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VOICE OF THE ENGINEER

July 21
Issue 15/2005
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THINKING INSIDE THE BOX

AUTOMATION DESIGNERS BRING BRAINS TO BUILDING SYSTEMS

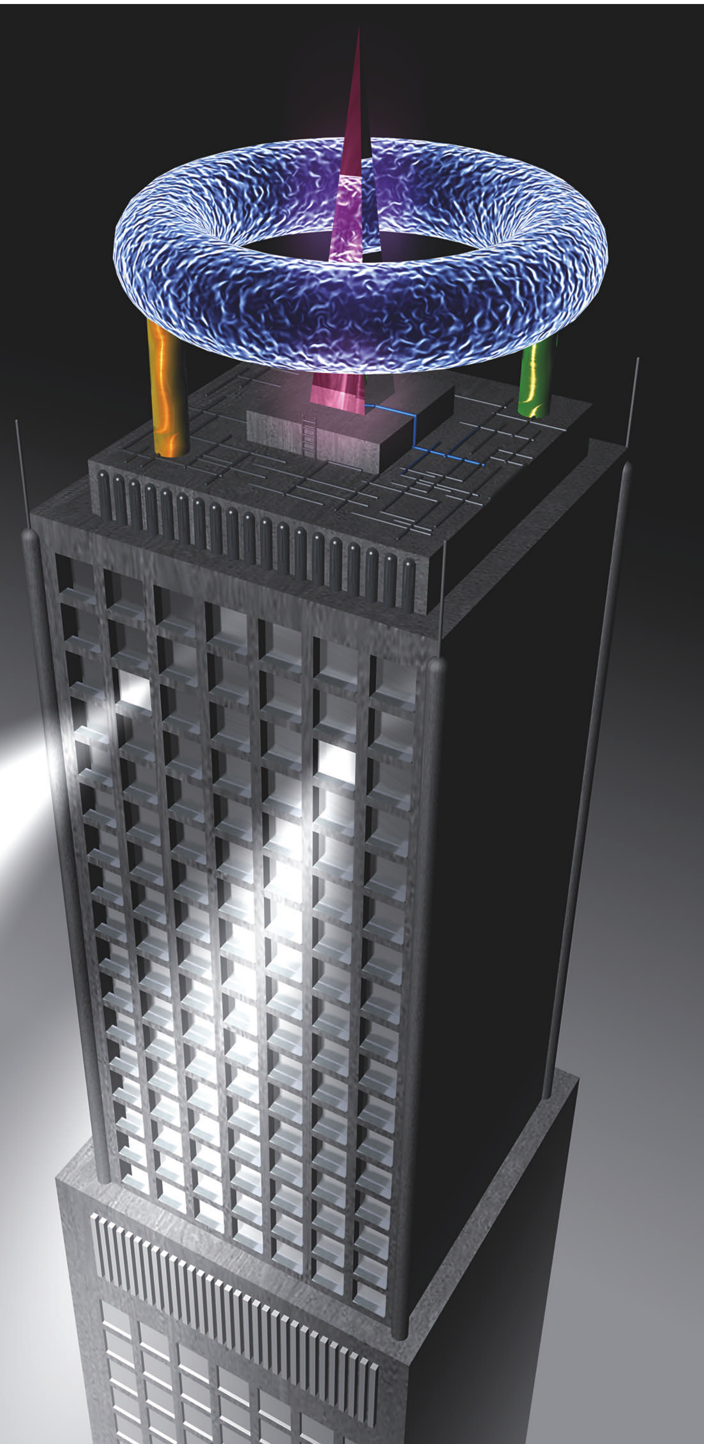
Page 48

SUN SETS ON IEEE 488, LAN AND PC STANDARDS VIE FOR ITS ROLE

Page 35

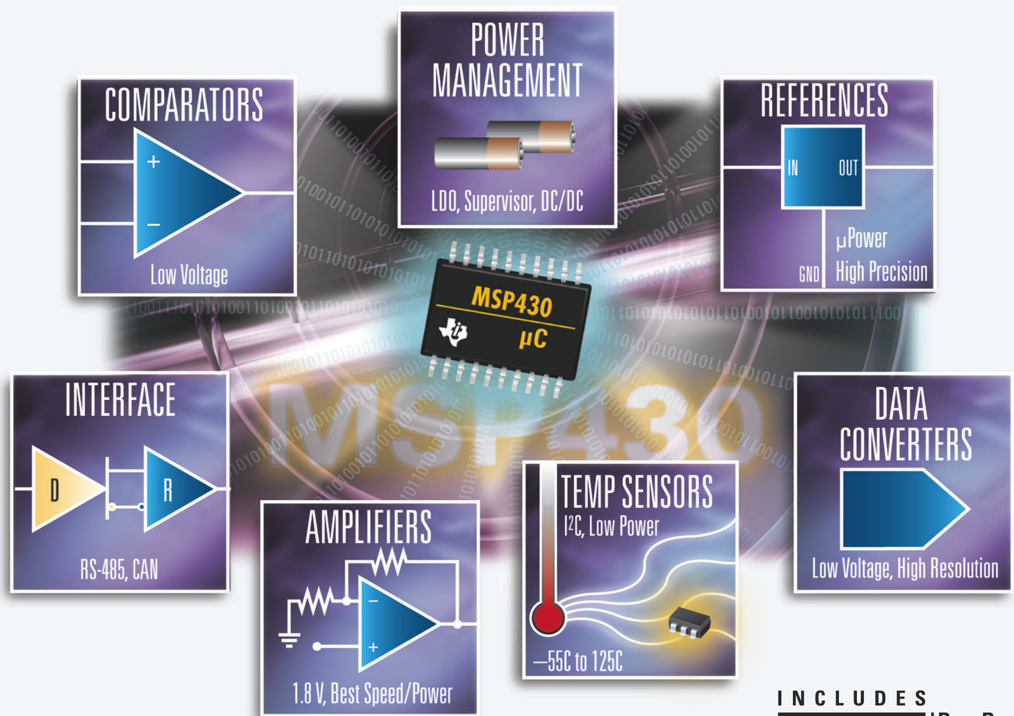
A BIT-O'-POWER: DIGITALLY CONTROLLED POWER CONVERSION

Page 59



ANALOG

µPower Analog for µPower Controllers



INCLUDES
Burr-Brown Products from Texas Instruments

Product Family	Device	Product Description	Key Specifications	Smallest Package	Price
Amplifier	OPA349	µPower, low voltage, RRIO op amp	1.8V to 5.5V, 2µA I_Q max, 10pA I_B max, 70kHz GBW, Gain = 1 stable	SC-70	$0.75
	OPA336	Highest precision µPower op amp in SOT23	2.3V to 5.5V, 20µA I_Q, 100kHz GBW, 60µV V_{OS}, RRO	SOT23	$0.65
	TLV2401	Sub-1µA op amp	2.5V to 16V, 880nA I_Q, 1.2mV V_{OS} max, RRIO, 18V reverse battery protection	SOT23	$0.80
	TLV2760	Wide bandwidth µPower op amp	1.8V to 3.6V, 20µA I_Q (10nA in shutdown), 500kHz bandwidth, RRIO	SOT23	$0.65
	INA321	µPower instrumentation amp with shutdown	2.7V to 5.5V, 40µA I_Q (10nA in shutdown), 200µV V_{OS}, RRO	MSOP	$1.10
Comparator	TLV3491	Fast nanoPower comparator	1.8V to 5.5V, 0.8µA I_Q, push-pull output, 6µs prop. delay, RRIO	SOT23	$0.42
	TLV3011/12	6µs comparator with 1.242V, 40ppm/°C reference	1.8V to 5.5V, 5µA I_Q, 3011: push-pull output, 3012: open collector output	SC-70	$0.75
Data Converter	ADS1222	Self-calib, 2-Ch, 24-bit low-power ΔΣ ADC w/shutdown	2.7V to 5.5V, 0.8ppm of FS noise, 0.8mW power consumption, 240SPS data rate	TSSOP	$2.95
	ADS8325	µPower, 100ksps, 16-bit SAR ADC with SPI interface	2.7V to 5.5V, 750µA I_Q (0.1µA in shutdown), 16-bits NMC	MSOP	$5.95
	DAC7554	Quad, 12-bit serial input DAC, R-R voltage output, shutdown	2.7V to 5.5V, 5µs settling time, 880µA I_Q (<1µA per DAC in shutdown)	MSOP	$5.60
Reference	REF31xx	High accuracy, low drift series voltage reference	0.2% accuracy, 15ppm/°C max, ±10mA output, 1.25V, 2.048V, 2.5V, 3V, 3.3V, 4.096V	SOT23	$1.10
Power Management	TPS797xx	10mA LDO voltage regulator with Power Good	1.8V operation, 1.2µA I_Q, 105mV dropout at 10mA output	SC-70	$0.34
	TPS6031x	Regulated charge pump boost converter	0.9V minimum V_{IN}, 2µA I_Q, 20mA output, up to 90% efficiency	MSOP	$1.05
	TPS383x	Supervisory circuit with ultra-low supply current	220nA I_Q, precision monitoring of 1.8/2.5/3.0/3.3V	SOT23	$0.85
Temp Sensor	TMP101	Programmable I²C digital temp sensor with shutdown	45µA I_Q (0.1µA in shutdown), –55°C to 125°C operation, 9- to 12-bit resolution	SOT23	$0.80
Interface	SN65HVD12	3.3V RS-485 differential transceiver with shutdown	1Mbps, 1µA in Sleep mode, 16kV ESD protection, 1/8 unit load (256 nodes)	SO-8	$1.75
	SN65HVD234	3.3V CAN transceiver with sleep mode	3.3Vcc, ±36V Bus-fault protection, 2µA in Sleep mode, 16kV ESD protection	SO-8	$1.45

For more µPower analog product info, visit: **www.ti.com/analogmsp430** ○ **800.477.8924, ext. 12333**

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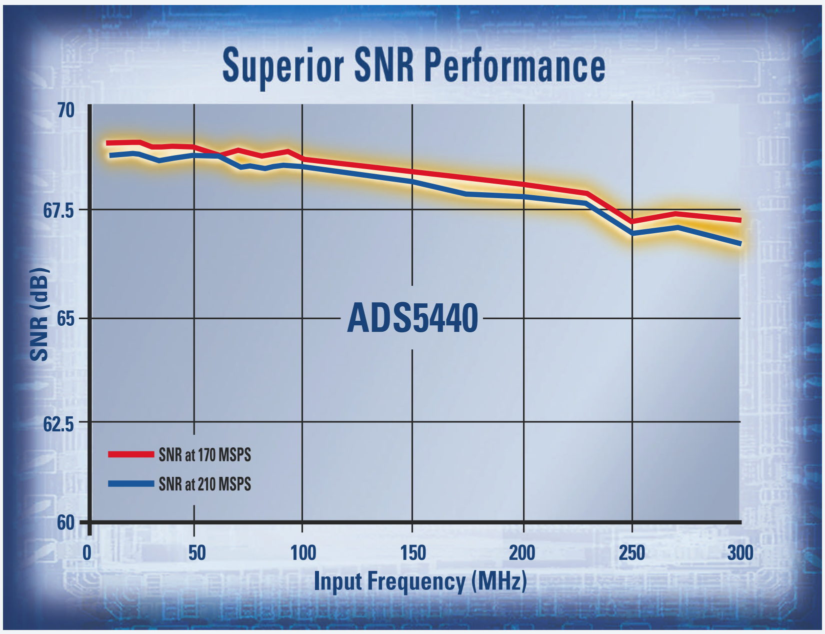

▶ Applications

- Software defined radio
- Test and measurement/ instrumentation
- Base stations:
  - Multi-channel receivers
  - Transmit digital pre-distortion (DPD)
- Communication Instrumentation

▶ Features

- SNR = 68 dBc at 170 MHz F_{IN} and 210 MSPS
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- Lead (Pb)-free/green
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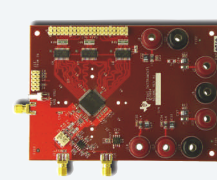
The **ADS5440** high-speed analog-to-digital converter from Texas Instruments features superior dynamic performance at high input frequencies. Providing breakthrough SNR performance, the ADS5440 enables improved receiver performance in multi-channel base stations and software defined radio (SDR) applications, and improved sensitivity for test and measurement equipment.

Device	Resolution (Bits)	Speed (MSPS)	SNR (dBc)	SFDR (dBc)
ADS5440	13	210	68 at 170 MHz IF	77 at 170 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

Evaluation Modules, Datasheets and Samples



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LPC2144	√	128KB	16KB	2	1	QFP64
LPC2146	√ + DMA	256KB	40KB	2	1	QFP64
LPC2148	√ + DMA	512KB	40KB	2	1	QFP64 QFN64

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Multiple serial interfaces

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- 2 enhanced UARTs
- 1 SPI
- 1 SPI/SSP

www.philips.com/microcontrollers

sense and simplicity

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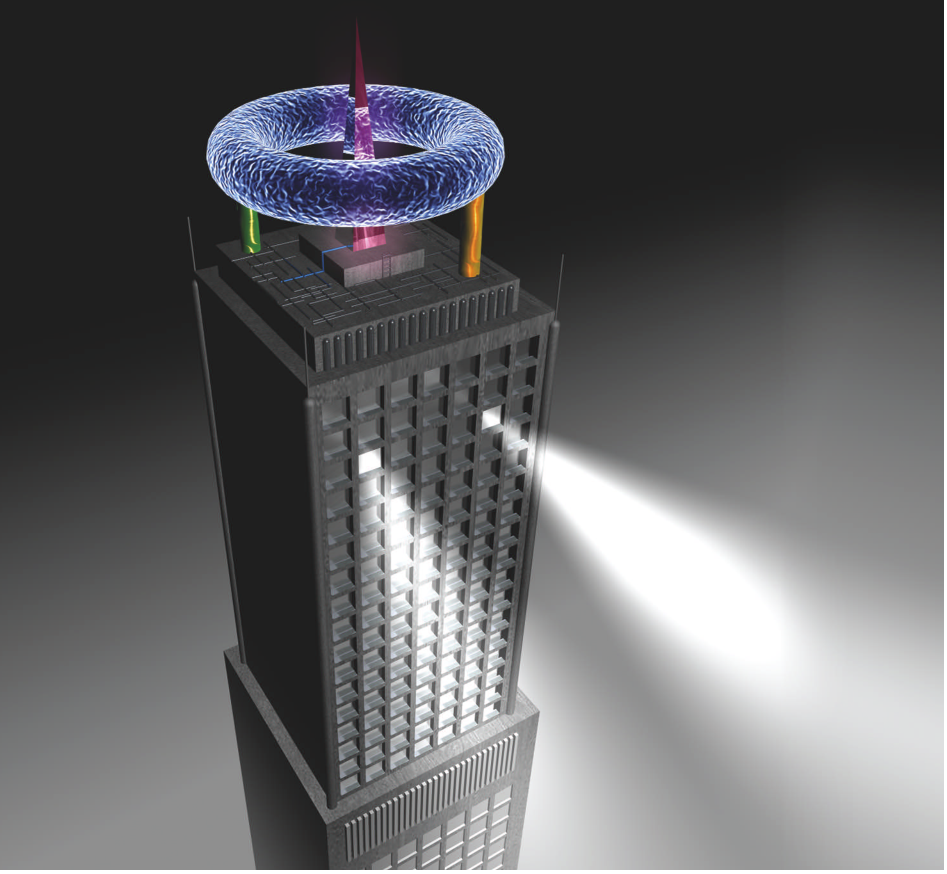
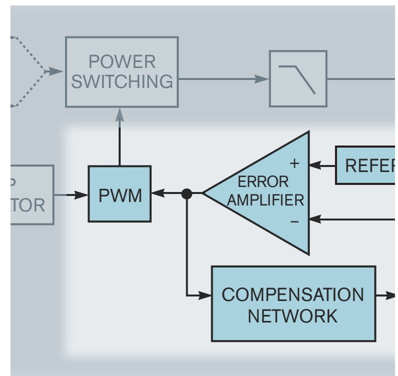
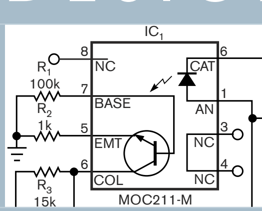




DESIGNIDEAS



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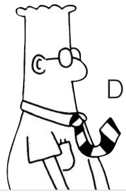

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90

DEPARTMENTS & COLUMNS

PRODUCT ROUNDUP

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EDN ONLINE

From the vault

The following articles from the EDN *archives touch on topics that Warren Webb's cover story on smart buildings raises (pg 48):*

RFID struggles while smart sensors animate intelligent buildings: RFID technology is having difficulty gaining wide acceptance despite all the attention it receives, but smart sensors are finding use in diverse and substantive applications.
➔www.edn.com/article/CA526504

Zigbee chip and software stack enable control networks: Zigbee is the leading candidate to form the foundation of wireless-control networks, and fully integrated Zigbee chips are finally ready.
➔www.edn.com/article/CA606443

Z-Wave chip aims to cut implementation cost: Z-Wave targets remote monitoring of home devices, including lighting, security systems, thermostats, garage-door openers, and entertainment systems.
➔www.edn.com/article/CA525674

Our new department "Tales From the Cube," in which readers share their engineering war stories, makes its second appearance in this issue (pg 32). In case you missed the debut in June, here it is:

Baby steps stop the crying: Danis Carter of Tyco Healthcare recounts his struggle with a problem that threatened to turn his potentially lethal Battlebot into a nonstarter.
➔www.edn.com/article/CA608177

Online only

Good stuff found only at www.edn.com.

Software targets communications design
The MathWorks recently rolled out Communications Blockset 3, an upgraded version of its software for designing and simulating the physical layer of communications systems and components.
➔www.edn.com/article/CA622674

Gear: Postcards from the edge of product evolution
HD and XM Radio come together, a backpack charges a phone, GPS confers bragging rights, and more.
➔www.edn.com/article/CA623401

On The Verge, a blog by Editor at Large Maury Wright: Read Maury's opinions—and post your responses—on mobile video, home-control networks, outsourcing, and more.
➔www.edn.com/ontheverge

Brian's Brain, a blog by Senior Technical Editor Brian Dipert: Join the discussion as Brian posts his analyses and opinions on virtually any technical topic.
➔www.edn.com/briansbrain

BY JOHN DODGE, EDITOR IN CHIEF

Some products fall down on the job—literally!

Overlooking the most mundane design details can significantly hurt a product. Recently, I've been using Omron's HJ-112 pedometer and the Pharos EZ Road GPS (global-positioning system), and both dubiously illustrate the point.

EZ Road isn't so easy when it comes to staying put. The unit includes both a suction-cup bracket that promises to secure it to the dashboard and clips that alternatively affix it to the air-conditioning vents. The suction-cup bracket is no good in my vehicle, because the dash has no smooth surface for an airtight bond other than the windshield, which, for obvious reasons, I do not want to obscure in any way. The clips, which the documentation annoyingly omits, are flimsy, causing the unit to frequently fall off the vent when you touch the unit.

I'm amazed that the Pharos folks, better known for piggybacking GPS on cell phones and PDAs, didn't figure out that a couple of small strips of Velcro tape would more than suffice (**Link 1**). As for the GPS unit, it works fairly well, but such automobile GPS add-ons have a long way to go before they qualify as polished products. My advice: Make an add-on seem as little as possible like an add-on, because the cockpit quickly becomes cluttered.

The 3.5-in., transreflective, 320×240-pixel LCD is decent, but you wonder whether its size, glare, and very existence next to the driver don't represent yet more dangerous distractions. After all, GPS often requires studying, as opposed to taking a quick glance at, what's on the display. Not surprisingly, traffic-law disclaimers and such load up the first page of the documentation. Drivers and passengers can also get in the way of the unit's display.

The touch-sensitive screen works accurately using the stylus or a finger, which is convenient while you're driving. The basic GPS functions, which are based on an SiRF Technology chip set, worked flawlessly (**Link 2**).

But the software you use to enter destinations and points of origin to create routes is a circular maze of frustration. The documentation isn't much help, although, I confess, I prefer to learn to use such devices by trial and error. The maps initially reside on a CD, and you must download them from a PC into the autoresident unit by means of a USB 1.1 port, which is slow. The unit, which is based on a 300-MHz Intel XScale PXA255 ARM microprocessor, comes with a scrawny 128-Mbyte secure-digital-memory card, which holds about five maps (**Link 3**). (The Boston area is one map, for instance.)

I had fun with this loaner product from Pharos and would urge any potential buyer to read additional reviews, in addition to my brief appraisal, before shelling out $500 (**Link 4**). My beef isn't so much with the electronics or even with the funky software but with the mechanism that holds the unit in place.

The Omron HJ-112 walking-style pedometer suffers from similar problems. Bending forces the belt clip to snap off. In fact, I've already lost one for this reason.

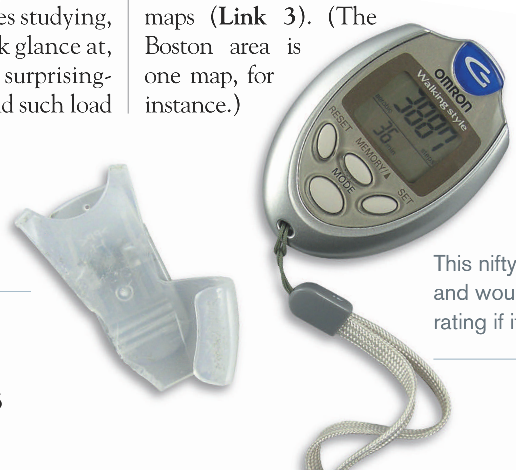
Still, as a daily walker, I love this simple, yet powerful, gadget, which measures total and aerobic steps, distance, and the calories you burn. It also keeps a running record for each of the previous seven days. (In the office, I average 5000 to 9000 steps; on weekends, I average 12,000 to 15,000.)

The unit is a nifty motivator, taking some of the humdrum out of my strolls (**Link 5**). And although I cannot swear to its distance accuracy (inches per stride times steps), my sense is that it's close. However, some reviews claim that the HJ-112 overestimates steps (**Link 6**). I'll take those additional steps.

All manner of walking pedometers, speedometers, and odometers abound, including those with GPS if you happen to get lost a lot (**Link 7**). But designers should first figure out how to get such gadgets to stay put. That would be one giant stride. EDN

WEB LINKS

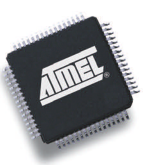
1. http://pharosgps.com/products/ezroad/c_ezroad.htm.
2. www.sirf.com/products.html.
3. www.intel.com/design/pca/prodbref/252780.htm.
4. www.pcmag.com/article2/0,1759,1763073,00.asp.
5. www.omronhealthcare.com/enTouchCMS/app/viewPromotion?promotionId=1005.
6. http://walking.about.com/cs/measure/a/pedaccuracy04.htm.
7. http://walking.about.com/cs/measure/bb/bybpedometer.htm.



The clip continually failed to hold the pedometer in place; thus, a car crushed the pedometer at a gas station.

This nifty pedometer worked well and would have earned a five-star rating if it had stayed put.

… Everywhere In Automotive



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Reed Electronics Group

Vol. III, Issue 7

ANALOG | edge

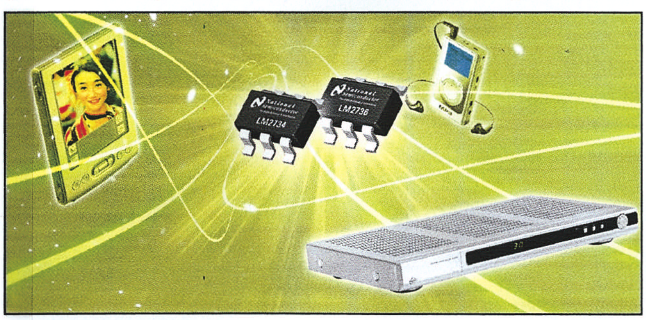
DESIGN | *idea:* Thermal Solutions in Power ▶▶▶

Featured Products

Industry's First High Power Density 1A SOT-23 Buck Switching Regulators

The LM2734 and LM2736 are monolithic, high-frequency (550 kHz and 1.6 MHz), PWM step-down DC-DC converters in six-pin, thin SOT-23 packaging.

With a minimum of external components and support through WEBENCH® online design tools, the LM2734/36 are easy to use. The control circuitry allows for on-times as low as 13 ns, thus supporting exceptionally high frequency conversion over the entire 3V to 20V input operating range down to the minimum output voltage of 0.8V. Switching frequency is internally set to 550 kHz (LM2734Y), 1.6 MHz (LM2734X), or 3.0 MHz (LM2734Z), allowing the use of extremely small surface-mount inductors and chip capacitors. External shutdown is included, featuring an ultra-low stand-by current of 30 nA. The LM2734/36 utilize current-mode control and internal compensation to provide high-performance regulation over a wide range of operating conditions.



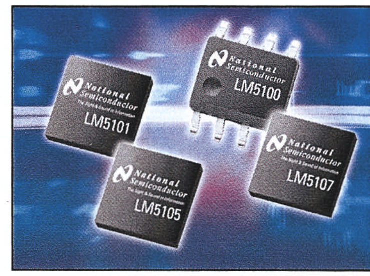
Features

- 3.0V to 20V input voltage range
- 0.8V to 18V output voltage range
- 1A output current
- 550 kHz (LM2734Y), 1.6 MHz (LM2734X), and 3.0 MHz (LM2734Z) switching frequencies
- Internal soft-start
- WEBENCH® design tools available
- Available in thin SOT23-6 packaging

The LM2734/36 are ideal for use in local point-of-load regulation, core power in HDDs, set-top boxes, battery-powered devices, USB-powered devices, DSL modems, and notebook computers.

www.national.com/pf/LM/LM2734.html
www.national.com/pf/LM/LM2736.html

100V Power MOSFET Drivers



The LM5100/01/05/07 high-voltage gate drivers are designed to drive both the high-side and the low-side N-Channel MOSFETs in a synchronous-buck or half-bridge configuration. The floating high-side driver is capable of operating with supply voltages up to 100V. The outputs are independently controlled with CMOS-input thresholds (LM5100) or TTL-input thresholds (LM5101/05/07). An integrated high-voltage diode is provided to charge the high-side gate drive bootstrap capacitor. A robust level-shifter operates at high speed while consuming low power and providing clean level transitions from the control logic to the high-side gate driver. Under-voltage lockout is provided on both the low-side and the high-side power rails.

