p-p at 20 MHz, and isolation is either 3000V dc or 1000V dc. The converters come in DIPs and SIPs and cost $4.80 (1000).

XP Power, **www.xppower.com**

High-voltage modules suit mass spectrometers

The high-voltage LS range modules provide low noise for 1W applications. Features include a reduced ripple to 2 ppm, a 10-ppm/°C temperature coefficient, and a 50-ppm (0.005%) drift for the 1- to 50-kV operating range.

Applied Kilovolts, **www.appliedkilovoltsms.com**

48V 1U power supply suits POE applications

An addition to the LC Series, the 48V model compact 1U-high switcher provides 1000W of output power over a 180 to 264V-ac input range and 800W output power from a 90 to 264V-ac input range. Targeting POE (power-over-Ethernet) applications, the switcher is IEEE 802.3af-compliant. The 48V model of the LC Series costs approximately $300.

Deltron Inc, **www.deltroninc.com**

Quad-output dc/dc converter has wide temperature range

The 30W model 70Q5.12SR quad-output dc/dc converter has a 40 to 120V-dc input range and 5 to 12V-dc output range. The outputs are isolated from both the input and from each other. Designers can parallel the devices for increased output current. The 5V outputs operate at 1.4A dc, and the 12V outputs operate at 700 mA dc. The case temperature range is −40 to +100°C. Measuring 3×2.5×0.6-in., the 70Q5.12SR costs $83.30 (1000).

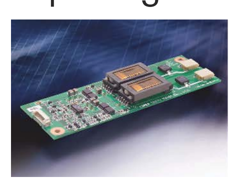
Calex Manufacturing Co, **www.calex.com**

Programmable, single-output dc power supply is SCPI-compatible

The Model 9120 single-output digital dc power supply offers clean, stable, and reliable power. Features include a 0 to 30V, 0 to 3A programmable output; a 10-mV, 1-mA display resolution; an RS-232 interface; SCPI (small-computer-peripheral-interface) compatibility; and remote sensing. The Model 9120 measures 8×21×38 cm and costs $689, including a one-year warranty, user manual, and line cord.

B&K Precision Corp, **www.bkprecision.com**

DC/AC inverter targets superbright LCDs



Designed for driving dual CCFL (cold-cathode fluorescent lamps), the KLS-150A compact single-board dc/ac inverter suits harsh environments with a temperature range of 0 to 60°C. Inverter specifications include a 10.8 to 13.2V, 12V typical input range; a 204-Hz PWM brightness-control frequency; 6.5W per lamp; 13W total power output at maximum luminance; 2100V rms start-up voltage; 930V rms output voltage; 50-kHz output frequency; and 1.2A input current. The KLS-150A measures 120×40×9 mm and costs $21.53 (10,000).

Taiyo Yuden Inc, **www.t-yuden.com**

productroundup

POWER SOURCES

Half-brick, 120A dc/dc-converter family has single output

Delivering 120A for the 1.2, 1.5, and 1.8V versions, the Polaris 2 half-brick dc/dc-converter family also supports 2.5V at 100A, 3.3V at 80A, and 5V at 55A. The device is an isolated, fixed-frequency design using synchronous rectification for 95% efficiency. Measuring 2.42×2.4×0.45-in., the Polaris 2 costs $99 (1000).

Cherokee International, www.cherokeepwr.com

Ultraminiature 40/60W power supplies are open-framed

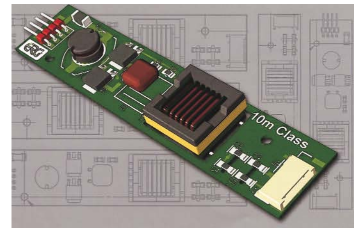
Devices in the ultraminiature open-frame modular switching OFM40/60 power-supply series feature single, dual, and triple outputs from 3.3 to 48V dc. Peripherals include 85 to 265V-ac universal input, 6W/in.^{3} power densities, and full safety approvals. Measuring 2×4×1.2 in., the OFM40/60 costs $16.

Astrodyne, www.astrodyne.com

Compact dc power system comes in 1RU package

The Gravitas X75-48S 1RU-high dc power system comprises a 1U-high base system that houses three 1×2U hot-swap rectifier modules. It also offers a dc-battery load-distribution section and a monitor and control section. It has an output of 30.3A at 54.4V dc for three modules. The power system costs $720.

Unipower Telecom, www.unipower-corp.com



10m-class inverter provides high starting voltage in a small package

Compatible with either U- or L-shaped lamps, these 10m-class inverters can power one or two lamp LCDs. The devices provide 12W output power, offer a 2400V rms starting voltage, and measure 109.7×13.34×10-mm. The inverters cost $9.50 each.

Endicott Research Group, www.ergpower.com

Linear power supply features dual output

The 22-100 linear power supply has an output voltage of ±15V and provides ±100 mA of output current. The device features noise and ripple at 2 mV rms, and 100, 115, 220, 230, and 240V ac can power it. Targeting power-sensitive analog circuitry, the power source includes ±0.05% voltage accuracy and ±0.04% line and load regulation. The 22-100 costs $77.73 (100).

Calex Manufacturing Co, www.calex.com

Modular power supply targets low- to medium-volume applications

Vega Lite power supplies are available in two models: the Vega 550, rated at 550W with a 115V-ac input voltage or 700W at a high line greater than 150V ac, and the Vega 750, rated at 750W at 115V ac or 900W at a high line greater than 150V ac. With 900W out-

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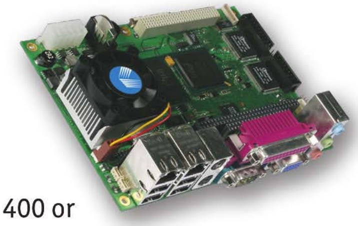

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put power, the power supplies feature one to 10 wide-range adjustable 1.8 to 56V output voltages and 60A output currents. Vega Lite power supplies cost $390.
Lambda, www.lambdapower.com

500W ac/dc and dc/dc power supply has NAVMAT compliance

Providing either five outputs for a VME system or eight outputs for a VXI system, the 57S81 includes an ac/dc and dc/dc power supply. Targeting military and aerospace programs including airborne, shipboard, ground-mobile, and C^3I applications, this device operates from an input of either 115 to 230V ac in single phase or 270V dc. Outputs provided include 5, 3.3, ±12, and 5V dc (standby) for VME systems or 5, ±12, ±24, −5.2, −2, and 5V dc (standby) for VXI systems. Designed and manufactured to NAVMAT (naval-materials-command) componenet derating guidelines, the 57S81 costs $4200 (100).
North Atlantic Industries, www.naii.com

Power source comes in MiniDIP

Part of the Budget Save product line, the G100E series provides 1000V-dc I/O isolation and 1W output power. Features include 5, 12, and 24V inputs; a −40 to +85°C operating range; single and dual outputs; 1 million hours MTBF; and 81% efficiency. The G100E series comes in a "MiniDIP" with an industry-standard pinout.
MicroPower Direct, www.micropowerdirect.com

50W power supplies include active PFC

The 50W JBW series power supplies include universal ac input with active PFC (power-factor correction) along with a ±10% output adjustment for user-controlled output voltage. Devices measure 26×55×190 mm and cost $36 (1000).
Kepco, www.kepcopower.com

Low-noise converter has 5-mV output noise

This low-noise, 10W dc/dc-converter series is available in case options that provide better performance and flexibility than those in the previous series. The cases provide a 2-to-1 input-voltage range, and 3- and 4-to-1 input voltages are available upon request; output noise is 5 mV. The converter comes in a coated metal case and measures 2×1×0.395 in. The series costs $55.60 for single-output models

and $59.30 for dual-output models.
Beta Dyne, www.beta-dyne.com

Bus converter boasts 97% efficiency

The QTS48T46096 46A bus converter features 420W and 95% full-rated power and operates at 70°C. The 9.6V output voltage increases power-system efficiency, reducing point-of-load V_{IN}/V_{OUT} deltas. The converter includes a 5-to-1 fixed-ratio design for a 7.2 to 11V output voltage and a 36 to 55V input voltage and supports 97% efficiency.
Power-One, www.power-one.com

Universal power supply comes in eight model voltages

Part of the 60W series of universal power supplies, the PW136 external power series includes a 100 to 250V universal input. The series includes 3.3, 5, 9, 12, 15, 18, 24, and 48V models, all of which are single-output devices delivering 23 to 60W of power. Made of impact-resistant polycarbonate, the enclosure measures 100×66×41 mm and can feature private-label markings. The PW136 costs $16 to $18 (1000).
Ault Inc, www.aultinc.com

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Two-slot ATCA backplane suits prototyping

With a point-to-point mesh topology that requires no switch cards, the two-slot ATCA (Advanced-TCA) backplane features a 10-layer stripline design for routing through signal-integrity studies. The product also includes connectors for direct plugging of the IPM sentry shelf manager or wired connections to other shelf managers. The ATCA costs $700 and has an optional full mesh implemented on the backplane.
Elma Bustronic, www.elmabustronic.com

Development-tool kit features enhanced IDE

The MetaWare development-tool kit includes a C/C++ compiler, a debugger, and an eclipse-based IDE (integrated development environment). New features of the kit include a source-management tool, a context-sensitive help tool, support for project collaboration, and a construction tool kit with examples. Available for Windows and Red Hat Linux platforms, the MetaWare development-tool kit costs $5495.
ARC International, www.arc.com