Features

- Drives both a high-side and low-side N-channel MOSFET
- Independent high-and low-driver logic inputs
- Bootstrap supply-voltage range up to 118V DC
- Fast propagation times (25 ns typical)
- Drives 1000 pF load with 15 ns rise and fall times
- Available in SOIC-8, LLP-8, and LLP-10 packaging

These devices are ideal for use in cascade current-fed or voltage-fed converters, half- and full-bridge power converters, high-voltage buck DC-DC converters, solid-state motor drivers, and solid-state solenoid drivers.

www.national.com/pf/LM/LM5100.html
www.national.com/pf/LM/LM5101.html
www.national.com/pf/LM/LM5105.html
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Paul Greenland
Director of Strategic Marketing
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Thermal Issues and Solutions in Power Management

Power converter design is a multi-disciplinary process; an effective designer needs to understand analog and mixed-signal circuit design, wound components, electromagnetic compatibility, packaging, and thermal design. Packaging and thermal design are driven by increased power density and the many trade-offs in power topology selection. The challenging environment in equipment destined to power the expanding information infrastructure brings thermal design into sharp focus.

The world of modular DC-DC converters or "bricks" is evolving at a rapid pace since the first full-brick was commercialized in the mid-eighties. For instance, the sixteenth-brick format is 1.2 square inches of PCB area with a staggering 33W to 50W throughput.

The telecom bus operates over a wider range, 36V to 72V, than its datacom counterpart that has a tighter tolerance. A bus converter converts this bus with isolation at each card (the first use of the brick format). The on-card power is then applied directly to the load circuits. However, in recent years the proliferation of DSP and digital ASICs has spawned an intermediate bus architecture in which the bus converter delivers an isolated 12V to 14V, which is further converted by point-of-load regulators, physically located at the loads on the card.

Once the power supply designer has selected the topology to match the application, considered the number of power conversion stages[1] and whether the converter is hard- or soft-switched, then the switch and rectifier selection takes center stage. Most bricks employ power MOSFETs for the power switches and low-voltage synchronous rectifiers. MOSFET technology has evolved considerably, presenting the designer with trench devices with benchmark $R_{DS\text{-}ON}$ and planar devices with low inter-electrode capacitance. Device selection, once the voltage and current rating has been established, depends on which characteristic, switching speed or $R_{DS\text{-}ON}$ dominates the loss. In recent times the ratio of C_{DG} to C_{GS} has influenced designers as an indicator of the likelihood of shoot-through in high-power, high-frequency, half-bridge power stages.

Switching Frequency & EMI Trade-offs

A perennial trade-off is that of switching frequency with efficiency and electromagnetic interference. Switching losses in the power switches, rectifiers and control circuitry increase with switching frequency. In modular DC-DC converters, increasing frequency is desirable as it drives down the size of the filter and energy storage components. However in hard-switched applications, the increased high-frequency harmonic content in the power devices results in larger displacement currents in the stray capacitances between devices and heat sinks or power planes, and through the interwinding capacitance of transformers. Such displacement currents manifest themselves as common-mode interference.

In DC-DC converter control and drive applications, IC design and packaging has embraced the challenge presented by the brick environment. At the circuit-design level, increased integration, in-board, high-voltage regulators, higher clock frequencies and low shoot-through drivers with programmable slew rate are available for new designs[2]. A key issue in power IC design is that of thermal regulation. Power ICs have integrated drivers, regulator pass transistors and power switches arranged at the periphery of the die next to the bond pads. As these devices operate, heat conducts through the body of the die creating a thermal "map" with isotherms (contour lines of constant temperature). Certain sub-circuits, particularly differential circuits where matching is critical, are adversely affected if the individual transistors are positioned on different isotherms. IC layouts must be adjusted such that transistors in such applications see the same temperature, at the same time, when the device is operating, which is not a trivial task. Photomicrographs of power ICs often reveal devices that are cross-coupled for first-order cancellation of thermal effects.

Figure 1. Top and bottom view of an LLP

The LLP® leadless leadframe package, shown in ***Figure 1***, is a leadframe-based chip scale package (CSP) that enhances chip speed, reduces thermal impedance, and reduces the printed circuit board area required for mounting. The small size and very low profile make this package ideal for the high component density, multi-layer PCBs used in modular DC-DC converters.

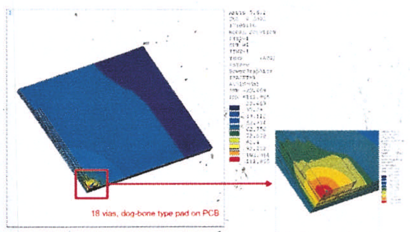

Figure 2. Finite element plot of an LLP

The LLP has the following advantages:

- Low thermal resistance
- Reduced electrical parasitics
- Improved board space efficiency
- Reduced package height
- Reduced package mass

IC package design is a painstaking process involving extensive thermal and mechanical modeling coupled with fabrication and measurement stages in which finite element models (as shown in ***Figure 2)*** are compared with spot measurements on the die or by thermal imaging. Generally spot measurements on the die are accomplished by measuring the forward drop of a diode in a test die incorporated within the new package. This tried and tested technique is used in many of the remote diode temperature-sensing devices[3] that protect the latest generation of microprocessors, DSPs and digital ASICs. One or more diodes in the test die may also be used to inject heat to verify the thermal characteristics of the die.

Package Design & Thermal Properties

Thermal properties of electronic packages[4] are characterized by θ_{JA} and θ_{JC}. θ_{JA} can be defined as an overall package thermal resistance, which is the sum of package internal and external thermal resistance. It can be expressed as:

$$\theta_{JA} = \theta_{JC} + \theta_{CA} = (T_J - T_A)/P$$

Where:

θ_{JC}: $(T_J - T_C)/P$, junction-to-case conductive thermal resistance (°C/W)

θ_{CA}: $(T_C - T_A)/P$, case-to-ambient convective thermal resistance (°C/W)

P: I (current) x V (voltage), device heat dissipation (W)

T_J: Average device junction temperature (°C)

T_A: Average ambient temperature (°C)

T_C: Case temperature at a prescribed package surface (°C)

θ_{JC} is dominated by the conductive thermal resistance within layers of packaging materials, and is highly dependent on the package configuration. If the heat flow is assumed to be perpendicular to each layer of the packaging material, θ_{JC} may be expressed as:

$$\Sigma t_i/(k_i A_i)$$

Where t_i, k_i, and A_i are the thickness, thermal conductivity, and heat transfer surface area of each packaging material layer, e.g., die-attach material, lead frame, die coating, and encapsulant or mold compound.

θ_{CA} is the external convective thermal resistance. It is greatly affected by adjacent ambient conditions, package boundary conditions, and conjugate heat transfer. In the LLP, low junction to ambient thermal resistance is primarily affected by reducing the resistance from the thermal plane on the PCB to the junction. The cross-section in ***Figure 3*** shows that the die is soldered to the die-attach pad, which is directly soldered to the power plane on the PCB. The area of the PCB power plane dominates θ_{CA}, in brick applications where conduction is the primary method of heat transfer and convection cooling is restricted due to the diminishing pitch between cards.

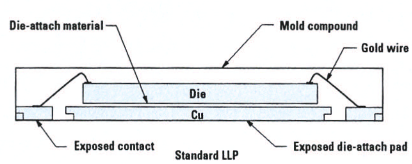

Figure 3. Cross-section of an LLP

Packaging Comparisons

The θ_{CA} may be improved by utilizing thermal vias in the power plane under the device. This improvement is second order compared with that achieved by increasing the area of the plane to which the LLP is soldered. A comparison between the LLP and a conventional small-outline package with the same pin count and die reveals the benefits.

Let's take an MSOP-8, where the PCB area is 15 mm^2 compared to an LLP-8 which is 9 mm^2. The dramatic difference is in the thermal resistance where the LLP-8 exhibits a thermal resistance (θ_{JC}) of 40°C/W versus 200°C/W for the MSOP-8.

In conclusion, a modular DC-DC converter is a most demanding environment for power ICs. The inexorable push to higher power density and the necessity for higher-efficiency drives power IC and package designers to set new standards in thermal resistance and volumetric efficiency. Giving power supply designers a brief glimpse into the package design, measurement and verification process is an important part of launching a new standard, particularly in power applications where new discrete power packages are a frequent part of the landscape. ■

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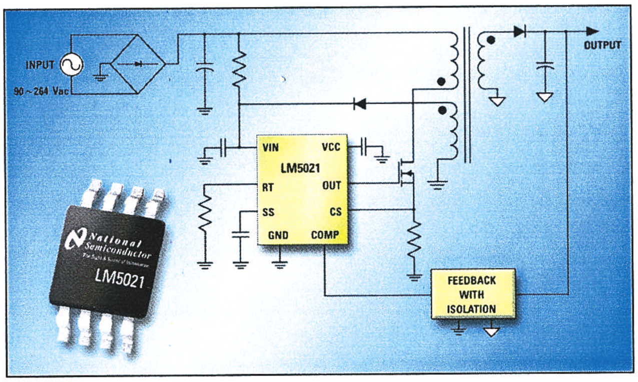
1. ***"Cascaded Converters Emerging in Distributed Power Systems"*** Ashley, D. PCIM Europe, March 2003
2. ***"Revolutionary Advances in Distributed Power Systems"*** Lam, E., Bell, R. & Ashley, D. Applied Power Electronics Conference, February 2003
3. **www.national.com/tempsensors**
4. ***"Package Thermal Characterization"*** National Semiconductor Corp., MS011816, August 1999

Featured Products



AC-DC Current-mode PWM Controller

The LM5021 off-line pulse width modulation (PWM) controller contains all of the features needed to implement highly efficient off-line single-ended flyback and forward power converters using current-mode control. The LM5021 features include an ultra-low (25 μA) start-up current, which minimizes power losses in the high-voltage start-up network. A skip-cycle mode reduces power consumption with light loads for energy-conserving applications (such as ENERGY STAR®, CECP). Additional features include under-voltage lockout, cycle-by-cycle current limit, hiccup-mode overload protection, slope compensation, soft-start and oscillator synchronization capability. This high-performance, 8-pin IC has total propagation delays less than 100 nS and a 1 MHz-capable oscillator that is programmed with a single resistor.

Features

- Ultra-low start-up current (25 μA maximum)
- Current mode control
- Skip-cycle mode for low standby power
- Single-resistor programmable oscillator
- Synchronizable oscillator
- Available in MSOP-8 and MDIP-8 packaging

The LM5021 is ideal for use in off-line, telecommunication, and consumer applications.

www.national.com/pf/LM/LM5021.html

800 mA Sub-bandgap Low-noise Adjustable Voltage Regulator

The LP3878-ADJ is an 800 mA adjustable output voltage regulator designed to provide high-performance and low-noise in applications requiring very low-output voltages. Output noise is typically 18 μV with a 10 nF capacitor to the bypass pin.

Using an optimized VIP (Vertically Integrated PNP) process, the LP3878-ADJ delivers superior performance including ground pin current that is typically 5.5 mA at 800 mA load, and precision 1% output voltage accuracy at room temperature. In addition, when the shutdown pin is pulled low, quiescent current is less than 10 μA.

Features

- Input voltage range 2.5V to 16V
- Adjustable output voltage range 1.0V to 5.5V
- 475 mV dropout (typ.) at 800 mA (V_{OUT} = 3.8V)
- Designed for use with low ESR ceramic capacitors
- 18 μV (typical) output noise
- <10 μA quiescent current in shutdown
- 1% V_{OUT} accuracy at room temperature
- -40°C to +125°C operating temperature range
- Over-temperature /over-current protection
- Available in PSOP-8 and LLP-8 packaging

The LP3878-ADJ is ideal for use in medical instrumentation, ASIC power supplies: in desktops, notebooks, and graphics cards; in set-top boxes, printers and copiers; in DSP and FPGA power supplies; and in SMPS post-regulators.

www.national.com/pf/LP/LP3878-ADJ.html

Intersil Switching Regulators

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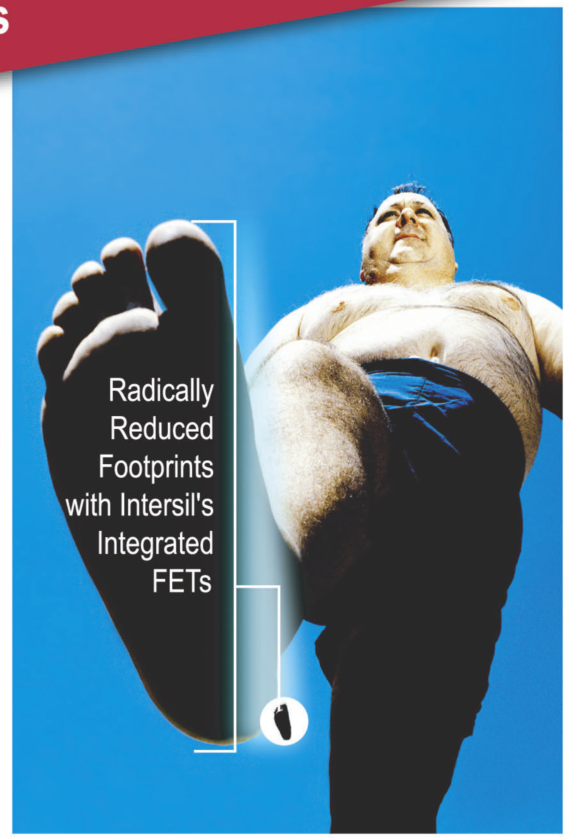
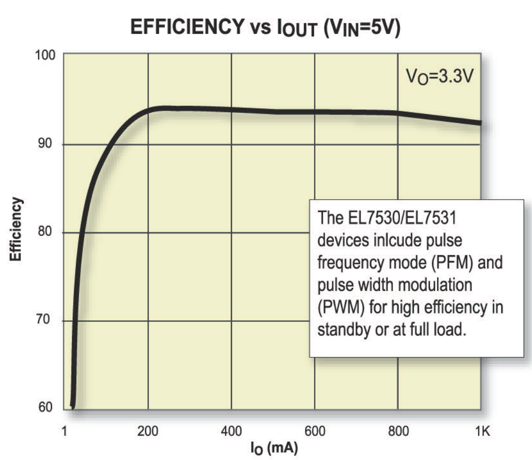
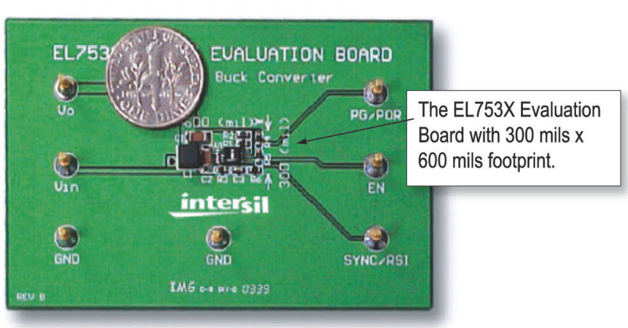


Reduce your PCB footprint to an incredible 300 mils x 600 mils with Intersil's highly efficient 0.6A to 2A DC/DC Switching Regulators with Integrated MOSFETs.

Intersil's EL7530, EL7531, EL7532, EL7534 and EL7536 family of DC/DC buck regulators with integrated MOSFETs are simple to use, compact and full-featured. Their high efficiency makes them especially well suited for battery-operated products.





EL753X Features:

- Extremely small 0.6A - 2A synchronous buck switching regulators
- V_{IN} = 2.5V - 5.5V
- 96% maximum efficiency
- 100% duty cycle (V_o close to V_{IN})
- 1.4MHz fixed PWM with small passives
- PFM/PWM auto-switchable (EL7530 and EL7531)
- 120μA quiescent current

Applications:

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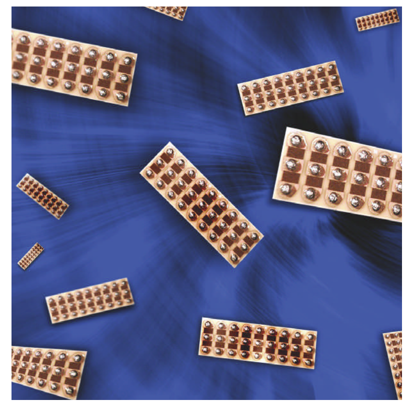
"Terminator" causes no panic, keeps fast signals from coming back

For high-speed digital lines, the CHC series of termination networks from the IRC Division of TT Electronics maintains maximum signal integrity with nine Thevenin pairs in an 18-resistor array. According to Jerry Seams, application manager, "The terminators provide both pullup and pulldown functions, and the BGA package eliminates wire bonds, reducing parasitic capacitance." These Thevenin pairs typically find use in DDR memory, ECL/PECL (emitter-coupled-logic/positive-ECL) and single-ended and differential-signal terminations.

The vendor fabricates the devices from tantalum-nitride thin-film elements, and they resist the corrosion that may occur with nichrome elements in humid applications. Absolute TCR (temperature coefficient of resistance) is ±100 ppm/°C. The elements are available in a wide range of values, as standard or custom orders, with the BGA package in a JEDEC-standard 8-9A size. The price is less than $1 (10,000). **—by Bill Schweber**

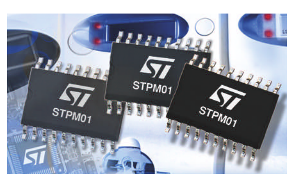
▷**TT Electronics IRC Advanced Film Division**, www.irctt.com.



Damp those ringing high-speed signals with the Thevenin-termination-pair resistor array, which is available in a BGA package for minimum size and parasitic capacitance.

Energy-metering IC targets range of applications

STMicroelectronics has released the STPM01 chip, which focuses on various electricity-metering issues and can function as a stand-alone power meter in low-end equipment or as a peripheral in complex microprocessor-based meters for remote metering, reactive power management, tamper detection, and other applications. The chip comprises an analog-front-end interface for low-, medi-um-, and high-end meters and includes analog, signal conditioning; two ADCs; a hard-wired DSP; an SPI interface to an external microcontroller; a block of 56 OTP (one-time-programmable) bits for meter calibration and configuration; a VFC (voltage-to-frequency converter); and two-current limited, low-drop voltage regulators for 3V analog and 1.5V digital circuitry.



The STPM01 chip uses an analog front end, which makes it compatible with various sensors, including shunts, current transformers, and Rogowski foils.

According to Fabrizio Librizzi, marketing and technical engineer for the company's Microcontroller, Linear, and Discrete Group, the chip's analog front end allows it to be compatible with various sensors, including shunts, current transformers, and Rogowski foils. And, depending on which type of meter the STPM01 resides in, it can provide users with real-time-meter information through a combination of passive and secondary components and LCDs and automatic feature-reading functions. These functions transmit energy readings to a central line, such as power-line modems, GSM (global system for mobile communications), and other applications.

"The big difference," says Librizzi, "is application management on the front end. Modularity is the same [in different meters] because of the analog front end, as is the interface for the electrical line, although the functions of the meters vary. From a silicon point of view, it is the same device." The STPM01 provides energy-related information without any type of "ripple." This approach, in turn, gives meter designers accurate and current information without averaging multiple current readings.

Engineers can digitally perform soft calibration—calibrating two or three parts of a current range to check on the linearity of a meter—to the device before installing it, which saves time and money. Designers can also program the chip for different sensors, allowing them to configure OTP blocks and design one board for various products, which shortens development time. The STPM01 operates over a mains-voltage range of 40V to 3 kV rms and a line frequency of 45 to 65 GHz. It is now available for sampling and costs $2 (1000).**—by Jeff Berman**

▷**STMicroelectronics**, www.st.com.

Single-chip WLAN device supports MIMO

Wire-line- and wireless-communication silicon provider Metalink Broadband has introduced the MtW8170 baseband chip, which is the company's second WLAN (wireless-LAN) offering in the last month. The new offering complements Metalink's MtW-8150, a single-chip WLAN RF device that supports MIMO (multiple-in, multiple-out) designs. It comprises two RF chains for wireless-video distribution in home environments for data rates beginning at 200 Mbps. The company says that the combination of the MtW8170 and the MtW8150, which it calls WLANPlus, will comply with an as-yet-undefined 802.11n standard and will find use in digital-video recorders, set-top boxes, HDTVs, media adapters, and other applications to provide multimedia connectivity in a home environment.

Ron Cates, Metalink's vice president of sales and marketing, says that the chip supports 2×2 RFIC MIMO, operates faster than 240 Mbps, and supports the 802.11e QOS (quality-of-service) standard. Along with MIMO, WLANPlus uses a MAC (media-access-control)-aggregation scheme and channel bonding for increased gigahertz per channel, enhanced performance, and higher throughput rates in an LPDC (low-density-parity-check) format with 40-MHz bonded channels for extended throughput and 20-MHz bonded channels for backward compatibility with 802.11a products. Channel bonding would suit 802.11n and is not available in competitors' offerings, such as those from Airgo Networks (www.airgonetworks.com).

Another notable benefit of the WLANPlus platform is that it operates in a 5-MHz band, unlike Airgo, which uses a 2.4-GHz band for Centrino-based laptops. A major difference between the two bands is that 2.4 GHz has only four available channels, whereas the 5-GHz band has 20 channels, which are critical for video transmission and are noise-free. And with a 5-GHz band, no dropped packets occur, and video feeds arrive in the order they were transmitted to get a high level of broadcast-video quality. The 5-GHz band also does not interfere with other devices or Bluetooth- and microwave-based bands. "Working off a cleaner spectrum should allow for better QOS of wireless-video distribution and will provide a greater range and bandwidth that is more suitable for home-video distribution, unlike 801.11g and 802.11a/g chips," says Sam Lucero, an analyst at In-Stat/MDR.

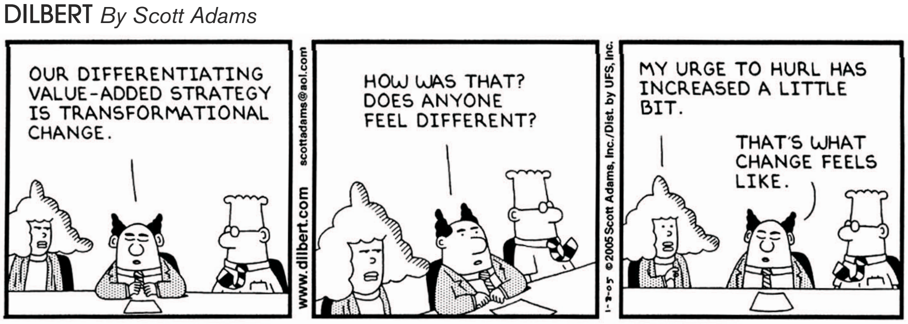
Metalink's MtW8170 will be available in sample quantities during the next quarter, and company officials say they target a price of approximately $25 (high volumes) for the chip set.**–by Jeff Berman**
▷**Metalink Broadband**, www.metalink.co.il.

FEEDBACK LOOP

"I have difficulty trying to mentor junior engineers when they believe they already know it all. People don't mind being told what to do, but they don't care to be told how to do it."

Joseph Travis in *EDN*'s Feedback Loop on www.edn.com/article/CA601846. Add your comments.

DILBERT *By Scott Adams*



07.21.05

Connector has nonmagnetic appeal

Specialty applications often require special components, such as Amphenol's modified version of its established Amphe-Lite series of connectors. The new version provides a nonmagnetic interconnect for applications such as MRI (magnetic-resonance imaging), in which magnetic materials distort the intense magnetic field and affect image quality, and SQUIDs (superconducting-quantum-interference devices). The connector housing comprises composite materials, and, when you mate them, they meet IP67 ratings.

The nonmagnetic contacts handle power, signal, and coaxial cabling, ranging from a single twinaxial contact to 128 contacts that accept crimped #22 AWG through #28 AWG, in various combinations. A mated pair sells for $20. –by Bill Schweber
▶Amphenol Industrial Operations, www.amphenol-industrial.com.

Nonmagnetic connectors in the Amphe-Lite series prevent a disturbance in the field, which adversely affects the operation of instrumentation such as MRI machines and SQUID units.

US military to adopt mobile-base-station technology

Software-defined-radio vendor Vanu Inc recently demonstrated a prototype of a mobile GSM (global-system-for-mobile-communications) cellular base station, which the company based on its proprietary Anywave all-software GSM base station. The US Army base at Fort Dix, NJ, will use the devices. The Army used Vanu's Anywave with satellite-backhaul technology from Globalstar (www.globalstar.com) to ensure that communications systems were in place and functional while military vehicles were moving. Vanu received a development contract in June 2004 from the US Army CERDEC (Communications Electronics Command Research, Development, and Engineering Center, www.monmouth.army.mil/cecom/rdec/about.htm) to develop the technology.

During the demonstration period, Vanu mounted the devices and other equipment onto Humvees. The equipment comprised three GSM networks, each integrating a prototype Anywave GSM cellular base station, a Hewlett-Packard (www.hp.com) 2.0 NEBS (Network Equipment Building Standards)-compliant server, and a Globalstar satellite. This deployment, according to Alok Shah, Vanu's director of product management, helped each Humvee unit achieve communications in localized areas, even if it lacked communication with the rest of the world. "The luxury of [employing call-connecting devices] in case satellite connections were down was not an option," says Shah.