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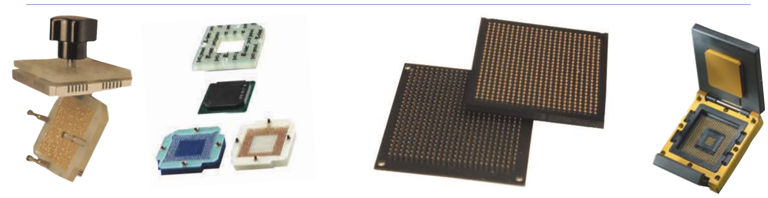

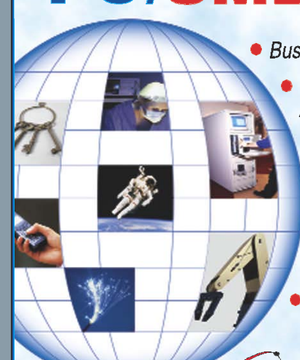

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National Semiconductor Corp, www.national.com

Advanced video-filtering devices target consumer-video applications

The ADA4410-6, ADA4411-3, and ADA4412-3 advanced filtering devices include six-pole filters and buffers. With six channels for video processing, the ADA4410-6 comes in 5×5-mm CSP-32 packaging and costs $1.80 (100,000). As a three-channel version of the ADA4410-6, the ADA4411-3 comes in a QSOP-24 package and costs $1.49 (100,000). With three channels and adjustable gain and offset, the ADA4412-3 comes in a QSOP-20 package and costs $1.29.

Analog Devices, www.analog.com

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YESTERDAY'S HYPE MEETS TODAY'S REALITY

STATS offers more than 100 commercial-free channels / transmits in 2332.5- to 2345-MHz band / costs about $10 month

Satellite upsets terrestrial radio firma

Conventional broadcast radio's business hasn't changed much since the introduction of AM radio in the 1920s and FM (and stereo FM) in the 1950s. Precious license assignments, varying signal reach, and lots of commercials, along with free reception, defined the situation.

But that situation is now changing rapidly. Competitors XM Satellite Radio (www.xmradio.com) in 2001 and Sirius Satellite Radio (www.sirius.com) in 2002 began broadcasting directly to users from satellites. Each system provides more than 100 commercial-free channels, for a fee of about $10/month, to specialized receivers that are now integrated as standard equipment into cars and available for home and portable units. XM's two geostationary satellites transmit in the 2332.5- to 2345-MHz band; the Sirius units are similar.

As of the end of 2004, Sirius had about 1.14 million subscribers, including a net gain of 480,000 during 2004; XM claimed 3.2 million, an increase of 1.8 million for the year. Although these numbers may look small compared with the 250 million people who tune in at least once a week to conventional broadcast radio, they represent a complete alteration of the established broadcast model, receiver-electronics architectures, and receiver suppliers.

—by Bill Schweber, Executive Editor

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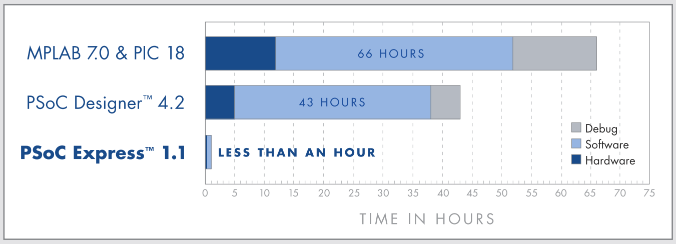

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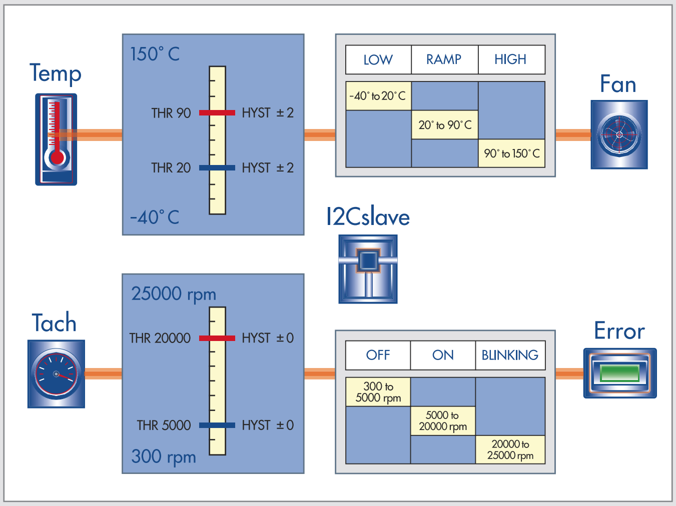

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