A basic mobile-switching-center technology in Anywave handles call-control functions and register handsets. The Globalstar satellite links enable the units to call one another through audio feeds and control signaling. If a satellite is unavailable, two users near one Humvee can still communicate over a network without an available satellite link. One Globalstar satellite link supports communications for a moving vehicle and as many as 30 Type 1 secure headsets within a three- to five-mile range. These satellite links need not point in a specific direction to connect with a satellite, unlike the standard-cell macro deployments that the military commonly uses.

The size, weight, and power of these systems are critical because the Humvees have limited space for extra equipment. "Typically, a system made up of off-the-shelf components could not fit into a Humvee," says Shah. "We will work on shrinking [these components] in future demonstrations and deployments. By compressing the backhaul to get information sent to the same links, we could work with smaller form factors and limited bandwidth."

John Winn, Vanu's vice president for sales and marketing, says that the company will increase its focus on ruggedizing the system for harsh environments and offer systems in different frequency ranges, with an eye on integrating a 900-MHz front end for in-building penetration.**—by Jeff Berman**

▷**Vanu Inc**, www.vanu.com.

The US military has mounted prototypes of the Anywave GSM base station on Humvees.

FEEDBACK LOOP

"From what I've seen, the best, brightest engineers have nothing to worry about—not even from the Chinese, Koreans, and Indians. There is always a place here for a talented engineer who can make money for the company no matter what business environment we are in."

"Jack Daniels" in *EDN*'s Feedback Loop on www.edn.com/article/CA529820. Add your comments.

Ethernet takes to industry

07.21.05

Not too long ago, many pundits said that Ethernet would be unsuitable for industrial, medical, or field applications. However, the momentum of the standard and its performance improvements proved them wrong. A successful installation, however, does mandate connectors that can withstand abuse and environmental conditions.

One such connector, the industrial circular-Ethernet connector from Tyco Electronics, is a sealed RJ-45 device with a quick-connect bayonet coupling mechanism that meets the ODVA (Open Devicenet Vendors Association) interoperability specification and IP67 sealing requirements for Category 5e cables. The positive-lock coupling ring ensures proper mating and retention between connector halves. Tyco offers the connector for $18 to $20 per mated pair (500) in pass-through and field-installable versions; the company also offers a protective cover for enhanced ruggedness.

—by Bill Schweber

▶**Tyco Electronics, www.tycoelectronics.com.**

Take Ethernet to the factory floor or field with these circular connectors from Tyco.

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Architecture targets USB applications

Structured-ASIC start-up ChipX, formerly Chip Express, is releasing a new structured-ASIC architecture with an initial device family focusing on applications using USB 2.0. Elie Massabki, vice president of marketing at ChipX, says that the new CX6000 architecture offers users two, three, or four metal layers to design with in an architecture that comprises eight layers. Users can customize metal layers three through six, but layers one and two handle local interconnect, test lines, and a clock tree, and layers seven and eight hold the power grid.

ChipX implemented the devices in UMC's (www.umc.com) 130-nm process. They have a maximum operating frequency of 250 MHz and a normal operating voltage of 1.2V. The CX6000 devices feature four low-jitter corner PLLs operating at 10 MHz to 1 GHz and synthesizable DLLs running at 50 to 500 MHz for deskewing and frequency multiplication. The family features synchronous SRAM in 9-kbyte blocks, which designers can configure in the devices' programmable metal layers as 1024×9, 512×18, and 256×36 bits. Each of those blocks is writable in 9-bit-wide words and comes in single-port, dual-port, or FIFO versions; average single and dual ports run at 740 MHz at 1.2V. Memory blocks have a BIST (built-in-self-test) controller.

I/O structures include LVTTL (low-voltage transistor-to-transistor logic), low-voltage CMOS, 840-Mbps LVDS (low-voltage differential signaling), LVPECL (low-voltage positive-emitter-coupled logic), HSTL (high-speed transceiver logic), SSTL (stub-series-terminated logic) 18/2/3, DDR, PCI, PCIX, and XOSC. I/O voltage ranges from 1.5 to 3.3V, and individual drive strength ranges from 2 to 16 mA.

The first offering in the CX6000 family is the CX-6200, which targets applications using USB 2.0. "USB is a large market and an industry standard, and there is a great need in the market for USB in a structured ASIC," Massabki says.

Wouter Suverkropp, strategic marketing director, says that, because USB requires a full subsystem, including PHYs (physical layers), controller IP (intellectual property), and a processor, the devices have been difficult to implement on standard-cell SOCs (systems on chips) and have been virtually nonexistent on FPGAs. According to Massabki, 6 million USB devices are on the market this year, and that number should increase by 2 million over the next two years.

The CX6200 includes a full subsystem for USB applications, including the USB 2.0 high-speed, USB OTG (On-the-Go) PHY and controller IP and a synthesizable 8051 processor to control the USB functions. The CX6200 devices have 140,000 to 1.8 million designable gates, 233 to 1037 Mbytes of memory, 105 to 280 configurable I/Os, and 56-pin QFN to 456-ball BGA packages. Prices for the smallest CX6200 devices will start at $5 (100,000).

—by Michael Santarini

▷**ChipX**, www.chipx.com.

IrDA gets faster, grows into new applications

RF wireless, in the form of Bluetooth, WiFi (Wireless Fidelity), UWB (ultrawideband), and RFID, is getting lots of attention. However, basic IrDA (Infrared Data Association) technology is still an appropriate, cost-effective link for many applications, especially with its simple protocol, lack of setup complications, well-defined functions, low power, and low cost. Because an insufficient data rate can impede its acceptance in some applications, Vishay's latest IrDA transceivers support the 4-Mbps FIR (fast-infrared) specification, and the company will soon support the 16-Mbps VFIR (very-fast infrared) with a device and an associated controller.

Typical applications are transfer of high-resolution camera-phone photos; transfer between mobile peripherals, such as MP3 devices; and in-home multimedia systems. According to Jim Toal, marketing manager at Vishay, "FIR is coming back into notebooks in Japan." Furthermore, according to Heinz Nather, PhD, Vishay's vice president of the Sensors and IRDC Division, the device lets users transfer a 329-kbyte, 1280×960-pixel image in 1.5 sec using FIR–25 sec faster than SIR (standard infrared) at 115 kbps.

The TFBS6711 and TFBS6712 FIR transceivers, which have different I/O voltages to match different system-interface requirements, measure 6×3 mm with 1.9-mm height and operate from 2.4 to 3.6V supplies. They support 4-Mbps transfer over 50-cm paths and conventional RC (remote-control) signals at 6.5m, through the use of IR emitters that closely match the wavelength of these ubiquitous RC receivers. Shutdown current is 0.01 μA, and idle supply current is 1.7 mA. The devices sell for $2 (OEM quantities).–by Bill Schweber

▶Vishay Intertechnology Inc, www.vishay.com.

07.21.05

FEEDBACK LOOP

"Every circuit path forms a loop and can have a current induced in it by magnetic field from outside the board. Ground fill, together with a ground plane and generous use of ground vias, breaks large areas into small ones, significantly reducing B-field window area and, therefore, EMI coupled from outside the board."

Dirk Gaede, in *EDN*'s Feedback Loop on www.edn.com/article/CA601835. Add your comments.


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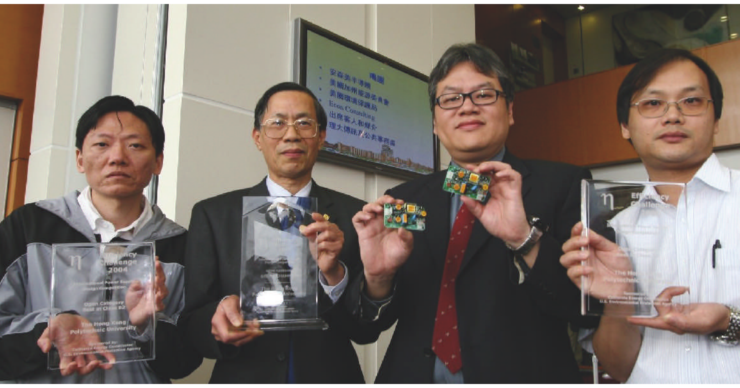

The HKPU design team—from left, Lee Chung-ping; Professor Lee Yim-shu; Martin Chow Hoi-lam, PhD; and Cheng Yiu-lam—show off their winning entries and the Efficiency Challenge trophies.

GLOBAL DESIGNER

Hong Kong team wins power-supply-design contest

Design contests are big things in Asia these days, because there is a feeling that Asian designers lack system-design expertise. Therefore, semiconductor companies, such as On Semiconductor, have started to promote design contests in the region to improve this deficiency. Seen in this light, Asian designers seem to be doing rather well.

Hong Kong Polytechnic University (HKPU, www.polyu.edu.hk) won the Grand Champion and Best in Class A2 awards in the Open Category in the Efficiency Challenge 2004 design competition. On Semiconductor recently bestowed the awards at the APEC (Applied Power Electronics Conference) in Austin, TX. HKPU's Grand Champion winning entry is a power-supply design for an external, stand-alone, AA-battery charger. The university's second entry, an external power supply for a cordless phone, won the Best in Sub-Class B2.

The HKPU team, comprising Martin Chow Hoi-lam, PhD; Professor Lee Yim-shu; Cheng Yiu-lam; and Lee Chung-ping, belong to the Power Electronics Research Centre in the university's Department of Electronic and Information Engineering. The team used On Semiconductor's devices in their award-winning design.

The Efficiency Challenge contest featured two major categories: the Open Category for power-supply designs without cost constraints and the Market Ready Category for cost-effective power-supply designs in consumer electronics. Companies and universities in the United States, Taiwan, and Hong Kong participated in the contest.

The HKPU team based its AA-battery-charger design on On Semiconductor's NCP1215A variable-off-time switch-mode power-supply controller. The design features 6.25V output voltage, 2.5W output power, and 0.4A output current. The power-supply design delivers an average active-power efficiency of 74% and a no-load power consumption of 0.16W. The judges observed that HKPU's AA-battery charger has an impressively low parts count and that the device delivers good efficiency for such a low output power. They noted also that its no-load power consumption of 0.16W is remarkable.

–by NS Manjunath, *EDN Asia*

▷**Applied Power Electronics Conference**, http://apec-conf.org.

Multistandard software-defined-radio adds DRM format

DRM (Digital Radio Mondiale), a proposed standard for digital radio, enables broadcasters to reuse frequencies below 30 MHz as progressively smaller audiences are listening to the conventional services, including AM, long wave, and short wave, in which the band operates. DRM uses compressed audio and digital QAM (quadrature-amplitude modulation) to achieve robust transmission and reception with added service features.

Broadcasters can achieve extended coverage—in some cases, continentwide—with the same power that previously covered a more limited area. Alternatively, they can cover the same geography with reduced power and can package multiple channels in the same spectrum allocation. An additional attraction for operators is that using the frequency often requires only a modest upgrade to transmitters. Depending on the data rate and codec they use, they can achieve near-FM quality. Many broadcasters are already experimenting with transmissions.

Now, RadioScape, which has for some time produced modules to receive DAB (digital-audio broadcasting), has introduced the RS500 module that adds DRM to DAB; FM/RDS (radio-data service); and long-, medium-, and short-wave radio. This module includes the same features as the earlier RS300 module, forming the core of a complete digital radio with pause, rewind, and record to an MMC memory card, plus full access to electronic-program-guide data. DRM permits features such as frequency shifts, in which the broadcaster moves the transmission between allocated frequencies in the course of a day to cope with the variable nature of propagation below 30 MHz, enabling receivers to track the channel shifts. RadioScape recently changed its profile to be a manufacturer of complete modules rather than a supplier of silicon and provider of licensed module designs.**—by Graham Prophet,** *EDN Europe*

▶**RadioScape**, www.radioscape.com.

▶**Digital Radio Mondiale**, www.drm.org.

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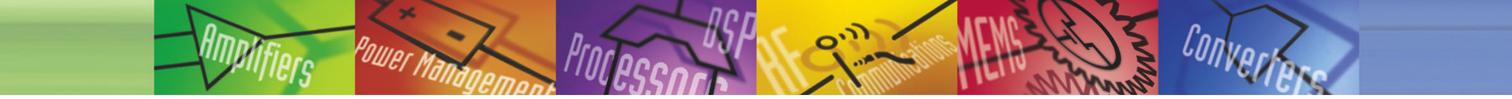
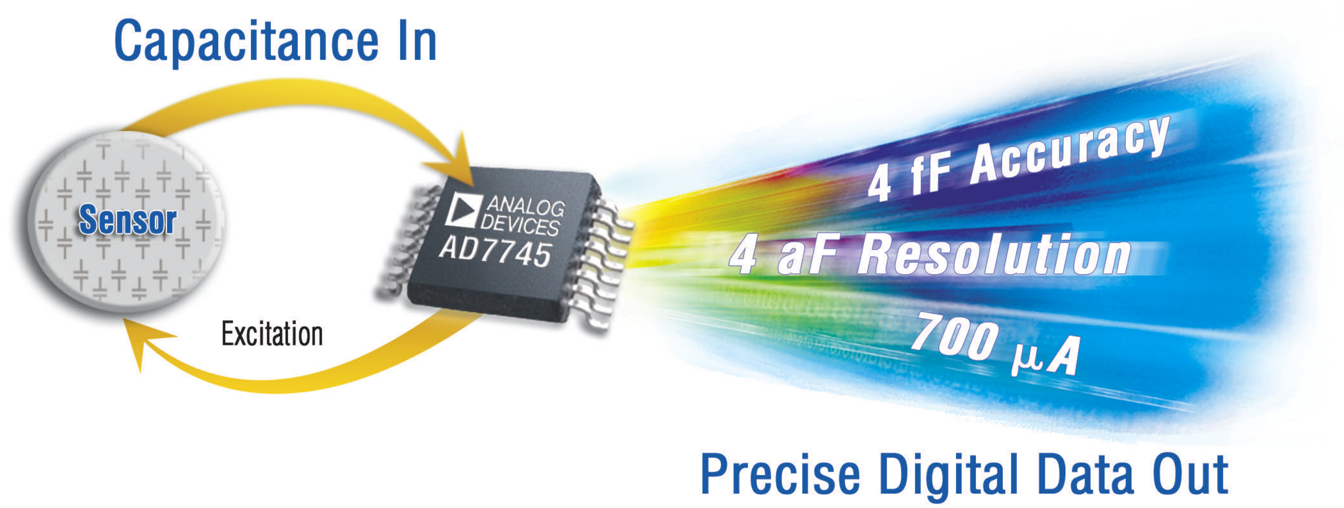


Now the shortest distance between a capacitive sensor and digital code is a single chip.



AD7745: Precision and integration …

- Resolution: 4 aF (21 ENOB)
- Accuracy: 4 fF
- Power consumption: 700 μA
- Capacitance input: 0 pF to 17 pF with ±4 pF range
- Package: 16-lead TSSOP
- Price: $4.60 (1k)
- CDCs also available: AD7746 and AD7747

… where it matters

- Pressure measurement
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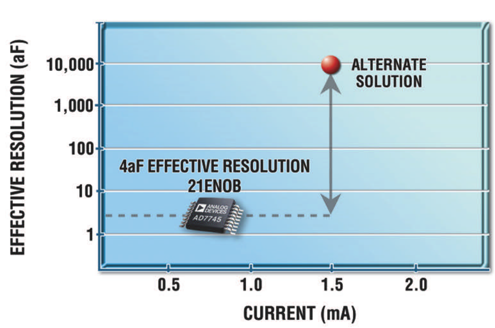
Unequaled accuracy and linearity with up to 65% lower cost

Now you can precisely measure and convert capacitance signals without all the time, expense, and performance problems of multichip discrete solutions. Our new AD7745 is a capacitance-to-digital converter (CDC) that combines a 24-bit Σ-Δ modulator, reference, clock, excitation, temperature sensor, calibration, and control registers in a single TSSOP. What used to take from six to 12 components can now be done in one innovative IC, with far greater accuracy, for up to 65% lower cost. The unique architecture of the AD7745 includes a patented analog front end interface that eliminates the negative effects of external parasitics. It's the ideal solution for any high precision, space-constrained, and power- and cost-sensitive application.



The AD7745 delivers high precision with unequaled accuracy, low noise, and low power.

To sign up for our NetSeminar: *Leveraging Advanced Converter Architectures for Impedance and Capacitance Sensors*, visit *www.analog.com/CDC*.

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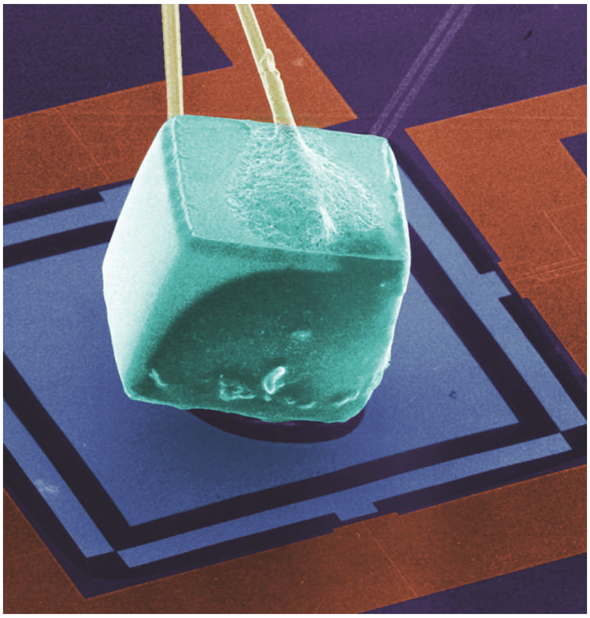
ANALOG DEVICES

THE LEADER IN HIGH PERFORMANCE ANALOG



The four small, light-blue rectangles at the midpoints of the membrane perimeter are chip-scale refrigerators that cool the germanium cube above it, and the membrane, to about 200 mK.

RESEARCH UPDATE

BY BILL SCHWEBER

IC may become its own cooler

A chip-scale refrigerator that can cool down to 200 mK and below may provide a new way to implement cryogenic sensors used for extremely sensitive instruments. Researchers at the NIST (National Institute of Standards and Technology) fabricated these devices using a diode sandwich of conventional metal, insulator, and superconducting metal, measuring 25×15 microns (**Reference 1**).

When researchers apply a voltage across the sandwich, the hottest electrons tunnel, following quantum-mechanical principles, from the normal metal—aluminum doped with manganese—through the aluminum-oxide insulator to the superconducting metal. This tunneling causes the temperature in the normal metal to drop and drains electronic and vibrational energy from the cooling object.

NIST builds the refrigerators using standard IC-lithography techniques. In the demonstration, the researchers cooled the contents of a silicon-nitrate membrane, measuring 450 microns on a side and 0.4 microns thick, with four such microrefrigerators, one at each corner of the membrane. On top of this membrane, they attach a germanium cube measuring 250 microns on each edge and weighing 80 µg. The cooled cube's volume is about 11,000 times that of the four refrigerator structures, a significant cooling achievement. The researchers believe that they may be able to reach down to 100 mK, suitable for a wide range of cryogenic sensors.

▷**National Institute of Standards and Technology**, www.nist.gov.

REFERENCE

1 Clark, AM, et al, "Cooling of bulk material by electron-tunneling refrigeration," *Applied Physics Letters*, April 25, 2005, http://apl.aip.org/apl/covers/86_17.jsp.

Free NIST software enhances scope timing

Researchers at the NIST (National Institute of Standards and Technology) have developed a technique for constructing an alternative, and more accurate, reduced-jitter oscilloscope timebase. The free software, which is suitable for new and older units, looks at both the signal under measurement and the two offset reference waves that an external source generates. The correction method can correct time records and provide an estimate of the residual timing error. Details and the timebase-correction package are available at the project's Web site, www.boulder.nist.gov/div815/HSM_Project/Software.htm.

▷**National Institute of Standards and Technology**, www.nist.gov.

Optical switch routes single photons of quantum cryptography

Researchers at NTT (Nippon Telegraph and Telephone), Japan, demonstrated switching of single photons for use in ultrasecure quantum cryptography, which may supersede public-key systems for even more secure links. (Any attempt to measure or eavesdrop on the photon changes its quantum state.) NTT developed the technique in collaboration with Stanford University.

The 8×8 optical matrix uses an interferometer to steer the photons, along with much more intense optical signals using the same pathways. By changing the temperature of one of the two arms of the interferometer, its refractive index and, thus, optical-path length changes. The fragile single photon changes paths, as well, in accordance with principles of the dual-particle/wave nature of light and quantum theory. You can find details at www.ntt.co.jp/news/news05e/0506/050614.html.

▶Nippon Telegraph and Telephone, www.ntt.co.jp.

07.21.05

Boost Precision and Accuracy with Single Chip Capacitance- and Impedance-to-Digital Converters

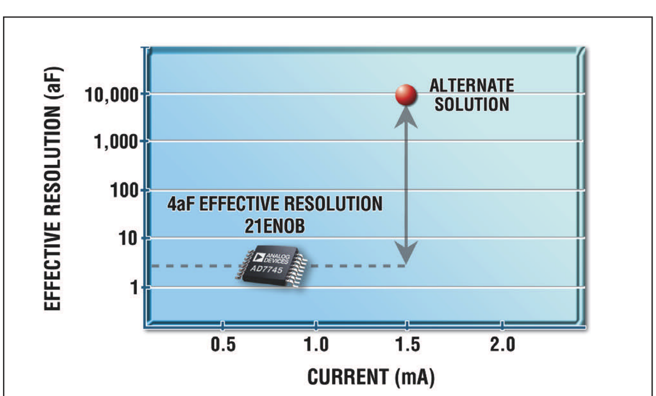
High precision capacitance- and impedance-sensing applications traditionally required a complex collection of discrete components that needed to be skillfully combined together to provide an overall measurement solution. Not only was this time consuming from a component selection perspective but as each application differed slightly, it also required significant design validation, evaluation, optimization, and qualification.

Overcoming Design Barriers with New Converter Architectures

By architecting an optimized solution that incorporates all of the required functionality on a single chip, Analog Devices has created two new converters that provide system level solutions for impedance and capacitance conversion and deliver higher precision and accuracy while reducing size, design time, cost, and power. This advanced level of integration is particularly important when processing small signals where excess noise, component tolerances, and temperature drift can adversely impact measurement accuracy. In addition to providing superior performance, both converters are available in small packages. Applications in the industrial instrumentation, automotive, and biomedical sectors can benefit from higher precision capacitance measurement or simplified impedance analysis—both at lower cost and without the inherent complexities and design limitations of multichip discrete designs.

Convert Capacitive Sensor Signals to Digital with High Precision

The architecture of the AD7745/AD7746/AD7747 capacitance-to-digital converters (CDC), which includes a patented analog front end interface, eliminates the negative effects of external parasitic capacitance. This architecture opens up high performance applications in medical instrumentation (for patient monitoring and blood pressure measurements), in industrial instrumentation (for pressure and level sensors and smart transmitters), and in automotive environments (for position and level sensing, as well as occupancy and proximity detection).

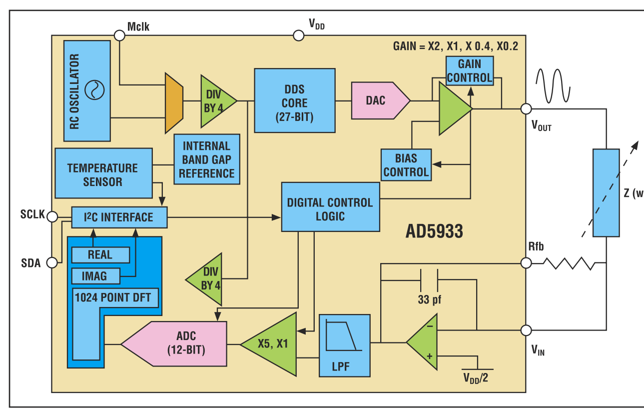


The AD7745 delivers high precision with unequaled accuracy, low noise, and low power.

The CDC is suitable for these applications because of its unique combination of high precision, small package, low power, low cost, low temperature drift, and low noise. The AD7745/AD7746/AD7747 are available in small 16-lead TSSOP packages at 1k unit pricing of $4.60 (AD7745/AD7747) and $4.95 (AD7746).

Measure Impedance More Accurately with Mixed-Signal Integration

The new AD5933/AD5934 impedance-to-digital converters (IDC) put direct digital synthesis (DDS), analog-to-digital conversion,



The AD5933 block diagram illustrates the advanced level of integration contained in its single-chip form factor.

and DSP on a single chip. The IDC measures impedances ranging from 100 Ω to 10 MΩ, excited with an on-chip frequency generator of up to 100 kHz. The response signal from the impedance is sampled by the on-chip ADC and its discrete Fourier transform (DFT) is processed by an on-chip DSP. The DFT algorithm returns both a real (R) and imaginary (I) data word at each frequency point (for a sweep), enabling phase and amplitude impedance calculations based on an initial calibration. The AD5933/AD5934 are available in small 16-lead SSOP packages at 1k unit pricing of $4.35 (AD5934) and $6.65 (AD5933). For additional product information, go to *www.analog.com/CDC* and *www.analog.com/IDC*.

Author Profiles: ***James Caffrey*** *is the product marketing manager for the Precision Converter group at Analog Devices, where he is involved with product and business development strategy for low voltage DACs.*

Conor Power *is the product marketing manager at Analog Devices for the Instrumentation and Automotive Converters group.*

BY HOWARD JOHNSON, PhD

Big hurl

A trebuchet hurls its load with a dynamic grace unmatched by other ancient machines of war. This ingenious device reigned supreme as the ultimate weapon for 1000 years, proving the value of a good engineering concept.

A trebuchet comprises three main components: a source of stored energy, a rigid beam acting as a mechanical impedance converter, and a lightweight sling—radically increasing efficiency and launch velocity.

My daughter Allie recently built one (**Figure 1**). She powered her tennis-ball-throwing machine with thick rubber straps, forming a substantial spring. To prepare the device for firing, you pull down on the beam, tensioning the straps (not in the photograph). **Figure 2** shows the beam in firing position, with the sling feeding horizontally back under the mechanism to Point A. Here, the ball begins its flight nestled in a wire basket that a steel trigger securely holds. Release the trigger, and the rubber spring, Point B, promptly hauls down the short end of the beam at Point C, raising the opposite end and propelling the sling, Point D, through a beautiful arc. At Point E, one side of the sling slips free from a strategically placed pin, releasing the load. The whole action, from trigger to release, takes 170 msec.

The blue stop-action markings show the beam accelerating wickedly at first, then slowing as the centrifugal force of the ball and sling, whipping upward at fearsome velocity, pulls back on the mechanism. This slowing action is the hallmark of a properly designed trebuchet. The spring or counterweight first pours energy *into* the beam, increasing its angular momentum. Then, the whipping action deducts the same angular momentum *from* the beam, bringing it to a standstill, pointing straight up, devoid of energy at the end of the cycle. The only things moving after the projectile cuts free are the projectile itself and portions of the sling.

Figure 1 Allie inspects her beam for damage.

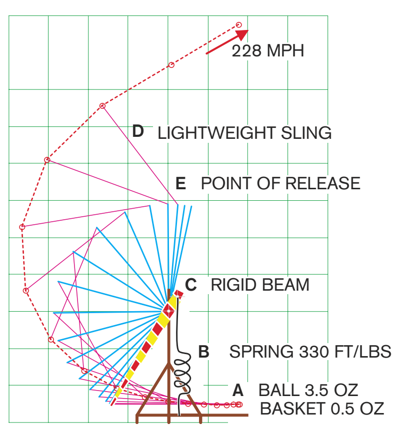


Figure 2 During competition, Allie's ball left the sling at 228 mph, traveling 235 ft into a slight head wind.

Nothing else harbors residual energy. The whipping action transfers almost all of the stored energy into the projectile.

A large trebuchet stores about 140,000 ft/lbs of energy, a massive amount of hand cranking. It delivers nearly 70% of that energy into the projectile, wasting precious little time or motion among the artillery crew. In contrast, the more primitive mangonel-style catapult cradles the projectile in a basket affixed to the end of a heavy beam. That device wastes most of its stored energy accelerating the heavy beam, smashing it into the end-stops at the point of release.

If you have studied resonant-mode switching power supplies, this energy-transfer story may sound hauntingly familiar. A good switcher first connects a source of power to an inductor, charging it with current. The switcher later transfers that same energy neatly into the load at the end of each cycle. Do it right, and the inductor ends each cycle devoid of energy—nothing wasted.

Transmission-line networks involve a related process. A transmitter interacts with the line; the line conveys its energy to the load. If all goes according to plan, nothing bounces back, and nothing is lost.

Engineers enjoy a long tradition of experience with dynamic processes. Over the centuries, they have developed many diverse means of dealing with them. It is my pleasure to help pass along this tradition to a new generation. Allie, congratulations on winning the 2005 Methow Valley Junior High Tennis Ball Catapult Fling. EDN

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Go to www.edn.com/050721hj and click on Feedback Loop to post a comment on this column.

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

Watching the currents flow

DANIEL VASCONCELLOS

It was late Sunday evening, and we were still trying to trace why the embedded DSL modem was feeding a strange 50-MHz carrier into the network—much stronger than −40-dB noise allows. And no 50-MHz signal existed on the design! Jeremy, the board designer, did his best to lay out a six-layer board and placed many bypass capacitors as numerous reviews suggest. He also kept power and ground planes everywhere on separate layers and kept the analog traces as far from noisy digital parts as he could. We had a faint hope that the board was picking up a spur from a clock line 1 in. away; our hope disappeared when the second, improved board revision made things worse.

Building mixed-signal, quiet boards is an art, and textbook recommendations on layout for signal integrity can fail if you take them literally. We could have been dealing with inductive coupling from the currents flowing in the ground plane, but my suggestion to watch the currents flow in internal layers surprised the team. Don't the electrons simply dive into the ground plane?

Unfortunately, physics claims that currents come only in loops. Even in planes, you can find where most of the current flows, such as the Gulf Stream in the ocean. These currents induce the noise in the traces above it, and no way exists to shield the magnetic field on the board. Finding or predicting these loops is part of the art of mixed-signal design.

WHEN WE TINKERED WITH A FEW DEDICATED BYPASS CAPACITORS BETWEEN THE PAIRS—VOILA!—THE NOISE CURRENTS FLOWING OUT OF THE CPU AREA SHRANK.

Once designers find them, they should make the loops as local as possible, and the low-noise signal traces should never run parallel to these currents.

We made a handy ac-current probe, a Magnepick. It is simply a toothpick with three to four turns of a thin wire making a tiny coil on its tip. It picks up the magnetic field parallel to the toothpick. We connected it to a spectrum analyzer (don't forget 50Ω termination) and, sniffing with it around the board, could—with maximum intensity—map the paths of select frequency components. We also made an improved-resolution version from the head of a floppy drive someone left on the bench. (Don't follow our lead if you value friendship.) The revelation was striking.

First, the recommendations for a 1-μF capacitor per digital IC and to not break planes were our biggest enemies. A cluster of chips exists in the corner of the board, with a processor in the center. The cluster of bypass capacitors also happened to be in the corner, and half of the noise current that should have been localized around the CPU rushed all the way to the corner of the board, where the main capacitance was concentrated. This path was the one of least ac impedance, and electrons quickly sensed this opportunity! Our analog trace was right above this path.

Second, not all of the V_{SS} pins on the CPU were equal. Some of them had much greater noise and carried currents of different frequencies! We could identify the pairs of V_{SS}/V_{CC} that apparently belonged to the same unit in the CPU by their noise-spectrum distributions—a secret the chip designers kept to themselves. We also found a 50-MHz clock in the design, internal to the CPU, when our probe was on top of the CPU package and around some pins. When we tinkered with a few dedicated bypass capacitors between the pairs—voila!—the noise currents flowing out of the CPU area shrank.

Although we now marginally meet the specification, Jeremy knows what he has to do next. He will break the V_{CC} plane into islands around the noisiest chips to isolate the currents into much smaller loops. Then, he will put ferrite beads (ac impedance) between them to break long paths of least resistance. He will route the analog traces away from remaining loops and make them orthogonal to reduce the inductive coupling. And he will hook up his bypass capacitors around the CPU close to the pairs we found. EDN

Dmitrii Derevensky is an engineer with a large semiconductor company. Like him, you can share your engineering war stories in Tales from the Cube. Contact Maury Wright at mgwright@edn.com.

TEXAS INSTRUMENTS
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BRIEF

Understanding Noise in Linear Regulators

***By John C. Teel** • Analog IC Designer, Member Group Technical Staff*

Types of noise in analog circuits may include thermal, flicker, and shot noise, among others. In an LDO application, noise is sometimes confused with power supply ripple rejection (PSRR). Many times the two are lumped together and loosely called "noise" just because both cause unwanted signals on the output. This is incorrect. PSRR refers to the amount of ripple on the output coming from ripple on the input. Noise, on the other hand, is purely a physical phenomenon that occurs with transistors and resistors (capacitors are noise-free) on a very fundamental level.

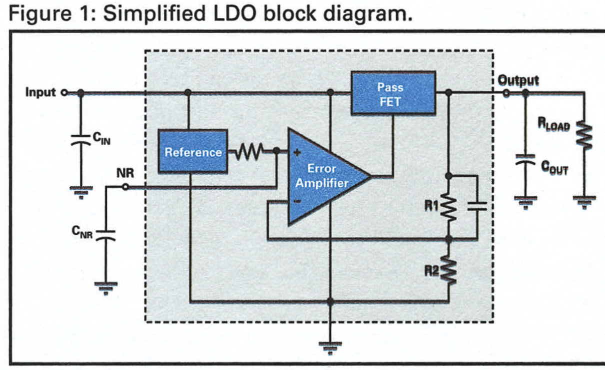
Noise in an LDO is indicated in two fashions. One is spectral noise density, a curve that shows noise ($\mu V/\sqrt{Hz}$) versus frequency. The other is integrated output noise, also commonly called output noise voltage (in μV_{rms}); it is simply the spectral noise density integrated over a certain frequency range and can therefore be thought of as the total noise in a specified frequency range. Since the output noise voltage is represented by a single number, it is very useful for comparison purposes.

Typically, noise in an LDO is specified as output-referred noise (noise occurs throughout the LDO but eventually must be referred to the output). The typical approach to finding the output-referred noise of an LDO is first to refer all noise contributors to the input of the LDO differential amplifier. To refer means to divide each individual noise contributor by the gain that exists between it and the op amp input (assuming the noise contributor is located downstream on the signal path). The next step is now to refer the total input-referred noise to the output by multiplying by the closed-loop gain of the feedback network.

$$A_{CL(DC)} = \frac{V_{OUT}}{V_{BG}},$$

The closed-loop gain of an LDO is simply where VBG is the internal bandgap reference. In many cases VBG is about 1.2 V (although some LDOs have sub-bandgap references and thus a VBG of less than 1.2 V). An LDO with an output voltage of 3.0 V will have almost twice the output noise voltage of a 1.5-V LDO; therefore it's very important when comparing noise on various LDOs always to compare those with identical output voltages. When this isn't possible, an approximation can be made by simply taking into account the ratio of the two output voltages. For example, when comparing the noise voltage of a 3.0-V LDO to that of a 1.5-V LDO, either multiply the noise voltage of the 1.5-V LDO by 2 or divide the noise voltage of the 3.0-V LDO by 2.

Figure 1: Simplified LDO block diagram.



The simplified block diagram in Figure 1 shows the primary noise sources in an LDO—the bandgap, the resistor divider, and the input stage of the op amp. The effects of some of these noise sources can be reduced if the latter are properly understood.

The dominant source of noise in an LDO is usually the bandgap. In most cases this is solved by adding a large low-pass filter (LPF) to the bandgap output so that none of the noise makes it into the gain stage. (This same filter is also used to improve PSRR). Typically this LPF is formed with a large internal resistor and an external capacitor. In most cases the cutoff frequency of this filter is set somewhere between 1 and 500 Hz, therefore filtering out nearly all of the noise coming from the bandgap. In many cases the down side of using too large an RC filter is that the time to charge the filtered bandgap increases drastically, which significantly slows down the output startup. This can be solved by using a low-noise, high-PSRR LDO with a fast-charge circuit such as the TPS793/4/5/6xx or one from the TPS799xx family. Even with a fairly large noise reduction capacitor of 0.01 µF, these LDOs are still able to start up in only 50 to 100 µs.

Another source of noise in an LDO is the resistor divider network. This noise is known as thermal noise and is equal to 4kTR (sometimes called 4kTR noise), where k is Boltzmann's constant, T is temperature in Kelvin, and R is the resistance. The resistor divider is tied to the input of the LDO differential amplifier, so this noise is amplified by the closed-loop gain of the LDO. When calculating this noise source, you can simply use the parallel combination of R1 and R2 since the op amp input sees them as being virtually in parallel. Therefore, to reduce this noise source, the most important thing to remember is that smaller feedback resistors create less thermal noise. Of course, the disadvantage of using smaller resistors is that they burn more current through the feedback divider; but if noise is of prime importance, then this sacrifice must be made.

The other source of noise is the internal LDO differential amplifier, which is usually designed in such a way that the input stage has a large amount of gain—more specifically, transconductance (g_m). This is done so that any noise coming from devices in the signal path located after the input stage have their noise attenuated by the gain of the input stage when they are referred back to the input. There is nothing outside of the internal circuitry that can be done to reduce this noise source.

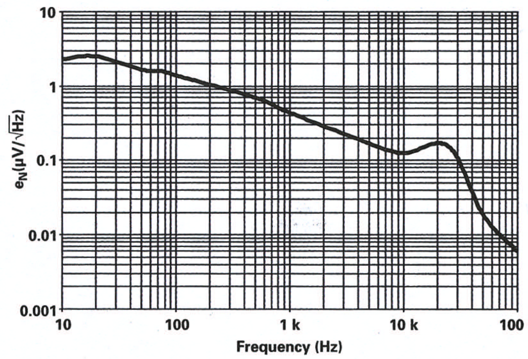
Many people are surprised that the huge power pass FET, which usually takes up at least half of the total die area in an LDO, isn't a primary noise contributor. The reason for this is the lack of gain. All of the primary noise sources (bandgap, resistor divider, and op amp input stage) are connected to the input of the differential amplifier and thus are not attenuated by any internal gain. Remember that the procedure for finding output noise is first to refer each noise contributor to the op amp input; so to find the noise from the pass FET you would first divide its noise contribution by the open-loop gain that exists between it and the op amp input. This gain is typically quite large; therefore, the noise contribution from the pass FET is usually negligible.

Also somewhat surprising is that neither the output capacitor, the load current, nor even the input voltage has any direct effect on the output noise, at least to a first order. However, load current and output capacitance do have an indirect second-order effect. As mentioned previously, output noise is calculated by multiplying the input-referred noise by the closed-loop gain. The closed-loop gain isn't constant at V_{OUT}/V_{BG} over the entire frequency range, and of course it eventually rolls off at high frequencies.

A fundamental rule of feedback analysis is that low phase margin will cause peaking in the closed-loop gain near the unity-gain frequency. Since the closed-loop gain amplifies the noise, this peaking increases the noise in that frequency range even more, thus increasing the total output noise. This effect can often be seen in spectral noise density plots like the one in Figure 2.

High load currents and low output capacitance contribute to output noise because they both make the LDO less stable, which reduces the phase margin. This phase margin reduction increases the closed-loop gain peaking, which in turn increases the output noise. Another significant effect is what many times a higher equivalent series resistance

Figure 2: Spectral noise density example



(ESR) capacitor will actually reduce noise. This is because a larger ESR creates a lower-frequency zero, which many times may improve the LDO stability. Finally, note that the peaking effect explains why, as previously mentioned, the output noise voltage of a 3.0-V regulator usually isn't quite twice as much as that of a 1.5-V regulator. A 3.0-V regulator tends to be a bit more stable than a 1.5-V regulator due to its lower feedback factor. This improved stability increases the phase margin, reducing the closed-loop peaking and thus the output noise voltage.

One final trick sometimes used to reduce noise is to add a capacitor across the top resistor in the resistor feedback divider. This works because at high frequencies the capacitor begins to reduce the closed-loop gain and thus the noise, so that the system begins to look like a unity-gain feedback configuration providing no noise gain. The tradeoff is that this could potentially slow down start-up time significantly, since the capacitor would have to be charged by the current in the resistor divider. The TPS799xx implements this technique via an internal capacitor and also includes a fast-charge circuit.

In summary, there are many ways to reduce noise in an LDO application. The most important is to start with a low-noise, high-PSRR LDO optimized for low-noise applications such as one from the TPS793/4/5/6xx family or the low-I_q TPS799xx family. The second way is to use as large a noise-reduction capacitor as is feasible for startup while keeping in mind that there's a point where increasing this capacitance will offer no further improvement. Finally, use small resistances for the resistor divider network (if the LDO is an adjustable version) and a small capacitor across the top resistor, if possible. Some less obvious improvements are to optimize the output capacitor along with the load current for the highest phase margin to reduce closedloop peaking. Many times, stability can be optimized by using the stability plots provided in some LDO data sheets.

Related Web Sites

www.ti.com/sc/device/*partnumber*

Replace *part number* with TPS79301, TPS79401, TPS79501, TPS79601 or TPS79901

THE DATA DETECTIVE

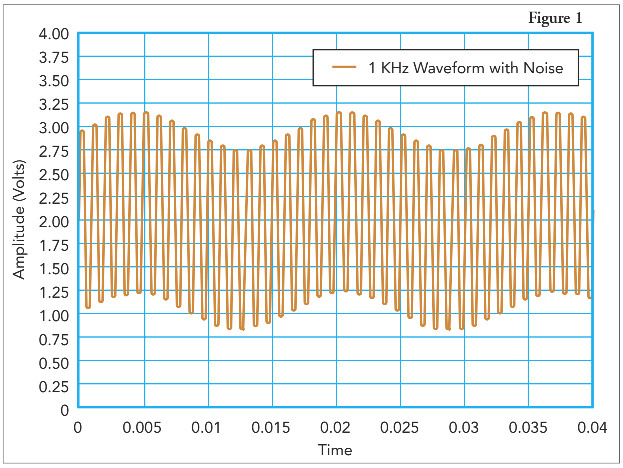
Stay Out of the Loop

Engineers know they must provide a complete circuit in measurement systems because current flow requires a return path. People who work with electronic devices may forget, though, that a ground-return circuit has resistance and a voltage can develop between ground points in electronic equipment. The resulting voltage can "ride" on signals you want to measure and throw off test results.

An example shows how currents can arise in a "ground" loop. Consider a function generator connected to an oscilloscope through a piece of coaxial cable. The cable provides a signal path and a ground, or return path. Both instruments reference their input or output to the ground in their building's electrical supply, which can create a long loop or independent circuit. Voltages of from several tens of millivolts to hundreds of millivolts, usually at the power-line frequency (Figure 1), can occur between the grounds in the two instruments. This sort of ground loop will add unwanted signals to measurement results.

You can eliminate ground loops or reduce their effects through careful design of measurement systems. To start,

Figure 1



ensure that your schematic diagrams include all signal paths, including power-line grounds. Highlighting ground connections and paths may let you identify potential ground loops.

Next, carefully match sensor outputs and instrument inputs. Divide signal sources into grounded and ungrounded categories and then choose an appropriate type of input. Inputs fall into three categories, single ended (ground reference), single ended (non-ground reference), or differential.

Grounded signal sources or sensors work well with differential inputs that reject common-mode signals from ground loops or from induced noise. Rejection comes at a cost, though: Each signal requires two inputs that go through a multiplexer to the + or - input of an instrumentation amplifier.

A pseudo-differential input, or non-references single-ended (NRSE) input also reduces ground loop noise, and it requires only one input per signal. NRSE inputs multiplex one side of a sensor to the + input of an instrumentation amplifier. Instead of referencing the amplifier's - input to local ground, that input connects to the other side of the sensor circuits.

Avoid connecting grounded sensors to single-ended inputs because they produce a ground loop. If you must make such a connection, you may need an isolation amplifier in the circuit to break the ground loop.

Ungrounded, or floating, signal sources inherently eliminate ground loops and they work well with either single-ended or differential inputs. Take care to ensure the common-mode voltage level of the signal, with respect to the measurement system ground, remains within the common-mode input range of the measurement device.

Bias currents on instrumentation-amplifier inputs can push the voltage on these "floating" terminals outside their specified range. A high-resistance path from the inputs to ground will "anchor" the voltage to a local reference. Resistors from about 10 kΩ to 100 kΩ work well with low-impedance sources such as thermocouples or signal-conditioning modules. The resistors do alter the input impedance of the differential inputs slightly, but usually not enough to affect final measurement values. (Always ground unused differential inputs.)

If you run into an elusive ground loop, do not eliminate it by disconnecting their power-line ground (the green wire) to "float" otherwise-grounded instruments. This condition puts users at risk of a lethal shock.

The Elusive Noise

Glenn has set up a data-acquisition system to monitor several dozen sensors. For the most part, the acquired data looks good. But the results from one sensor show an underlying low-frequency signal that Glenn knows the sensor cannot produce. Unfortunately, he doesn't know where the signal does come from.

Can you help Glenn track down the underlying signal added to the sensor's output and determine how to eliminate it?

http://rbi.ims.ca/4394-502

For further reading

"Ground Loops and Returns," National Instruments. zone.ni.com.

Go to http://rbi.ims.ca/4394-502 to solve the challenge!

The ubiquitous RJ-45 Ethernet connector is inexpensive and incorporates a locking tab to prevent accidental disengagement (courtesy CBT Nuggets).

TECH TRENDS DAN STRASSBERG • CONTRIBUTING TECHNICAL EDITOR

Sun sets on IEEE 488,

LAN and PC standards vie for its role

THE MOVE FROM A T&M-INDUSTRY INTERFACE STANDARD TO ONE OR MORE COMPUTER-INDUSTRY STANDARDS PRESAGES MOSTLY GOOD NEWS FOR TEST-SYSTEM DESIGNERS.

Like old soldiers, instrument-interfacing and -communication standards never die; they just fade away. The reason is that instruments themselves, except for the low-cost, handheld variety, which many managers and engineers regard as expendable, often last for many years. This longevity stems only partly from the care that instrument makers exercise in designing and manufacturing their products. Other reasons include the considerable cost of most lab instruments and the relatively benign environments in which most such units operate.

Instruments' longevity—even in manufacturing-test functions—has an important side effect: Standards that govern instrument communication and interfacing are slow to change. Moreover, these standards usually evolve in ways that allow substituting new instruments for older models in new instances of legacy applications, enabling engineers to avoid massive rewrites of costly, custom, application-specific software that controls many T&M applications and that processes and presents the instrument-acquired data.

So it is that IEEE 488, which first became an IEEE standard in 1975 and, before that, had existed for at least five years as HPIB (the Hewlett-Packard Instrumentation Bus—decades before HP spun off its T&M business as Agilent Technologies), is still very much alive and is unlikely to become a relic for another decade. Nevertheless, after three decades or so of using IEEE 488, instrument users could do worse than to start rehearsing that final chorus of *Happy Trails to You* in preparation for bidding farewell to the venerable T&M bus.

VYING TO REPLACE 488

Several computer-industry standards are vying to replace IEEE 488. For example, whereas all new Agilent instruments continue to incorporate IEEE 488 ports, the company's new products also include both USB and LAN Ethernet ports (see **sidebar**, "One company's approach to USB instruments"). For now, Agilent says it hasn't decided when—or even whether—to eliminate the IEEE 488 ports, although doing away with them would at worst present only minor problems to engineers who use the company's products in test systems. If, for a new system, you couldn't purchase an instrument with a built-in IEEE 488 port and you had to select an otherwise-similar unit that instead included only a USB port, software written to control the older instrument would likely require little or no modification to work with the replacement unit. The driver software's compliance with a standard called USB-TMC (USB test-and-measurement class)-USB488 is intended to ensure compatibility (**Reference 1**).

Using USB instead of IEEE 488 to interface instruments to the host PC can prove attractive for several reasons. Unless other system instruments require installing an IEEE 488 interface in the PC, using USB saves the cost of the interface card and the cost and inconvenience of the bulky, balky IEEE 488 cables. All PCs now incorporate USB ports, making

AT A GLANCE

- Although IEEE 488 won't disappear immediately, its use will soon start to decline, and it's not too early to think about how you will replace it.

- Computer-industry I/O standards, particularly Ethernet and USB, have the inside track to become the T&M-industry I/O standards. Both of these standards are likely to be important in T&M.

- The LXI (LAN extensions for instrumentation) Consortium is promulgating an Ethernet-based modular-instrumentation standard that uses a cabled bus and modules with internal power supplies instead of the card cages, backplanes, and shared power supplies found in VXI and PXI (VME and PCI extensions for instrumentation, respectively).

- System integrators want to include PXI and VXI cages in systems based on other forms of instruments. Odds favor the development of standards that permit such configurations.

those ports essentially free, and the ports on PCs manufactured in recent years conform to USB 2.0, whose high-speed mode supports data transfers at nominal rates as high as 480 Mbps (60 Mbytes/sec). In contrast, IEEE 488.1-2003 operates to only approximately 1.8 Mbytes/sec (7.7 Mbytes/sec using National Instruments' HS 488 variant, which instruments from several manufacturers support). Although, in practice, USB 2.0 isn't 33.3 times as fast as IEEE 488.1 or even 7.8 times as fast as HS 488, its maximum data-transfer rate is usually greater than that of either version of 488. In addition, USB cables are thin, flexible, and much less expensive than IEEE 488 cables of equal length.

But USB is not without its drawbacks, especially in systems that were originally intended to use IEEE 488. Unlike 488, which allows direct peer-to-peer communication (instrument-to-instrument in the T&M context), USB is host-centric: Communication between instruments can take place only by way of the host PC. The network topologies also differ: 488 uses a daisy chain; USB uses a star or a hierarchy of stars.

NONSIMULTANEITY

The subjects of how quickly and with what degree of timing uncertainty instruments in any bus-based system can get the host's attention or respond to host commands and other instruments' attention requests are highly complex. Although VXI (VME extensions for instrumentation), PXI (PCI extensions for instrumentation), and other modular-instrumentation platforms incorporate trigger facilities that focus on minimizing uncertainty in the timing of instruments' responses to trigger signals, triggering simultaneity appears to be of less interest to many users than is a system's speed of processing acquired data sets. Older versions of IEEE 488 supposedly required mere microseconds for an instrument to obtain the host's attention or to begin responding after a command's arrival. But, according to Joe Mueller, an Agilent engineering fellow, to solve problems with the reliability of this approach, IEEE 488.2 added features that, depending on the application, can increase and make less predictable the delay between an instrument's receipt of a command or request and the start of the response.

Under USB, an instrument that wants the host's attention normally must wait for the host to poll it. Explains Alex McCarthy, National Instruments' VXI and Instrument Control Group manager, "Although designers familiar with USB can find ways around this restriction, they usually can't reduce the delay and uncertainty in queries or write-then-read activities to much less than 500 μsec."

On a different level, although many people consider them trivial, important differences exist between USB and 488 connectors: USB connectors rely on friction to stay connected when somebody tugs on a cable; captive screws hold together mated pairs of the much larger and more expensive IEEE 488 connectors, making accidental disengagement essentially impossible.

Another issue that figures strongly in any consideration of USB versus IEEE 488 is the potential longevity of the standards. So far, IEEE 488 has proved to be a survivor—partly because its roots lie in the slow-moving T&M industry. USB, on the other hand, is a child of the fast-paced PC business, in which standards figuratively come and go in the blink of an eye. Although USB is now clearly a dominant technology, nobody can guarantee that its dominance will endure for another decade. Those who doubt the validity of this statement need look only as far as such standards as RS 232 and IEEE 1284 (the lineal descendent of the Centronics parallel port). In PC terms, these standards held sway for an eternity. Five years ago, almost everyone considered them cornerstones of PC technology; within the last few years, however, they have become nearly irrelevant.

HI-SPEED CERTIFIED USB ™

With the advent of USB 2.0, the USB Implementers Forum created this new logo that USB-compatible products can display—on the product itself, on its packaging, or both.

Because it is a parallel bus, IEEE 488 requires relatively expensive multipin connectors that are stackable to facilitate daisy-chained instrument connections. Captive screws secure mated pairs and prevent accidental disengagement (courtesy mycableshop.com).

DATA ACQUISITION ♥ USB

Currently, USB is enjoying considerable success in data acquisition. Such suppliers as Data Translation, IOtech, Keithley, Measurement Computing, and National Instruments offer data-acquisition units that plug into PCs' USB ports.

These mostly low-cost units are displacing PC plug-in boards, not only in laptop-based applications that offer no convenient way to use plug-in pc boards, but also in applications based on desktop PCs. Many of these USB-based data-acquisition modules consume such small amounts of power—0.5A or less at 5V dc—that they can draw all of their operating power from the bus, thereby avoiding the inconvenience of separate "wall-wart" power modules.

Not many higher performance USB-based instruments are likely to be frugal enough with power to do the same thing, however. Still, the small amount of power the bus makes available to USB devices doesn't explain the near-total absence of high-performance USB-based instruments that rely on host PCs for their controls and displays but that otherwise can replace traditional benchtop units. Although you can buy DSO- and logic-analyzer modules that rely on PCs for their user interfaces, few of them offer the performance of traditional benchtop instruments. Much more common are traditional instruments that, despite including full front-panel controls and displays, also incorporate USB ports for connection

ONE COMPANY'S APPROACH TO USB INSTRUMENTS

By Bob Rennard, Agilent Technologies

Agilent Technologies is the world's largest manufacturer of test-and-measurement instruments. The company is committed to basing the interfacing of its new instruments on PC-industry-standard I/O technology–specifically on USB and Ethernet. In devising a workable scheme for the USB connections, Agilent's designers had to resolve several issues. Table A and Figure A show the varieties of USB connectors and their main systems use.

In general, the capability an instrument provides depends on the instrument and when its manufacturer developed its platform. Agilent's newest products have both host and device connectors, because they offer different capabilities to serve different use models. These products have one USB 2.0 Type B (or Type Mini-B) socket on the back, through which users can control them using the USBTMC (USB test-and-measurement class)-USB488 protocol, which is essentially SCPI (standard commands for programmable instruments) over USB. These instruments may also have one or more USB 2.0 Type A sockets on the back, the front, or both, through which they can act as a host to accommodate other USB devices, such as a mouse, a keyboard, and a flash drive.

The new 6000 series scopes have both high-speed (nominally, 480-Mbps) USB-device and full-speed (nominally, 12-Mbps) USB-host capabilities. These scopes use standard A connectors for the host ports and standard B connectors for the device ports. A forthcoming PC-based product (not a scope) also offers full-speed USB host capabilities via USB A connectors, like those on PCs, as well as USB device-side capabilities via a standard B connector. Newer power supplies offer high-speed capabilities with standard B connectors.

Currently, Infiniium scopes have only USB-host ports, like those of PCs, using standard A connectors. If a PC-based Infiniium is running a program that controls other instruments over USB through its Type A ports, then–in theory–that program could be moved fairly seamlessly to an external PC and continue to control those other instruments over the PC's USB Type A ports.

Figure A USB connectors come in the three principal types pictured here and explained in **Table A**. Each type exists in plug and socket forms; plugs go on cables; sockets go on equipment. The connectors rely on friction to secure mated pairs (courtesy USB Implementers' Forum).

TABLE A USB-CONNECTOR TYPES

Connector type	Where found
Type A socket	Host or hub
Type A plug	Host/hub end of device cable
Type B plug	Device end of device cable
Type Mini-B plug	Device end of device cable
Type B socket	Device
Type Mini-B socket	Device (initially, digital cameras)

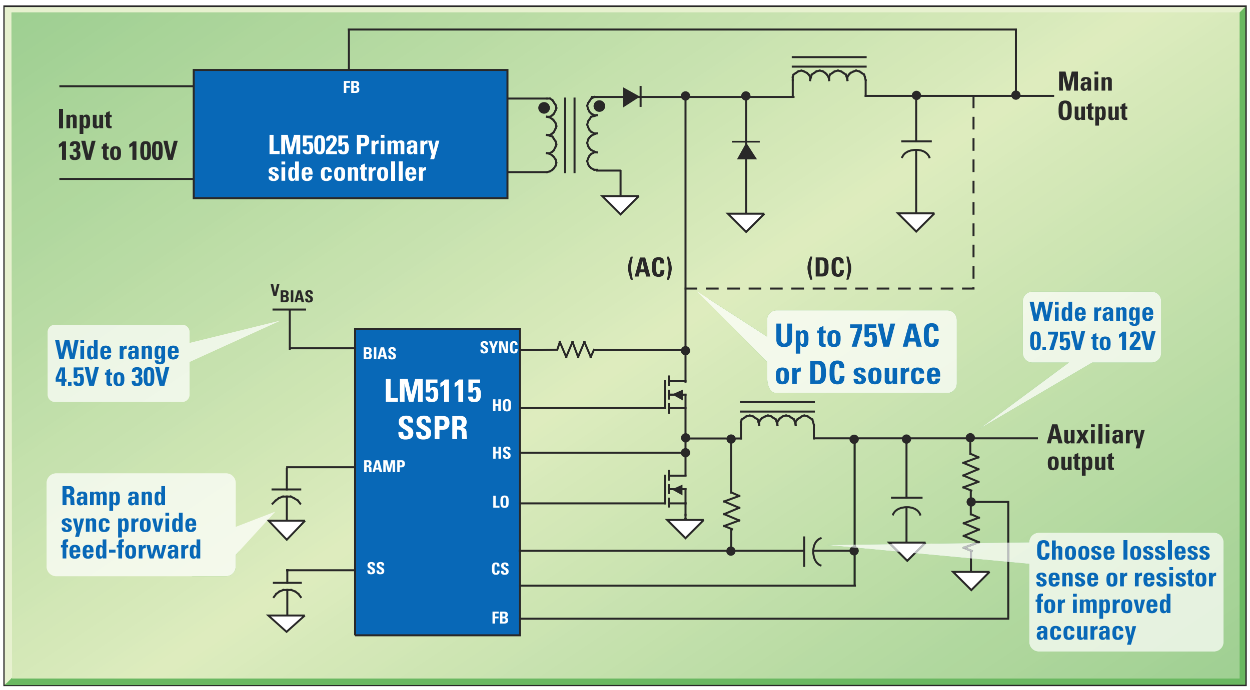
Note: Neither this table nor Figure A includes connectors used on devices and cables that conform to the USB OTG (On-the-Go) specification. At different times, depending on how they are configured, OTG devices can act as hosts or peripherals.

AUTHOR'S BIOGRAPHY

Bob Rennard is president of the LXI Consortium, which he co-founded, and is LXI Program Manager in Agilent Technologies' Electronic Products and Solutions Group. Besides an engineering degree, he holds a master's in business administration from Northwestern University (Evanston, IL). He has held a number of positions in Agilent's test-and-measurement business, including marketing manager for spectrum analyzers and signal generators.

Secondary-side post regulator (SSPR) doubles as high-voltage DC-DC controller

Feature-rich LM5115 controller simplifies design of multiple output DC-DC converters



LM5115 Features

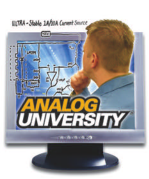
- Provides multiple outputs from main DC-DC or AC-DC converter
- Operates directly from secondary-side phase signal or DC input
- Leading-edge modulation for SSPR from current-mode primary controller
- Up to 1 MHz switching frequency reduces component footprint and profile
- Integrated gate drivers with 2.5A peak output current
- Available in TSSOP-16 and tiny LLP-16 packaging

Ideal for use as a secondary-side post regulator in the design of multiple output AC-DC or DC-DC power supplies or as a DC-DC controller for use in point-of-load (POL) regulators

Shown actual size

TSSOP-16
4.4 x 5.0 x 0.9 mm

LLP-16
5.0 x 5.0 x 0.8 mm



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into instrumentation systems.

It is worthwhile to ask why so few USB-based units that rely on PCs for their user interfaces perform functions more complex than those of data-acquisition boards. For example, National Instruments, the leading supplier of computer-based measurement products, hasn't yet offered USB-interfaced versions of its PXI 5660 and 5670 2.7-GHz RF signal analyzer and generator or its PXI 4071 7½-digit Flex DMM (digital multimeter). Such units would be usable outside of PXI systems. Clearly, NI is committed to PXI, a form factor and a market that it created and nurtured. However, if its customers were clamoring for equivalent instruments in a different form, the company would be likely to pursue the significant business opportunity. You have to conclude that, so far, few users have demanded such products.

Michael Lauterbach, PhD, director of product management for scope manufacturer LeCroy, offers a possible explanation. Says Lauterbach, "I've seen some excellent software emulations of scope front panels on PC monitors, but many users find that the realistic-looking 'knobs' that they can 'rotate' with a mouse and the buttons that they can 'push' in a similar manner aren't acceptable substitutes for real knobs that actually turn and buttons that travel in and out." Moreover, says Lauterbach, despite its 480-Mbps maximum data rate, USB 2.0 can't match the speed of the display adapters in several modern high-performance scopes. Designers developed some of these boards for video gaming, and they use 16-lane versions of PCI Express that transfer data at 32 Gbps, more than 66 times USB 2.0's theoretical maximum data rate.

Despite these arguments, representatives of National Instruments call USB 2.0 an attractive interface for many kinds of high-performance instruments. Although, like most other companies, NI maintains strict secrecy on new products that may or may not be under development, and NI personnel violated no company confidentiality rules when discussing this article with *EDN*, you have to wonder whether the company isn't simply waiting for an appropriate expression of customer interest to introduce more USB-based products.

ETHERNET AND LXI

USB is scarcely the only PC-standards-based instrument-interfacing game in town, however. The key competitor is the ubiquitous Ethernet, which has existed for approximately as long as IEEE 488 but continues to reinvent itself in versions that offer higher speed and, to a lesser extent, lower latency. As a progenitor of most of today's ultra-high-speed serial buses, Ethernet was decades ahead of its time in implementing a peer-to-peer architecture. And with 10- and 100-Mbps versions already widely deployed, a 1-Gbps version starting to make inroads, and a 10-Gbps version in the works, you can hardly discount Ethernet's speed. (IEEE 488 has also undergone revisions that have increased its speed, but not to the same degree as Ethernet. Still, IEEE 488 partisans point out that Ethernet's bandwidth increases haven't increased the speed of T&M applications as much as you might expect because most such applications transfer data packets smaller than those for which Ethernet is optimized.)

Ethernet's speed and longevity are only two of many factors that motivated the creation of the LXI (LAN extensions for instrumentation) Consortium. Ethernet is ubiquitous: In factories, in offices, and now even in some private homes, it is difficult to find a spot that is more than a few feet from an Ethernet LAN. With that ubiquity comes an unrivaled infrastructure.

LXI defines three classes of modular instruments, not surprisingly named A, B, and C (**Figure 1**). Somewhat counterintuitively, though, the most general and full-featured class is A, which provides more features than B, which, in turn, of-

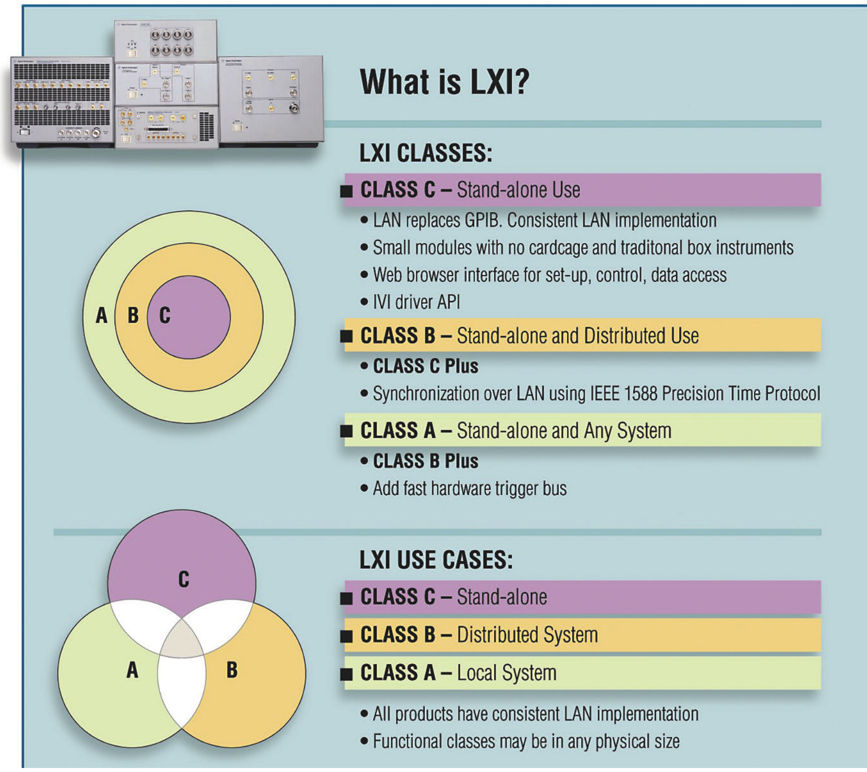
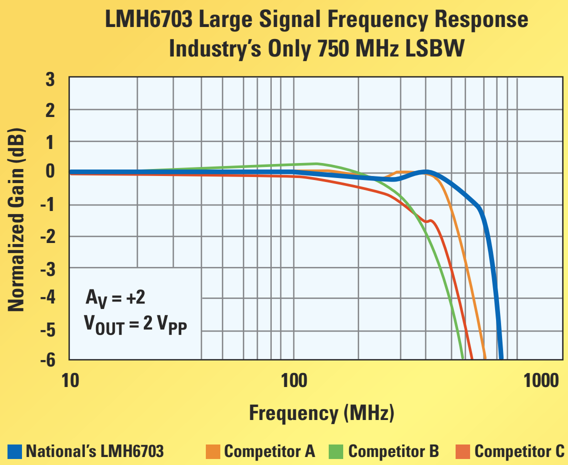
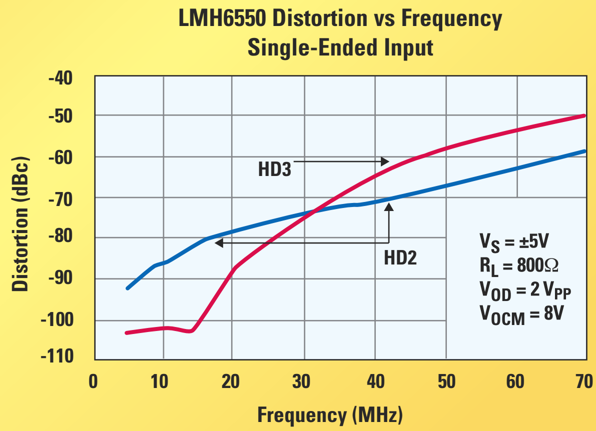


Figure 1 LXI instruments fall into three classes based on feature sets. Class C is the most basic; Class A is the most comprehensive. The photo at the top shows an LXI system comprising rack-and-stack instruments (courtesy Agilent Technologies).

National's LMH® High-Speed Amplifiers — Delivering Performance Where It Counts

Featuring Industry-Leading Speed with Low Power Consumption





High-Speed Amplifier Products

Product Number	Description	Features
LMH6702	Single, low distortion, wide bandwidth	1.7 GHz SSBW, 720 MHz LSBW, 2nd/3rd harmonic distortion (HD): -100/-96 dB at 5 MHz
LMH6703	Single, low distortion, wide bandwidth with shutdown	1.2 GHz SSBW, 750 MHz LSBW, 2nd/3rd HD: -87/-100 dB at 5 MHz
LMH6738	Triple amplifier with individual disable	750 MHz SSBW, 400 MHz LSBW, 3300 V/µs
LMH6704	Single, programmable gain (-1,+1,+2), shutdown	650 MHz SSBW, 400 LSBW, 2nd/3rd HD: -62/-78 dB at 10 MHz
LMH6739	Triple, programmable gain (-1, +1, +2), individual shutdown	750 MHz SSBW, 400 MHz LSBW, 3300 V/µs
LMH6570	Single 2:1 mux with shutdown	500 MHz SSBW, 2200 V/µs, -70 dB crosstalk, 400 MHz LSBW
LMH6572	Triple 2:1 mux with shutdown	350 MHz SSBW, 290 MHz, LSBW -90 dB crosstalk
LMH6574	Single 4:1 mux with shutdown	500 MHz SSBW, 2200 V/µs, -70 dB crosstalk, 400 MHz LSBW
LMH6550	Fully differential ADC/Video driver with disable	400 MHz SSBW, 1100 V/µs, 2nd/3rd HD: -78/-88 dB at 20 MHz
LMH6551	Fully differential ADC/Video driver	300 MHz SSBW, 800 V/µs, 2nd/3rd HD: -80/-95 at 5 MHz

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fers more features than the most basic class, C. If the consortium finds a need to create another class by adding features to A, it may have to modify its class-naming scheme.

A ROSE BY ANY OTHER NAME

The name LXI itself is both a blessing and—some would say—a curse. Its similarity to VXI and PXI immediately suggests modular instrumentation. Unfortunately, the name also fosters a misconception—at least on the part of neophytes—that LXI must be the successor to PXI, just as PXI was (more or less) the successor to VXI. However, LXI follows a design philosophy different from PXI's. Unlike with PXI, a (usually smaller) CompactPCI-based version of the VME-based VXI, LXI's developers designed it around a cabled bus—not around a card cage and backplane, such as those of PXI and VXI.

The name may or may not be responsible for another problem: difficulty in obtaining the wholehearted support of the largest modular-instrument manufacturer, National Instruments. NI officials understandably feel uneasy about endorsing any standard that they believe might threaten PXI. The odds favor the coexistence of PXI and LXI, with each addressing somewhat different market segments, albeit with substantial overlap between them. PXI appears better suited to manufacturing test. LXI may be better suited to R&D, although LXI's use of Ethernet, which can connect into networks of truly global extent, suggests uses in companies having design and manufacturing facilities on several continents. Moreover, LXI proponents are optimistic about the possibility of systems that combine LXI with PXI and VXI hardware. Nevertheless, NI's adoption of a wait-and-see attitude toward LXI—sending representatives to every consortium meeting, but so far not formally joining—means that consortium members may have to wait longer than they'd prefer to get a clear view of the road ahead.

Besides the use of Ethernet, LXI's most obvious difference from PXI is in packaging. PXI modules work only in card cages, which use a backplane to interconnect multiple modules. The card cages, which are available with varying numbers of module slots, also contain power supplies and cooling facilities and house a slot-zero card. Usually, a PXI slot-zero card is a modular embedded PC that includes a system board and a hard drive. However, some PXI slot-zero cards lack PC capabilities and connect to external PCs—usually, standard desktop units, which cost less and usually offer more advanced features than those of modular PCs.

These National Instruments RF modules are representative of CompactPCI-based PXI's modular architecture. The modules require a card cage that includes power supplies and cooling facilities. Each cage must also include a slot-zero module. Many slot-zero modules are full-featured embedded PCs.

LXI systems, on the other hand, will be based on standard PCs and modules that communicate via a cabled bus rather than a card-cage backplane (though LXI may soon allow attaching PXI and VXI cages as modules on the cabled bus). The LXI FAQ (**Reference 2**) refers to modules with integral power supplies, but these supplies need not operate directly from the ac line. Modules may draw their primary power—most likely, approximately 48V dc—from a supply that serves multiple modules or from the LAN itself through its new POE (power-over-Ethernet) features (**Reference 3**). POE provides as much as 12.95W to each powered device. A new specification, POE+, still in its formative stages, may triple the available power.

MANY SIZES AND SHAPES

It is possible to implement LXI modules of many sizes. Although the FAQ suggests that developers will design most modules as system components and not as rack-and-stack instruments, "modules" can, in fact, be ac-line-powered, full-rack-width units, whose heights are multiples of the standard $1\frac{3}{4}$-in. increment. These modules can have front-panel controls and displays that function just as do those of rack-and-stack instruments. In other words, the modules can be rack-and-stack instruments in every sense of the words. They can even include USB and IEEE 488 interfaces as long as they also include a rear-panel-mounted RJ-45 Ethernet connector.

The mere presence of an Ethernet connector does not guarantee LXI compatibility, however. LXI also imposes requirements on how conforming modules use Ethernet to communicate. As for the RJ-45-connector location, the current requirement is that it be on the module's rear surface and that connections to the DUT (device under test) be on the front.

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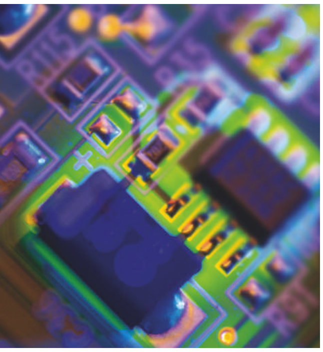

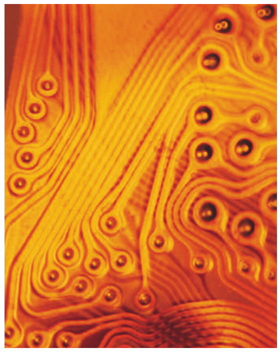

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The consortium is currently discussing whether the RJ-45 connector must be on the rear or whether other locations might also be acceptable; the rear-panel requirement is a sticking point for modular-instrumentation systems, such as PXI. Allowing the connector on the front could qualify PXI and VXI card cages containing appropriate slot-zero cards running appropriate software as LXI modules.

Among the issues that LXI addresses is discovery: determining just which instruments are connected to the network when you apply power to a system. This phase of LXI operation is one of the few for which LXI has drawn upon a T&M industry standard. The consortium's philosophy is to avoid specialized standards and protocols wherever possible and to take advantage of standards with broad computer-industry support, because, in the words of the LXI FAQ, "More engineers work on LAN alone than [work] in the entire test-and-measurement industry." In the case of discovery, however, the LXI Consortium selected a specialized LAN protocol curiously named VXI-11—not because of any connection with VXI hardware or protocols, but because it originated with the VXI Consortium.

PEACEFUL COEXISTENCE

The LXI Consortium hasn't specified the LAN protocols to be used for transferring acquired data from instruments to the host. Apparently, different consortium members are committed to different protocols, and the consortium concluded that all of these protocols could coexist peacefully within a system. The consortium did specify that each LXI device must present an interactive HTML page on which users can specify the device's application-specific operating parameters but allowed the code that generates this page to reside either in the device or in the host.

For triggering and synchronization, the consortium drew on IEEE 1588, a protocol that depends on time-tagging of events. Consortium members believe that 1588 will enable synchronization of events to within approximately 50 nsec—maybe less with extraordinary care. Although such numbers are impressive considering the cable lengths involved in LANs, they don't approach the degree of simultaneity achievable in much smaller systems, such as VXI and PXI. So the consortium added a provision for an LVDS (low-voltage-differential-signaling) trigger bus in LXI Class A devices. Instruments that reside in the same equipment rack should be able to use this bus, which will provide closer synchronization than is possible with 1588.

One of the visions for LXI is that the standard will enable test-equipmen man-

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POWERpuzzler #4

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Designing for Efficiency?

by Peter Vaughan
Manager of Product Applications
Power Integrations

Take a break from your daily routine and test your power supply design knowledge by answering the three questions below regarding new mandatory energy efficiency requirements. Check your answers at ***www.powerint.com/puzzler4*** and enter for a chance to win a new Apple iPod Mini.

Question 1: beginner

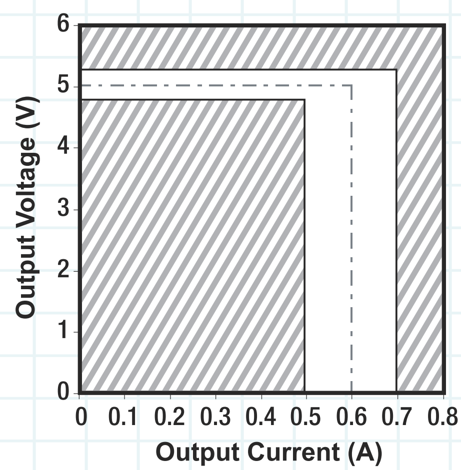
Recent energy efficiency regulations set minimum standards for the efficiency and no-load power consumption of certain AC-DC and AC-AC power supplies. In China and Europe, minimum energy efficiency targets are already in place and in several U.S. states, regulations are becoming mandatory. The California Energy Commission (CEC) has set mandatory requirements for external power supplies (EPS) sold in California from July 2006. Which of the following is true? CEC requires that:

a. EPS rated at under 10 W should consume less than 0.5 W under no-load conditions
b. EPS rated at 10 W to 250 W should consume less than 0.75 W under no-load conditions
c. An Active Mode minimum efficiency must be met, based upon the average of the efficiencies at 25%, 50%, 75% and 100% load
d. All of the above

(Hint: visit *www.powerint.com/greenroom*)

Question 2 : advanced

A 3 W, 5 V CV/CC charger requires the characteristics as shown:

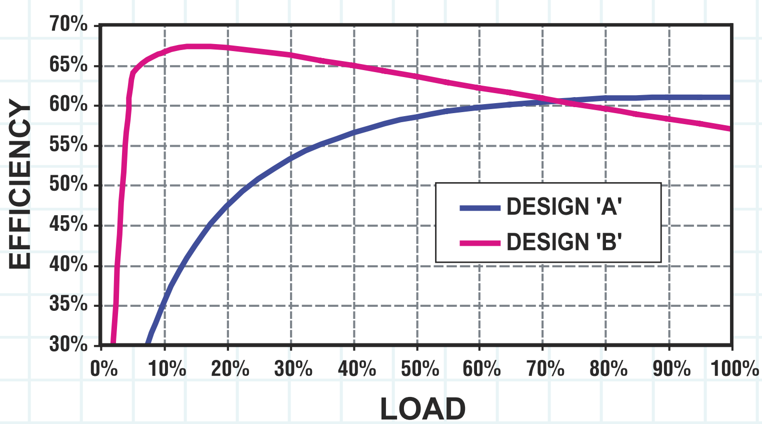


Which is the best choice of power supply to meet CEC no-load requirements and why?

a. A linear transformer with an IC linear post regulator
b. A Switched Mode Power Supply (SMPS) designed using discrete components, with a characteristic of increasing frequency at light loads
c. An SMPS designed using an IC that operates at a fixed frequency
d. An SMPS designed using an IC with a characteristic of decreasing frequency at light loads

Question 3 : expert

The CEC Active Mode minimum efficiency requirement for a 3 W, 5 V output EPS is 58.9%. CEC also requires less than 500 mW no-load consumption at this rated output power level.



For your 3 W, 5 V CEC-compliant charger, two designs points, 'A' and 'B', are being considered, with efficiency versus load characteristics as shown in the figure. Which would be a better choice to meet the CEC requirements and why?

a. DESIGN 'A': an SMPS with 450 mW no-load consumption and 100% load efficiency of 61%

b. DESIGN 'B': an SMPS with 30 mW no-load consumption and 100% load efficiency of 57%

*The answers to these questions can be found at **www.powerint.com/puzzler4**. Check out how well you did and enter to win an Apple iPod Mini!*

ufacturers to create otherwise-identical instruments that will be available in two forms: with front panels that are blank except for DUT connections and with front panels that contain controls and displays as well as DUT connections. The first type is intended for system applications, whereas the second is for stand-alone operation. Consortium President Bob Rennard believes that this flexibility can help to reduce instrument prices by allowing test-equipment manufacturers to allocate instrument-design costs to larger numbers of units.

Not surprisingly, cost is at the heart of many discussions of modular instruments. Some in the industry say that formats, such as PXI, which require the use of backplanes and common power supplies, are inherently more expensive than rack-and-stack configurations. To rebut that assertion, NI has produced examples of PXI systems that cost less than equivalent rack-and-stack systems. Meanwhile, Agilent has developed examples that show just the opposite. Rennard says that most real-world systems use instruments in multiple formats and that system integrators therefore demand cross-platform interoperability, which the LXI Consortium is working hard to ensure. **EDN**

FOR MORE INFORMATION

INSTRUMENT MANUFACTURERS:

Aeroflex Inc
www.aeroflex.com

Agilent Technologies
www.agilent.com

Data Translation Inc
www.datx.com

Geotest
www.geotestinc.com

Hyperlabs Inc
www.hyperlabsinc.com

IOtech Inc
www.iotech.com

Keithley Instruments
www.keithley.com

LeCroy Corp
www.lecroy.com

Measurement Computing Corp
www.measurementcomputing.com

National Instruments
www.ni.com

VXI Technology Inc
www.vxitech.com

INDUSTRY ORGANIZATIONS:

Interchangeable Virtual Instrument Foundation
www.ivifoundation.org

LXI Consortium
www.lxistandard.org

USB Implementers Forum Inc
www.usb.org

VXI Consortium
www.vxi.org

VXI Plug and Play Systems Alliance
www.vxipnp.org

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AUTHOR'S BIOGRAPHY

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RAQ's

Rarely Asked Questions

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Slow "starting" ADCs (or the beneficial effects of in diagnosing converter problems)

Q. *To save power, my ADC is powered up only to make a measurement. The system is very accurate in continuous operation, but completely unpredictable when power is strobed.*

A. As a by product of the security-obsessed Soviet system, Russians can be very reluctant to provide all the details of an applications problem. Alexei, whom I met at a seminar in Novosibirsk in Siberia, was no exception. He complained that his ADC (analog-to-digital converter) was badly out of specification and sometimes did not work at all, but was reluctant to provide details of his system. So I provided some vodka, caviar and blinis, and we toasted Mother Russia, Catherine the Great, the Trans-Siberian Express, and analog engineers everywhere. He loosened up and revealed that he was only powering his ADC for just long enough to do a conversion and then shutting it down again.

Microprocessors reset with each start, but few ADCs do, so after power-up their logic is randomized. The first conversion (or in some pipelined converters the one when the initial data exits the pipeline) resets the logic, but the first results may be totally wrong.

Furthermore, not only the data output is affected. The EOC (end of conversion) or "busy" output may also be confused—if this output is used to initiate the next conversion, the system may not self-start on power-up. If such latch-up always occurs, the problem will be recognized during system design, but if it only occurs occasionally (as with the original ADC84 in the 1970s) the problem can be overlooked—with dire results.

Data converters should perform one or more "dummy" conversions after power-up before the conversion results are actually used. During these "dummy" conversions the output data, and anomalous behavior of EOC or other logic outputs, should be ignored by the system.

Such problems rarely occur in converters with "sleep" circuitry where the supply is still present but the device is switched to a low consumption standby mode for power saving.

Logic is not the only possible cause of start-up errors in converters. Thermal stabilization, capacitance charging, and slow starting of regenerative current mirrors can all degrade reference accuracy for many milliseconds after power-up.

Alexei programmed some dummy conversions and I boarded the Trans-Siberian Express for Vladivostok leaving a working system, and a happy, if over fed, engineer behind me.

To learn more about behavioral problems in ADCs & how to avoid them

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http://rbi.ims.ca/4394-504

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

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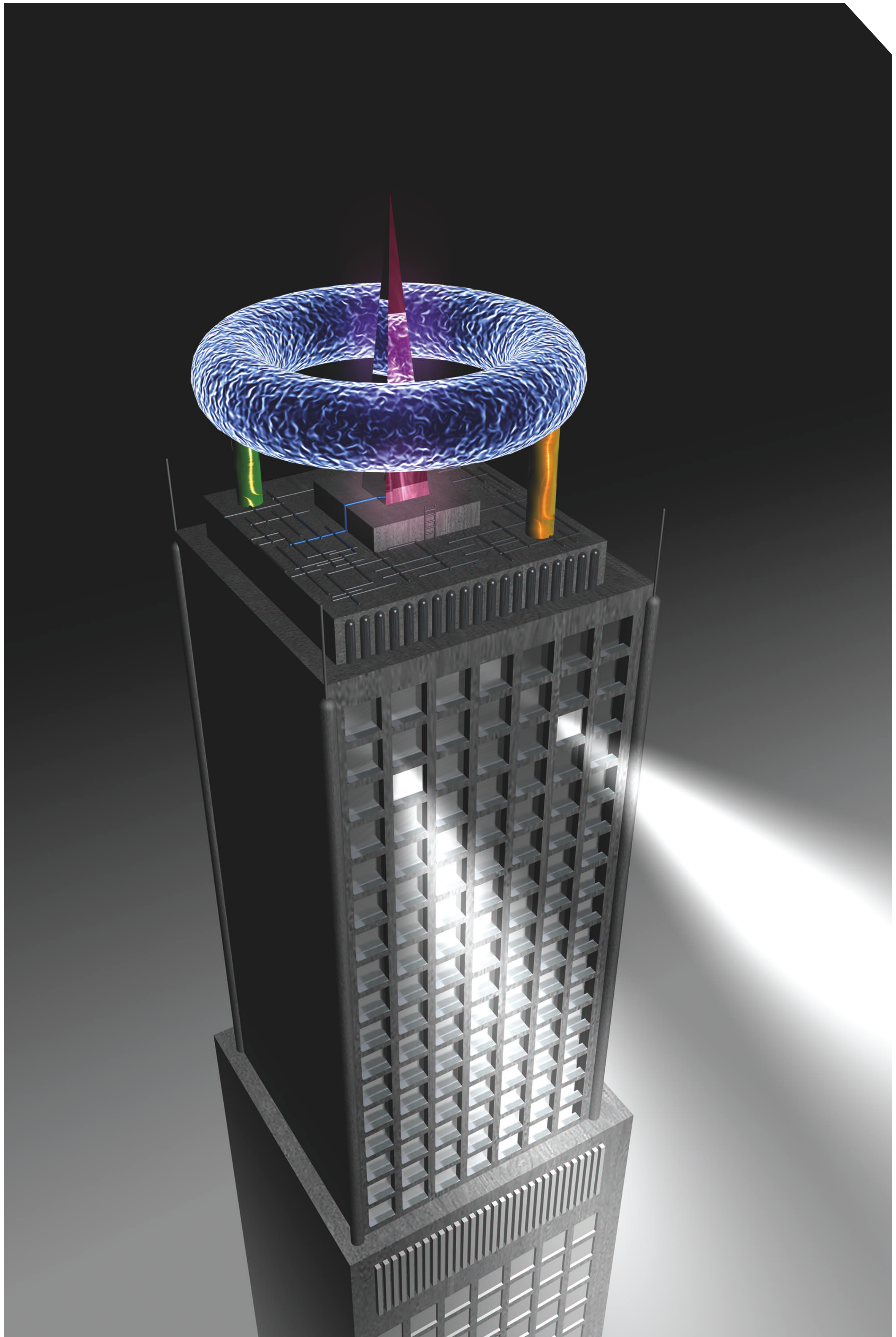

STUCK IN A HIGHLY FRAGMENTED INDUSTRY, BUILDING-AUTOMATION DESIGNERS ARE FORMULATING NEW INITIATIVES TO PROVIDE INTEROPERABILITY, SIMPLIFY MANAGEMENT, CONSERVE ENERGY, PROVIDE SECURITY, AND REDUCE COSTS.

BY WARREN WEBB • TECHNICAL EDITOR

Thinking inside the box: Buildings get a brain

Although engineers have envisioned and implemented many *Jetsons*-like conveniences throughout the home, factory, and office, most end users are reluctant to pay extra for the hardware and software necessary to simplify mundane tasks. For example, subsystems to enable voice controls, automatically feed the pets, or create lighting or entertainment scenes when you walk through the door are available today, yet they appeal to only a small audience. In areas having high consumer interest, such as security or energy conservation, the lack of compatible products makes it difficult to devise a fully integrated system. Recognizing these industry problems, product manufacturers have proposed new initiatives, updated standards, and revised communications protocols that promise to accelerate the acceptance of smart-building technology.

Smart-building technology relies on distributed sensors, remotely controllable actuators, device networking, and decision-making software to coordinate and optimize building subsystems, such as those for security, the environment, information transfer, and safety. In a truly integrated building-automation system, any subsystem may use components and sensors. For example, an open window is important to both the security subsystem and the heating or air-conditioning function. Likewise, temperature sensors could detect a fire or signal the need for routine maintenance. Unlike today's stand-alone building systems, this type of data reuse requires components and subsystems that share and store sensor information.

Distributed sensors are vital to collecting the information that smart environments require. You can divide sensors into physical, motion, force, and biochemical categories. Physical sensors make pressure, temperature, and humidity measurements, and motion sensors record position, velocity, and acceleration. Force sensors indicate strain, torque, and vibration. The biochemical category includes everything from reactive agents to personal-identification items, such as fingerprints, voice analysis, and retinal scans. The biggest challenges to distributed sensors are transforming the measurement into a common format, efficiently transferring the data, and reducing the power required at each node.

SMART SENSORS

The National Institute for Standards and Technology and the IEEE in 1993 began work on the distributed-sensor problem with a proposed family of standards entitled "A Smart Transducer Interface for Sensors and Actuators." The objective of these standards is to provide interchangeability among manufacturers, ensure that all transducers connect to

AT A GLANCE

- Smart-building systems rely on networked sensors, remotely controlled actuators, and decision-making software.
- Although extravagant building-automation devices are possible, most end users are reluctant to pay extra for convenience-only items.
- Wireless links, power-line communications, and Ethernet cabling permit building systems to share data without new wiring.
- The added cost and diversity of systems have slowed the adoption of automatic building-interoperability standards.
- Web-services technology allows incompatible automatic-building systems to exchange data and enable remote operation.

control networks in the same way, and promote self-identifying, -configuring, and -calibrating sensors. The first standard in the family, IEEE 1451.2, defines the interface between the transducer hardware, called the STIM (smart-transducer-interface module), and the NCAP (network-capable application processor), or network controller (**Figure 1**). Manufacturers simply implement sensor circuitry for the STIM side of the 1451.2 interface and then choose a network controller depending on the application. Although the NIST and the IEEE in 1997 first approved the standard, industry adoption has been slow. Several changes, including the addition of alternate physical layers to use existing, widely available data-transfer methods to reduce sensor cost and complexity, are under way.

Another approach to the distributed-sensor problem is to piggyback on the TCP/IP networks now present in most buildings for data exchange. The OASIS (Organization for the Advancement of Structured Information Standards) has proposed an initiative to define XML (eXtensible Markup Language) and Web-services-based mechanisms for building control systems. The OASIS oBIX (Open Building Information Exchange) Technical Committee is working to define a standard Web-services protocol to enable communications between building mechanical and electrical systems and enterprise applications. Because oBIX integrates with enterprises, it will allow continuous visibility of mechanical- and electrical-control systems and will identify problems and trends for system analysis or human interaction. The scope of oBIX is to develop a Web-services-interface specification to simply and securely obtain data from HVAC, access control, utilities, and other building-automation systems. The oBIX approach has the advantage of operating with legacy mechanical and electrical subsystems.

Although not at the sensor level, many modern building subsystems interconnect with established but incompatible communications protocols, such as LonWorks, BACnet (Building Automation and Control Network), and ModBus, in addition to numerous proprietary protocols. Although these building-automation networking protocols operate over TCP/IP networks, they lack the sophistication to deal with enterprise routers, firewalls, security, and application traffic. BACnet is the common term for the ANSI/ASHRAE Standard 135-2001, which ANSI (American National Standards Institute) and the ASHRAE (American Society of Heating Refrigeration and Air-Conditioning Engineers) support. BACnet is a nonproprietary, open-protocol communication standard that represents data in terms of "objects," "properties," and "services." This standard method of representing data and actions enables devices from different manufacturers to interoperate; however, most BACnet devices are limited to the heating, ventilating, and air-conditioning industry. For example, the Mach-Vision from Reliable Controls is a programmable user interface for direct digital-control applications. This BACnet-certified device features a Basiclike program language, five reconfigurable inputs, four scalable outputs, and closed-loop capability (**Figure 2**).

PROTOCOL CHIP

Unlike BACnet, LonWorks requires the use of a proprietary Neuron chip from Echelon Corp in each controller. LonWorks finds use mainly in the lighting, utilities, and transportation industries and has more automated building installations than BACnet. The LonWorks protocol provides a set of services that allow device application software to send and receive messages over the network without needing to know the topology of the network or the names, addresses, or functions of other devices. The LonWorks protocol can optionally provide end-to-end acknowledgment of messages, authentication of messages, and priority delivery for real-time applications.

The ModBus protocol is an open-messaging structure that Modicon developed in 1979; it establishes master-slave/client-server communication between devices. ModBus originated as a standard

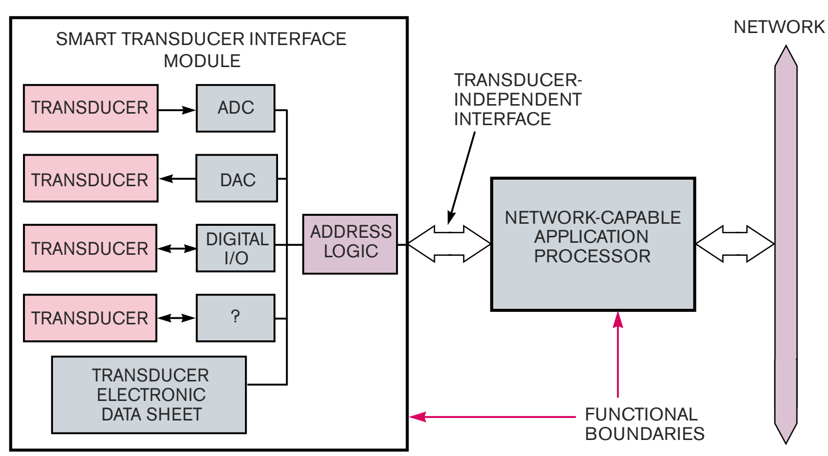

Figure 1 IEEE 1451.2 defines the interface between smart sensors or actuators, signal-conditioning circuitry, and the network controller.

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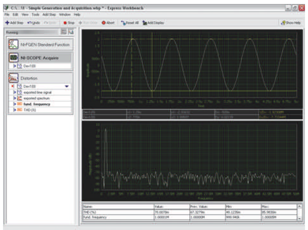

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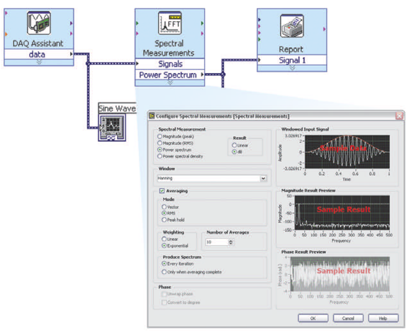

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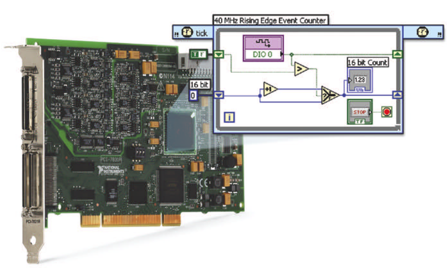

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for programmable-logic controllers to access simple integer and binary values. The protocol is well-understood and finds wide use across many industries. Its main strengths are its simplicity and its ease of implementation in low-level devices. ModBus is the standard in power metering, UPS, and generators. Ken Crater, president of the ModBus Suppliers and Users Association, says, "Straightforward protocols such as ModBus are easier and faster to code, apply, and troubleshoot than more complex protocols. This [approach] reduces cost and helps companies move more quickly in their markets." You can freely download the ModBus specification from the Internet, and a number of open-source implementations of the protocol are available.

Because of the large number of sensors that a smart-building environment employs, designers prefer networking schemes that require no installation of new interconnecting cables. Wireless links, power-line communications, and even telephone-line sharing are viable alternatives that eliminate new wiring. For example, Echelon's PL3120 and PL3150 power-line smart transceivers enable LonWorks-compatible products to communicate over a building's electrical network (**Figure 3**). The transceivers include an 8-bit Neuron processor core for running applications and managing network communications. A dual-carrier feature automatically selects a second frequency if noise is blocking the signal. The transceivers are available in a $345 Mini EVK (evaluation kit) allowing designers to experiment with smart light switches, thermostats, and other simple devices and sensors using power-line communications.

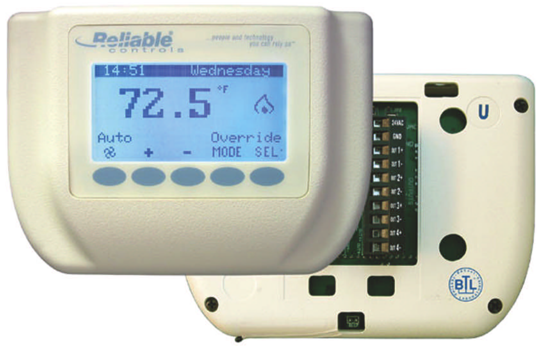

Figure 2 The Mach-Vision, a programmable user interface from Reliable Controls, communicates using the BACnet (Building Automation and Control Network) Protocol.

Wireless networks with extremely low power consumption are ideal for many smart-building-sensor applications. To meet this need, the IEEE in May 2003 ratified the 802.15.4 standard for ultra-low-power, low-data-rate networks operating in the unlicensed-frequency bands. The standard defines the PHY (physical layer) and MAC (medium-access-control) sublayer specifications for low-rate devices communicating at 20 kbps in the 868-MHz band, 40 kbps in the 915-MHz band, and 250 kbps in the 2.4-GHz band.

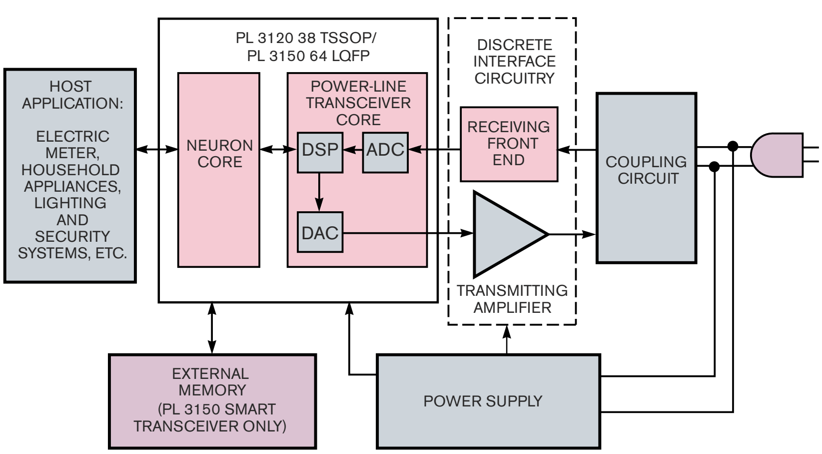

Figure 3 Echelon's smart power-line transceivers enable LonWorks-compatible products to communicate over a building's electrical network.

Networks may be in star or peer-to-peer topologies and include addressing for more than 65,000 nodes. Transmitters use DSSS (direct-sequence spread spectrum) with BPSK (binary phase-shift keying) in the sub-GHz bands and O-QPSK (offset-quadrature phase-shift keying) at 2.4 GHz. The standard provides for 16 channels in the 2.4-GHz band, 10 channels in the 915-MHz band, and one channel in the 868-MHz band. The channel-access method is CSMA-CA (carrier-sense multiple access with collision avoidance). The specification describes two types of network nodes: an FFD (full-function device) that can perform any network duties and an RFD (reduced-function device) with limited resources and functions for cost-sensitive applications.

ZIGBEE NETWORKS

IEEE 802.15.4 defined a global standard for the PHY and MAC layers, and the ZigBee Alliance defined the remaining network, security, and application layers for the low-rate, low-power wireless specification. The ZigBee-defined network layer is responsible for device discovery and network configuration. ZigBee allows star and mesh topologies along with a combination of the two—cluster-tree networks. Each network must have at least one FFD, or coordinator, to provide initialization, node-management, and node-information storage. To minimize cost and power consumption, the remaining nodes can be the simple, battery-operated RFDs. Designers can use ZigBee networks with several data-transmission schemes. For periodic data, such as with wireless sensors, nodes wake up at set times, transmit sampled data to the coordinator, and go back to sleep. A light switch delivers intermittent data and may connect and communicate with the network only when someone activates it. Repetitive data applications, such as real-time-control systems, may use ZigBee's guaranteed-time-slot capability to ensure communications without latency or contention. These network-layer data-delivery strategies allow system designers to trade communications frequency for battery life in RFD nodes. Low duty cycles allow nodes with coin-type bat-

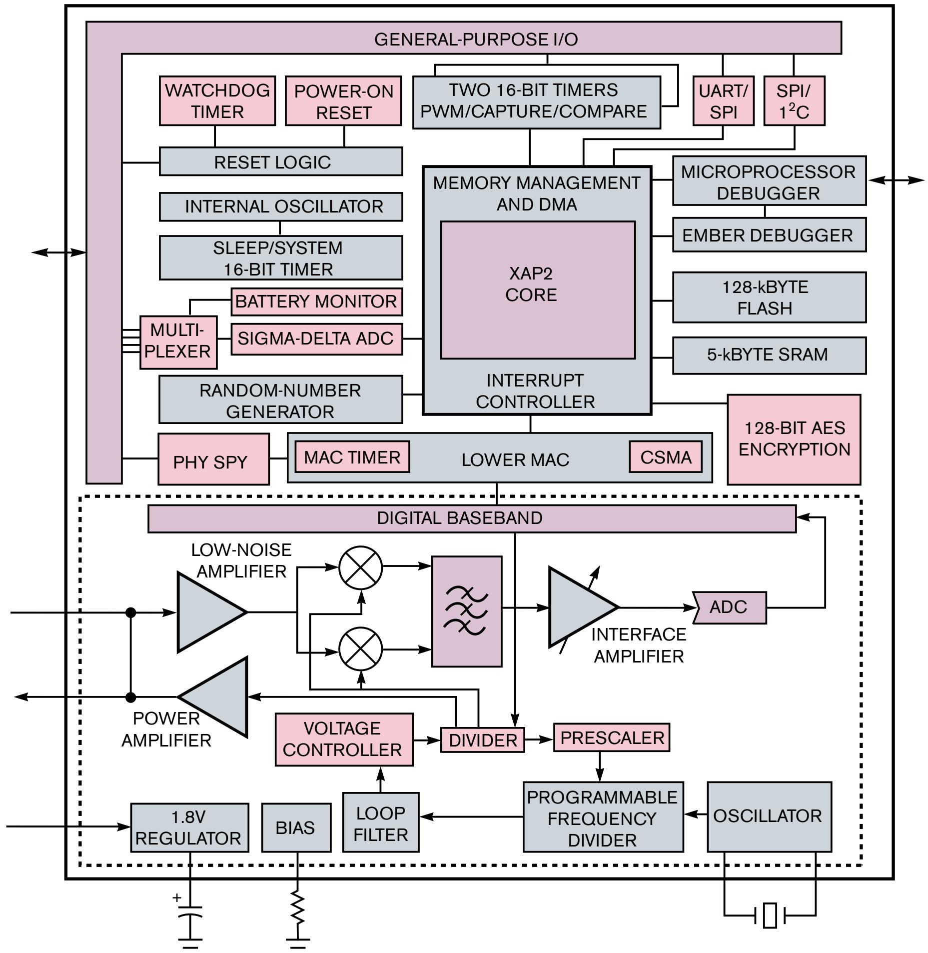

Figure 4 The EM250 ZigBee system on chip combines a 2.4-GHz, IEEE 802.15.4-compliant radio transceiver with a 16-bit microprocessor.

teries to remain operational for years.

With the huge number of sensor nodes that a typical smart-building environment requires, cost becomes critical. Designers can cut costs by removing functions and limiting compatibility with external systems. Juan Alvarez, MSP430 microcontroller-marketing manager for advanced embedded controls at Texas Instruments, says, "Customers want both low cost and low power in sensor networks. A fully compliant ZigBee device requires 40 kbytes of flash memory and 5 kbytes of RAM. That can be expensive in a simple node that may be dormant 95% of the time and wake up only periodically to transmit short bursts of data. Although full functionality in ZigBee makes sense for interoperability, low cost may be a greater need."

Attacking the high cost of ZigBee-compatible nodes, Ember recently announced the EM250, a true ZigBee system on chip that combines a 2.4-GHz, IEEE 802.15.4-compliant radio transceiver with a 16-bit microprocessor (**Figure 4**). For use with EmberZNet, Ember's latest ZigBee-compliant embedded mesh-networking software, the EM250 targets designs requiring long battery life, low external-component count, and an industry-standard networking protocol. The EM250's integrated microprocessor operates at 12 MHz and includes 128 kbytes of flash and 5 kbytes of RAM to accommodate user applications based on the EmberZNet networking library. The EM250's deep-sleep mode requires less than 1 μA, even with the sleep timer running. For applications requiring extended range, Ember also provides an easy method of connecting an external amplifier. The Ember EM250 costs less than $4 per unit in high volumes. Venkat Bahl, Ember's vice president of marketing, says, "The ability to market Ember-enabled products with the official ZigBee-compliant designation will bring the same kind of market acceptance and excitement that WiFi [Wireless Fidelity] certification brought to wireless-LAN vendors."

WEB CONNECT

Automated Logic has adopted Internet technology in its WebCtrl (Web-based building-control) system. With its native BACnet architecture and support for ModBus and LonWorks, WebCtrl integrates building-subsystem information with information-technology protocols (**Figure 5**). WebCtrl's standard Web-services interface uses SOAP (Simple Object Access Protocol) and XML technology for cross-platform data sharing with other computer systems. Steve Tom, director of technical information at Automated Logic, says, "XML provides a standard method for a building-automation system to communicate with another computer, whether that computer is in another building system or a completely different application. Today, building-automation manufacturers are adding XML support into their Web servers and operator workstations because it is the standard for com-

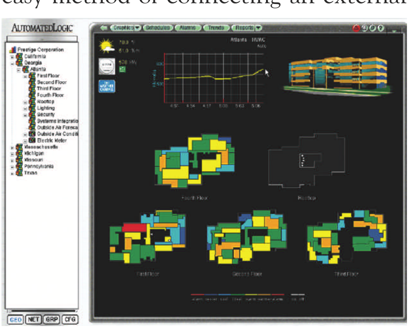

Figure 5 WebCtrl, Automated Logic's Web-based building-control system, uses SOAP/XML technology for cross-platform data sharing.

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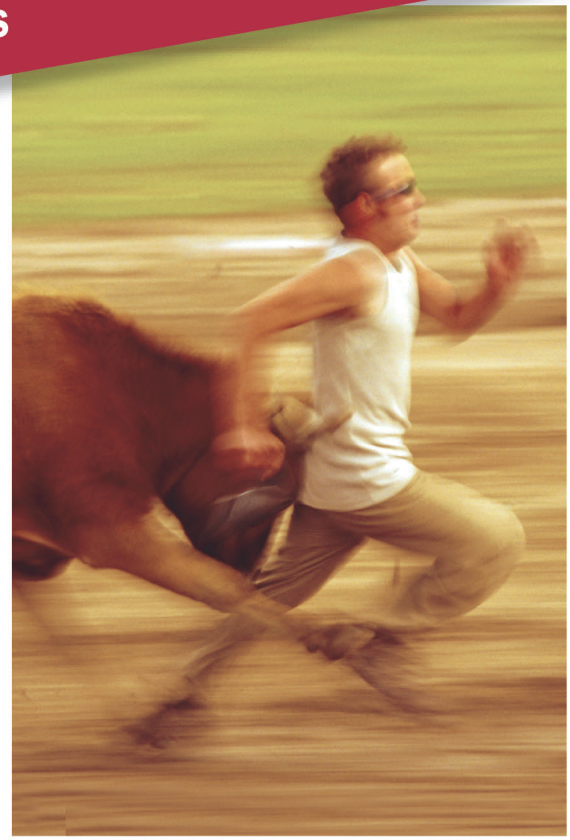
Intersil High Speed Op Amps

Intersil High Performance Analog

Need More Analog Speed?

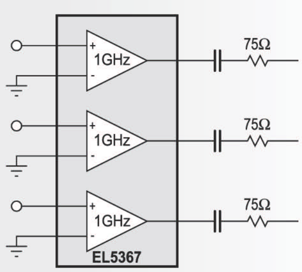
Intersil offers a wide portfolio of High Speed Op Amps, including the industry's first Triple 1GHz Current Feedback, the industry's fastest Amplifier in an SC-70 package, and a Voltage Feedback with over 700MHz of available bandwidth.

Datasheet, free samples, and more information available at **www.intersil.com/edn**



World's Fastest and Only Triple 1GHz Current Feedback Amplifier

- Handles ultra-high resolution video with room to spare
- 1GHz gain of 1 bandwidth
- 800MHz gain of 2 bandwidth into a 150Ω load
- 6000V/μs typical slew rate
- 8.5mA per channel supply current



Part No.	BW (MHz)	SR (V/μs)	I_S (mA)	Av (min) (V)	I_{OUT} (mA)	V_{OUT} (V)
EL5360	200	1700	0.75	1	70	±3.4
EL5362	500	2500	1.5	1	100	±3.6
EL5364	600	4200	3.5	1	140	±3.8
EL5367	1000	6000	8.5	1	160	±3.8

Read more about the "Best Video Op Amp" in analogZONE's 2004 Products of the Year awards at www.analogzone.com

World's Fastest Amplifier in a Tiny SC-70 Package

Get blazing speed in a tiny package. The EL5167 allows you to significantly reduce board size by packing 1.4GHz performance in an SC-70 package. The EL5167 is the smallest and fastest high speed amplifier available with a scant 9mA power consumption.

- 1.4GHz bandwidth
- 6000V/μs slew rate
- Less than 9mA power consumption

Part No.	# of Amps	BW (MHz)	SR (V/μs)	I_S (mA)	Av (min) (V)	I_{OUT} (mA)	V_{OUT} (V)	V_{OS} (max) (V)
EL5160/1	1	200	1700	0.75	1	70	±3.4	5
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

Get Current Feedback Performance with Voltage Feedback Control

Intersil's EL5104 eliminates that nasty tradeoff between ease of use, DC accuracy, and pure speed. We've pushed the usability scale up to and above 700MHz with virtually unlimited slew rate, almost zero overshoot, and low power consumption. Ground-breaking EL5X0X family of Voltage Feedback Amplifiers provides unmatched AC performance in this architecture. Use in place of any current feedback amplifier.

- Virtually unlimited slew rate
- 700MHz gain of 1 bandwidth
- Almost zero overshoot
- Low power consumption

Part No.	# of Amps	BW (MHz)	SR (V/μs)	V_N (nV/√Hz)	I_S (mA)	I_{OUT} (mA)	V_{OUT} (V)	V_{OS} (max) (V)
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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HIGH PERFORMANCE ANALOG

municating with other systems at that level." (See **Reference 1**.) XML data exchange allows maintenance-management systems, accounting systems, wide-area utility-management programs, and other high-level computer applications to use the standard enterprise tools to retrieve information from WebCtrl. It also means these tools can write data to WebCtrl, so building-control applications can use weather forecasts, real-time energy pricing, and other external factors as integral parts of building-control applications.

Smart-building technology will eventually become part of the pervasive computing movement in which computer interactions are natural and unstructured (**Reference 2**). Until then, Web technology seems to be the best approach for bringing together the highly fragmented building-automation industry. Internet protocols and Web services allow incompatible systems to share data and integrate into the enterprise information-technology structure. EDN

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1 Tom, Steve, "The ABC's of XML for BAS," www.automatedlogic.com/alcinternet.nsf/webview/news_white_papers.

2 Cook, DJ and DK Sajal, *Smart Environments: Technology, Protocols, and Applications*, Wiley-Interscience, 2005.

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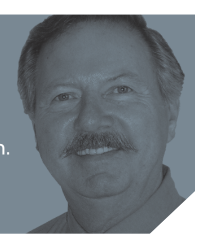

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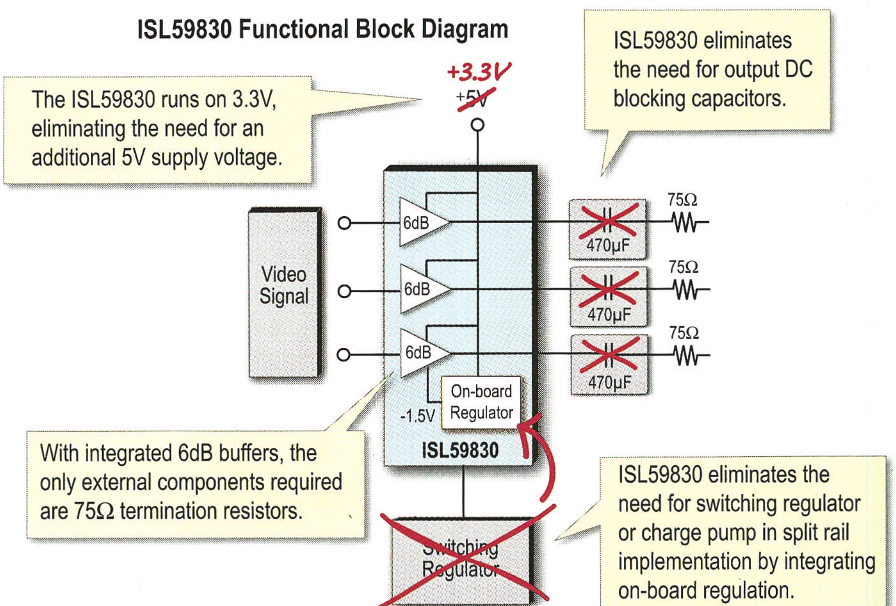
Eliminate Extra Voltage Supply with Integrated Triple +3.3V Video Buffer

The ISL59830 triple video buffer delivers DC-accurate coupling of video onto a 75Ω double-terminated line, and 300MHz of -3dB bandwidth performance.

Available in Pb-Free Package

ISL59830 Functional Block Diagram



Key Features:

- Triple single-supply buffer
- Operates from single +3.3V supply
- Eliminates need for DC blocking capacitors
- Fixed gain of 2 output buffer
- Output 3-statable
- Enable/disable functions
- 50MHz 0.1dB bandwidth
- 300MHz -3dB bandwidth

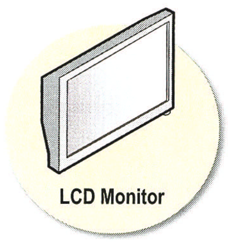
Video Amplifiers - Rail-to-Rail

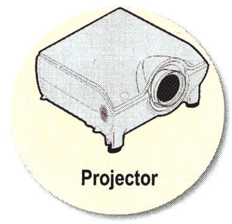
Device	# of Amps	BW @ -3dB (MHz)	SR (V/µs)	V_S (V)	V_N (nV√Hz)	Rail-to-Rail	Gain A_V (min) (V)	I_S (mA)	I_{BIAS} (mA)	I_{OUT} (mA)	V_{OUT} (V)	V_{OS} (max)(mV)	Package
EL8100	1	200	200	3.3 to 5	20	Out	1	2	1.5	80	0.1 to 4.9	6	6 Ld SOT-23, 8 Ld SOIC, 8 Ld SOT-23
EL8101	1	200	200	3.3 to 5	20	Out	1	2	1.5	80	0.1 to 4.9	6	5 Ld SOT-23
EL8102	1	500	600	3.3 to 5	12	Out	1	5.6	6	150	0.1 to 4.9	8	6 Ld SOT-23, 8 Ld SOIC
EL8103	1	500	600	3.3 to 5	12	Out	1	5.6	6	150	0.1 to 4.9	8	5 Ld SOT-23
EL8200	2	200	200	3.3 to 5	20	Out	1	2	1.5	65	0.1 to 4.9	6	10 Ld MSOP
EL8201	2	200	200	3.3 to 5	20	Out	1	2	1.5	80	0.1 to 4.9	6	8 Ld SOIC
EL8202	2	500	600	3.3 to 5	12	Out	1	5.6	6	65	0.1 to 4.9	8	10 Ld MSOP
EL8203	2	500	600	3.3 to 5	12	Out	1	5.6	6	150	0.1 to 4.9	8	8 Ld MSOP, 8 Ld SOIC
EL8300	3	200	200	3.3 to 5	20	Out	1	2	1.5	80	0.1 to 4.9	6	16 Ld QSOP, 16 Ld SOIC
EL8302	3	500	600	3.3 to 5	15	Out	1	6	6	150	0.1 to 4.9	8	16 Ld QSOP, 16 Ld SOIC
EL8401	4	200	200	3.3 to 5	20	Out	1	2	1.5	80	0.1 to 4.9	8	14 Ld SOIC, 16 Ld QSOP
EL8403	4	500	600	3.3 to 5	12	Out	1	5.6	6	65	0.1 to 4.9	8	14 Ld SOIC, 16 Ld QSOP
ISL59830	3	200	500	3.0 to 3.6	20	Y	2	50	N/A	50/-18	-1.8 to 3.3	25	16 Ld QSOP

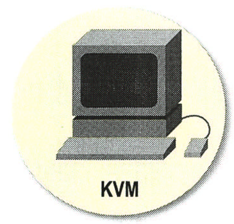
World's Only QXGA Capable Video Analog Front End

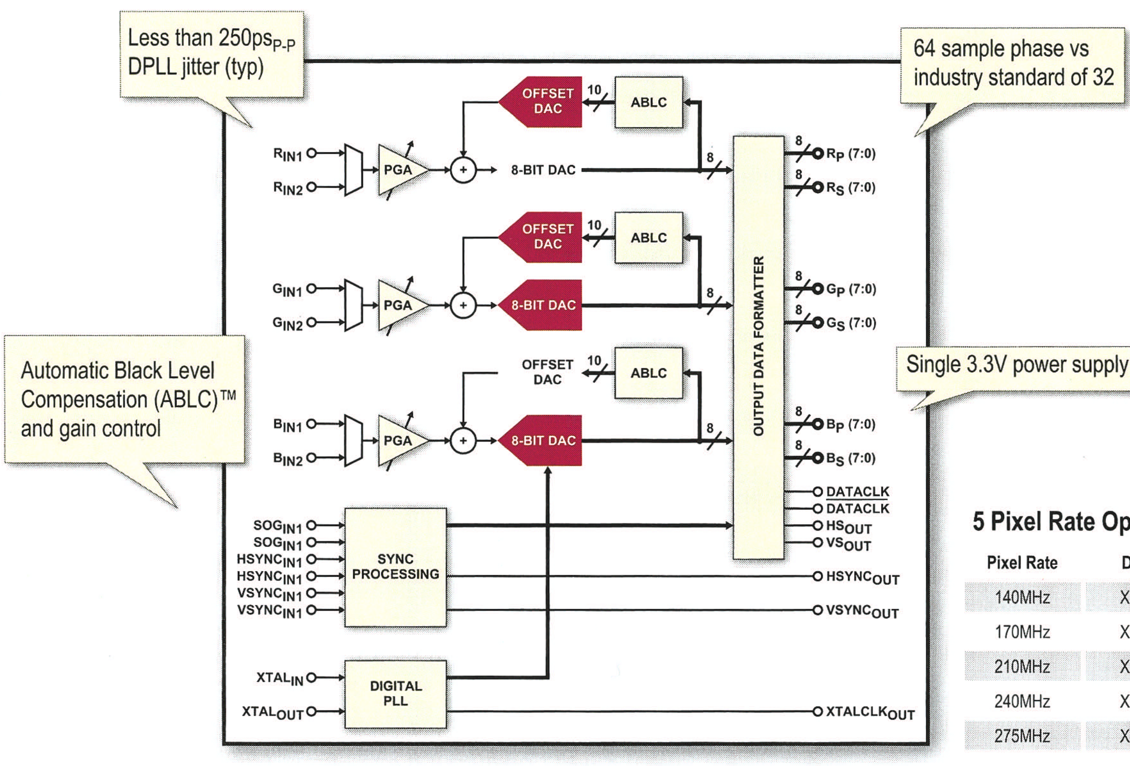
X98027 Digitizes at 275MSPS

Available in Pb-Free Package









5 Pixel Rate Options

Pixel Rate	Device
140MHz	X98014
170MHz	X98017
210MHz	X98021
240MHz	X98024
275MHz	X98027

Analog Front Ends

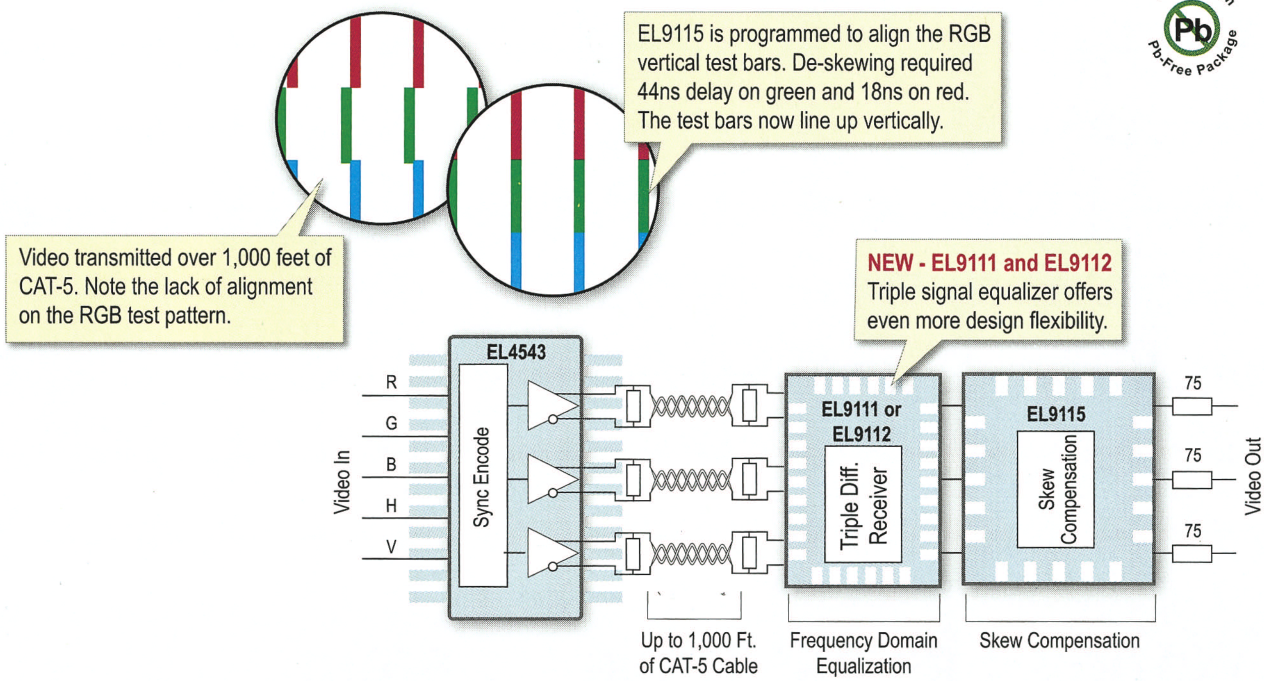
Device	Resolution (bits)	Max Conversion Rate (MSPS)	Typical PLL Jitter (ps) (p-p)	Sample Phase Choices	Programmable Input Bandwidth (MHz)	CSYNC and SOG Support	Typical Power Dissipation @ Max Conversion Range (mW)	Package
X98014*	8	140	250	64	100 to 780	X	990	128 Ld MQFP
X98017*	8	170	250	64	100 to 780	X	1030	128 Ld MQFP
X98021*	8	210	250	64	100 to 780	X	1090	128 Ld MQFP
X98024*	8	240	250	64	100 to 780	X	1150	128 Ld MQFP
X98027*	8	275	250	64	100 to 780	X	1180	128 Ld MQFP

* New Product

World's Only Programmable Triple Analog Delay Line

Intersil's EL9115 compensates skew introduced by CAT-5 cable, enabling high-quality video through 1,000 feet of cheap twisted pair cable.

Available in Pb-Free Package



CAT-5 Video Line

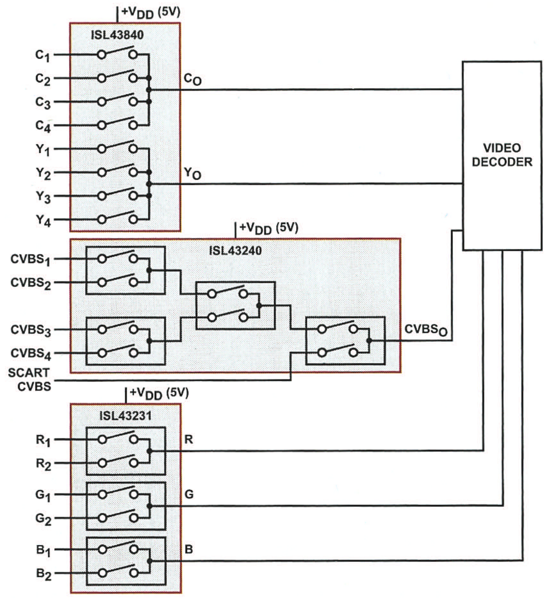
Device	Device Description	BW @ -3dB (MHz)	SR (V/µs)	Gain A_V (min)(V)	I_S (mA)	I_{OUT} (mA)	Package
EL4543*	Triple Differential Twisted-Pair Driver with Embedded Sync Encoding	350	1200	2	13	60	24 Ld QSOP
EL5170	Single 100MHz Differential Twisted-Pair Driver	100	1100	2 (fixed)	7	80	8 Ld MSOP, 8 Ld SOIC
EL5171	Single 250MHz Differential Twisted-Pair Driver	250	800	1	7	90	8 Ld MSOP, 8 Ld SOIC
EL5172	Single 250MHz Differential Line Receiver, Single Output Amplifier	250	800	1	6	95	8 Ld MSOP, 8 Ld SOIC
EL5173	Single 450MHz Differential Twisted-Pair Driver	450	900	2 (fixed)	12	55	8 Ld MSOP, 8 Ld SOIC
EL5174	Single 550MHz Differential Twisted-Pair Driver	550	1100	1	12	60	8 Ld SOIC
EL5175	Single 550MHz Differential Line Receiver, Single Output Amplifier	550	622	1	10	60	8 Ld MSOP, 8 Ld SOIC
EL5176	Single 250MHz Differential Twisted-Pair Driver with Enable	250	775	1	7	40	10 Ld MSOP
EL5177	Single 550MHz Differential Twisted-Pair Driver with Enable	550	1100	1	12	50	10 Ld MSOP
EL5370	Triple 100MHz Differential Twisted-Pair Driver, Fixed Gain Amplifier	100	1200	2 (fixed)	7	85	24 Ld QSOP
EL5371	Triple 250MHz Differential Twisted-Pair Driver, Fixed Gain Amplifier	250	700	1	7	70	28 Ld QSOP
EL5372	Triple 250MHz Differential Twisted-Pair Receiver	250	800	1	5	95	24 Ld QSOP
EL5373	Triple 450MHz Differential Twisted-Pair Driver, Fixed Gain Amplifier	450	1100	2 (fixed)	12	55	24 Ld QSOP
EL5374	Triple 550MHz Differential Twisted-Pair Driver, Fixed Gain Amplifier	550	850	1	12	60	28 Ld QSOP
EL5375*	Triple 550MHz Differential Line Receiver, Single Output Amplifier	550	900	1	10	60	24 Ld QSOP
EL9110	Differential Receiver (5 pole) and Equalizer	150	1500	1	30	60	16 Ld QSOP
EL9111*	Triple Differential Receiver/Equalizer with Embedded Sync Decoding	150	1200	1	30/channel	60	28 Ld QFN
EL9112*	Triple Differential Receiver/Equalizer	150	1200	1	30/channel	60	28 Ld QFN
EL9115	Triple Analog Video Delay Line	100	800	1	60	90	20 Ld QFN

* New Product

Dual 4:1/Triple 2:1/Quad 2:1 Switches

The ISL43231, ISL43240, and ISL43840 analog switches select between various analog sources including Composite Video Broadcast Signals (CVBS), S-Video (Y/C), and Component Video (RGB).

Available in Pb-Free Package



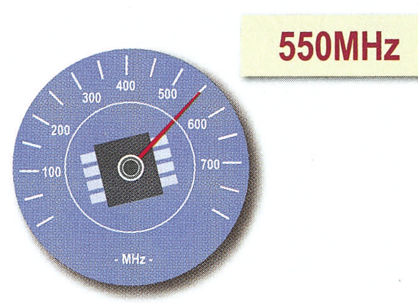
Allow selection and isolation between video sources with minimal signal degradation and crosstalk.

Key Features:

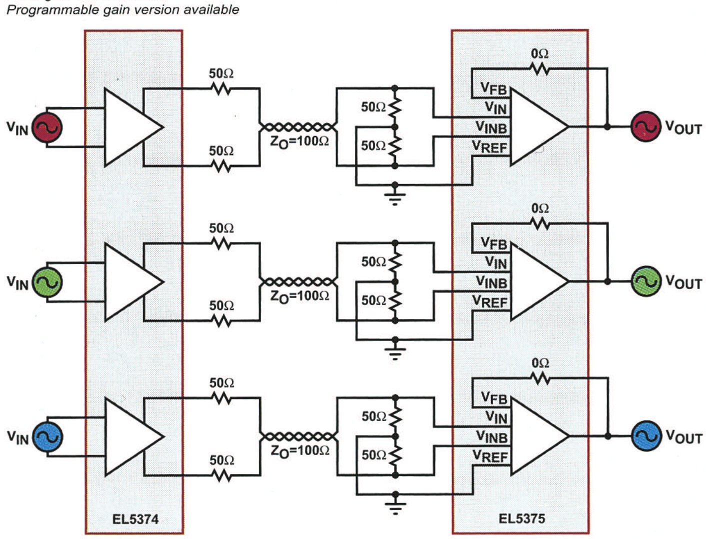
- >150MHz bandwidth
- >60dB crosstalk at 10MHz
- Fast switching times
- Single supply operation
- Pb-free available
- QFN packaging

World's Fastest Triple Differential Driver

The EL5374 monolithically drives RGB signals over CAT-5 and the EL5375 receives these signals for high resolution video.



Fixed gain version shown
Programmable gain version available



Receiver feedback resistors are external

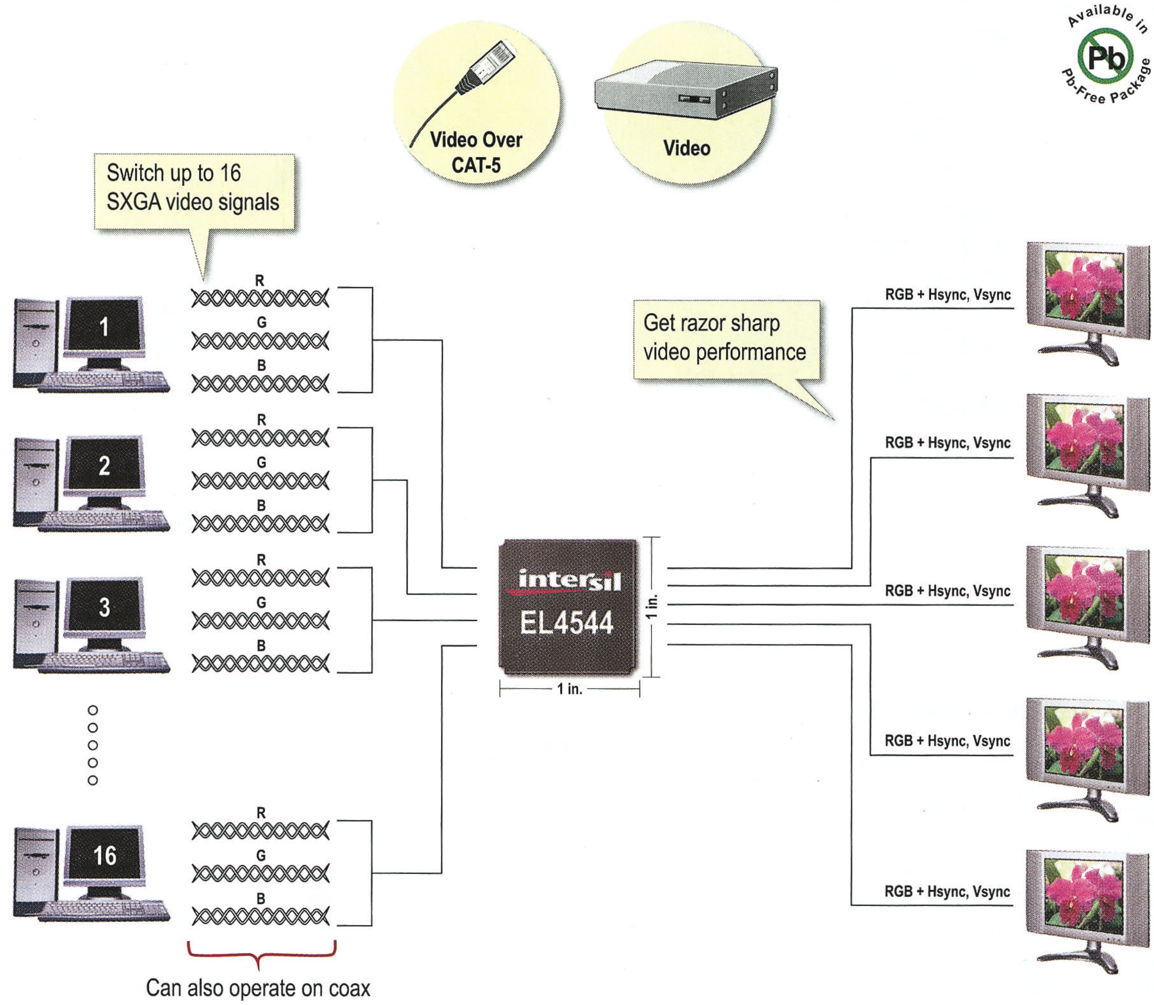
Key Features:

- Fully differential inputs, outputs, and feedback
- Differential input range ±2.3V
- 550MHz 3dB bandwidth
- 1100V/µs slew rate
- Low distortion at 5MHz
- Single 5V or dual ±5V supplies
- 60mA maximum output current
- Low power - 12.5mA per channel

Industry's First Fully-Integrated 16x5 RGB Video Crosspoint Solution

Intersil's EL4544 with video sync extraction and pixel-by-pixel overlay for on-screen display.

Available in Pb-Free Package



Video Crosspoints

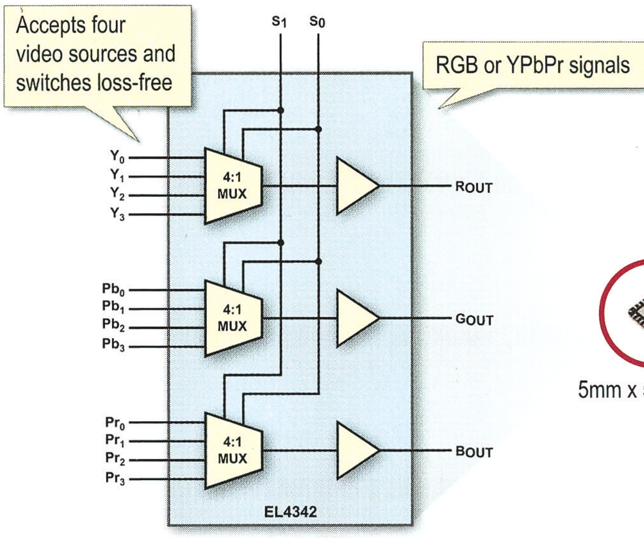
Device	Switch or MUX	Configuration	BW @ -3dB (MHz)	Slew Rate (V/µs)	I_S (V)	Gain A_V (min) (V)	I_{OUT} (mA)	Diff Gain (%)	Diff Phase (°)	Package
EL4544	MUX	Buffered Triple 16x5	300	1000	400	1 to 4	60	0.05	0.05	356 Ld BGA

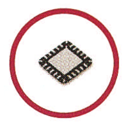
Device	Switch or MUX	Configuration	$r_{DS(ON)}$ (Ω)	$T_{(ON)}$ (ns)	$T_{(OFF)}$ (ns)	Leakage (nA)	SRC Cap (pF)	DRN Cap (ON) (pF)	I_{CC} (A)	V_{CC} Range (±V)	Package
HA456	XPT	Buffered 8x8	0.25	185	30	1600	2.5	2.9	68m	±4.5 to ±5.5	44 Ld PLCC
HA4314B	MUX	Buffered 4x1	15	160	320	30000	1.5	2.5	10.5m	±4.5 to ±5.5	14 Ld PDIP, 14 Ld SOIC, 16 Ld QSOP
HA4344B	MUX	Buffered 4x1	15	160	320	30000	1.5	2.5	10.5m	±4.5 to ±5.5	16 Ld SOIC
HA4404B	MUX	Buffered 4x1	15	160	320	30000	1.5	2.5	10.5m	±4.5 to ±5.5	16 Ld SOIC

Device	Configuration	$r_{DS(ON)}$ (Ω)	Freq. Response Typ. -3dB 14V (MHz)	Crosstalk Typ. -40dB 14V (MHz)	V_{CC} Range (±V)	Package
CD22M3494	Unbuffered 16 x 8 x 1	36	45	3	4V to 15V	40 Ld PDIP, 44 Ld PLCC

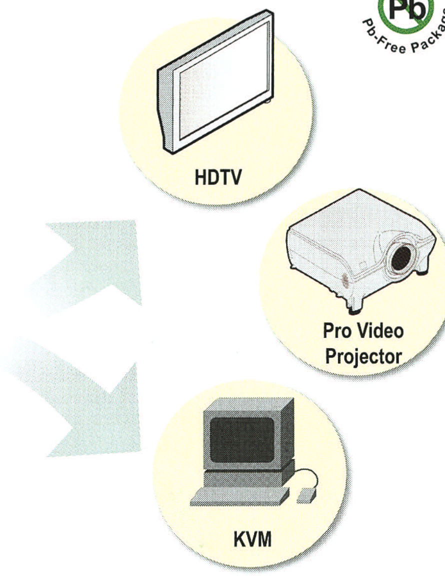
First Quad Component Video MUX

EL4342 Triple 4 x 1 Video MUX





5mm x 5mm QFN



Available in Pb-Free Package

Key Features:

- Set to gain-of-1 (fixed)
- High-speed 3-state outputs
- Power-down mode
- ±5V operation
- 500MHz -3dB bandwidth
- Low supply current of 16mA/channel
- QFN (5mm x 5mm) packaging

Video MUXes with Integrated Op Amps

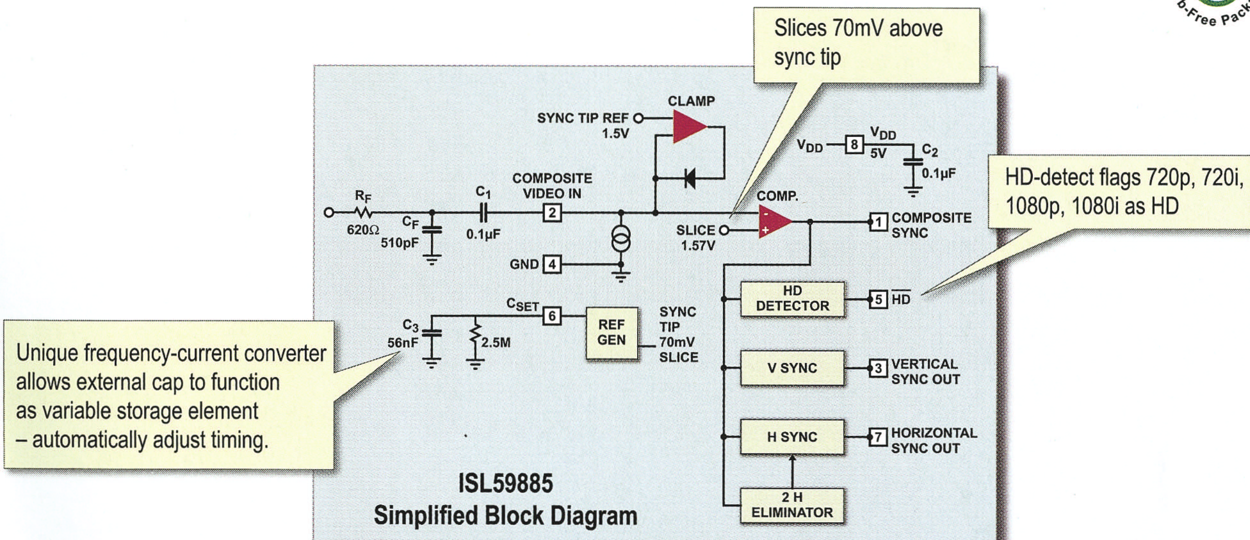
Device	Configuration	BW @ -3dB (MHz)	SR (V/μs)	I_S (V)	Gain A_V (min) (V)	I_{OUT} (mA)	Diff Gain (%)	Diff Phase (°)	Package
ISL59420*	2 to 1	500	900	5	1	100	0.05	0.05	10 Ld MSOP
ISL59440*	4 to 1	500	900	7	1	100	0.05	0.05	16 Ld QSOP
ISL59421*	2 to 1	1000	1500	10	1	100	0.05	0.05	10 Ld MSOP
ISL59441*	4 to 1	1000	1500	14	1	100	0.05	0.05	16 Ld QSOP
EL4340*	Triple 2 to 1	500	900	11	1	100	0.05	0.05	24 Ld QSOP
EL4342*	Triple 4 to 1	500	900	16	1	100	0.05	0.05	32 Ld QFN
ISL59424*	Triple 2 to 1	1000	1500	22	1	100	0.05	0.05	24 Ld QFN
ISL59445*	Triple 4 to 1	1000	1500	32	1	100	0.05	0.05	32 Ld QFN

Switches

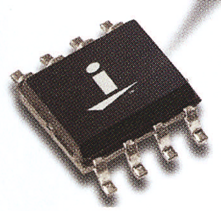
Device	Configuration	R_{ON} @ 5V (Ω)	$T_{(ON)}$ (ns)	$T_{(OFF)}$ (ns)	BW @ -3dB (MHz)	Off Cap (pF)	On Cap (pF)	I_S (μA)	V_S (V)	Package
ISL43110	Single NO	11	37	21	220	15	40	0.05	+2.4 to +12	5 Ld SOT-23, 8 Ld SOIC
ISL84514	Single NO	13	47	28	220	14	30	2 (Max)	+2.4 to +12	5 Ld SOT, 8 Ld SOIC
ISL43144	Quad NO	18	52	40	330	10	34	0.01	+2 to +12, ±2 to ±6	16 Ld QFN, 16 Ld TSSOP
ISL8392	Quad NO	20	60	30	330	12	34	0.01	+2 to +12, ±2 to ±6	16 Ld SOIC
ISL43210	Single 2x1	19	25	17	500	8	28	0.05	+2.7 to +12	6 Ld SOT-23
ISL43231	Triple 2x1	81	32	18	250	3	14	0.1	+2 to +12, ±2 to ±6	20 Ld QFN
ISL84053	Triple 2x1	125	50	40	250	3	14	0.1	+2 to +12, ±2 to ±6	16 Ld QSOP, 16 Ld SOIC
ISL43240	Quad 2x1	30	52	40	330	10	30	0.01	+2 to +12, ±2 to ±6	20 Ld QFN, 20 Ld SSOP
ISL8394	Quad 2x1	25	50	30	330	12	39	0.01	+2 to +12, ±2 to ±6	20 Ld SOIC
ISL43640	Single 4 x1	115	25	24	350	4	20	0.0001	+2 to +12	10 Ld MSOP, 16 Ld QFN
ISL43840	Dual 4x1	81	32	18	250	3	18	0.1	+2 to +12, ±2 to ±6	20 Ld QFN
ISL43841	Dual 4x1	81	32	18	250	3	18	0.1	+2 to +12, ±2 to ±6	20 Ld QFN
ISL43741	Diff 4x1	81	32	18	280	3	18	0.1	+2 to +12, ±2 to ±6	20 Ld QFN
ISL43681	Single 8x1	81	32	18	250	3	26	0.1	+2 to +12, ±2 to ±6	20 Ld QFN

* New Product

Auto-Adjusting HDTV Sync Separator Saves Board Space



ISL59885 Simplified Block Diagram



Key Features:

- The ISL59885's auto line rate adjust eliminates the need for an external network of R-C blocks and a switch to select a particular block from a particular frequency.
- Very little performance variation over 200°C temperature range.
- Composite sync output is simply a reproduction of the input signal with the active video removed.
- Vertical sync pulse is output during the start of the vertical cycle of the incoming video signal.
- Horizontal sync out allows better genlocking than verticals sync-based genlocks. Horizontal output pulses are inhibited until 75% of the line time is reached, then the horizontal output operation is enabled again.

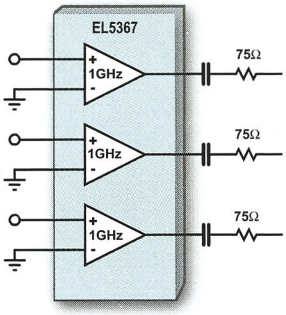
Video Sync Separators

Device	Slicing		Color Burst Filter		Outputs						Composite Prop Delay (ns)	Supply Current (mA)	Package
	Fixed (70mV)	Input Adaptive	Internal	External	Composite	Horizontal	Vertical	Burst	Odd/ Even	Sync Amplitude			
EL1881	X	-	-	X	X	-	X	X	X	-	30	1.2	8 Ld PDIP, 8 Ld SOIC
EL1883*	X	-	-	X	X	X	X	X	-	-	30	1.2	8 Ld SOIC
ISL59885*	X	X	-	X	X	X	X	-	-	-	30	2.2	8 Ld SOIC
EL4511	-	X	Variable	-	X	X	X	X	X	X	-	2.1	24 Ld QSOP
EL4501		X	Variable		X	X	X	X	X	X	225	10.5	24 Ld QSOP
EL4581	-	X	Fixed	-	X	-	X	X	X	-	260	1.7	8 Ld PDIP, 8 Ld SOIC
EL4583	-	X	Variable	-	X	X	X	X	X	X	250	2.5	16 Ld PDIP, 16 Ld SOIC

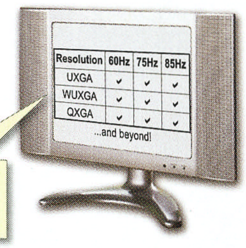
* New Product

World's Fastest Triple Current Feedback Amp

Drive QUXGA with one device



Named **"Best Video Op Amp"** in 2004 by analogZONE.



Support all existing resolutions with slew rates ~5000V/µs.

Video Amplifiers - High Speed (>50MHz)

	Device	# of Amps	BW @ -3dB (MHz)	Slew Rate (V/µs)	V_S (min) (V)	V_S (max) (V)	V_N (nV/√Hz)	Gain A_V (min) (V)	I_S (per amp) (mA)	I_{OUT} (mA)	V_{OUT} (V)	V_{OS} (max) (mV)
Current Feedback	EL5160, EL5161	1	200	1700	±2.5	±5.5	4	1	0.75	70	±3.4	5
	EL5260, EL5261	2	200	2000	±2.25	±6.6	4	1	0.75	70	±3.4	5
	EL5360	3	200	1700	±2.25	±6.3	4	1	0.75	70	±3.4	5
	EL5162, EL5163	1	500	4000	±2.5	±5.5	3	1	1.5	100	±3.6	5
	EL5262, EL5263	2	500	2500	±2.25	±6.6	3	1	1.5	100	±3.6	5
	EL5362	3	500	2500	±2.25	±6.3	3	1	1.5	100	±3.6	5
	EL5462	4	500	4000	±2.5	±5.5	3	1	1.5	100	±3.75	1.5
	EL5164, EL5165	1	600	4700	±2.5	±5.5	2.1	1	3.5	140	±3.8	3.5
	EL5364	3	600	4200	±2.25	±6.3	2	1	3.5	140	±3.8	5
	EL5191	1	1000	2800	±2.25	±5.5	3.8	1	9	120	±3.7	15
	EL5367	3	1000	5000	±2.25	±5.5	1.7	1	8.5	160	±3.8	5
	EL5166	1	1400	6000	±2.5	±5.5	1.7	1	8.5	160	±3.8	5
Voltage Feedback	EL5170	1	100	1100	±2.25	±6.0	28	2 (Fixed)	7	80	±3.3	25
	EL5370	3	100	1200	±2.25	±6.0	28	2 (Fixed)	7	85	±3.8	25
	EL5100, EL5101	1	200	2200	±2.25	±6.6	10	1	2.5	100	±3.4	4
	EL5300	3	200	2200	±2.25	±6.6	10	1	2.5	100	±3.4	4
	EL5371	3	250	700	±2.25	±6.0	26	1	7	70	±3.7	25
	EL5372	3	250	800	±2.25	±6.6	26	1	5	95	±3.6	25
	EL5106	1	350	4500	±2.25	±6.6	12	±1, 2 (Fixed)	1.5	125	±3.6	10
	EL5306	3	350	4500	±2.25	±6.6	12	±1, 2 (Fixed)	1.5	125	±3.6	10
	EL5102, EL5103	1	400	2200	±2.25	±6.6	6	1	5.2	150	±3.7	5
	EL5202, EL5203	2	400	2200	±2.5	±6.6	6	1	5.2	150	±3.9	5
	EL5302	3	400	2200	±2.25	±6.6	6	1	5.2	150	±3.7	5
	EL5173	1	450	900	±2.25	±6.0	25	2 (Fixed)	12	55	±3.6	30
	EL5108	1	450	4500	±2.25	±6.6	8	±1, 2 (Fixed)	3.5	135	±3.8	5
	EL5373	3	450	1100	±2.25	±6.0	25	2 (Fixed)	12	55	±3.6	30
	EL5308	3	450	4500	±2.25	±6.6	10	±1, 2 (Fixed)	3.5	135	±3.8	5
	EL5374	3	550	850	±2.25	±6.0	21	1	12	60	±3.8	25
	EL5375	3	550	900	±2.25	±6.6	21	1	10	60	±3.8	16
	EL5104, EL5105	1	700	3000	±2.25	±6.6	10	1	9.5	160	±3.8	10
	EL5204, EL5205	2	700	3000	±2.5	±5	10	1	9.5	160	±3.8	10
	EL5304	3	700	3000	±2.25	±6.6	10	1	9.5	160	±3.8	10

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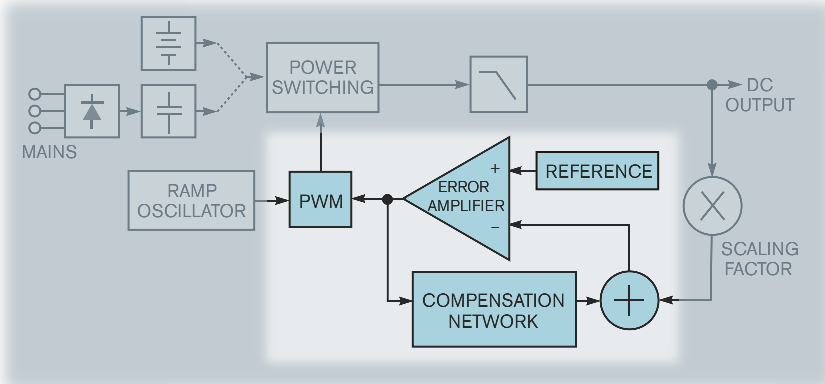


Figure 1 An analog SMPS control loop compares a scaled sample of the output voltage with a fixed reference and servos the PWM timing to force the two quantities to match.

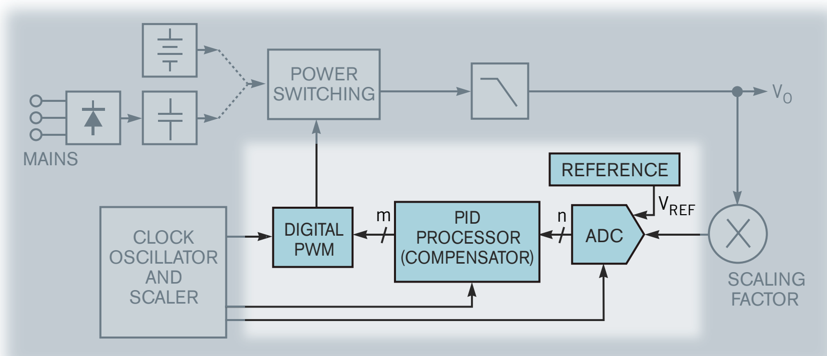


Figure 2 A digital SMPS control loop replaces the error amplifier with an ADC. The digital PWM requires a high-speed clock to provide the necessary edge-timing resolution.

BY JOSHUA ISRAELSOHN • TECHNICAL EDITOR

A BIT-O'-POWER: digitally controlled power conversion

IRONICALLY, PERHAPS, THE LAST SUBSYSTEM TO UNDERGO A SUBSTANTIVE SHIFT FROM AN ANALOG- TO A DIGITAL-CONTROL ARCHITECTURE IS THE MOST UNIVERSAL: THE POWER SUPPLY. BEWARE THE HYPE, HOWEVER. DIGITAL POWER CONTROL MAY BRING PERFORMANCE BENEFITS TO SOME APPLICATIONS, BUT UNTIL YOU BECOME FAMILIAR WITH THE INNER MACHINATIONS, THEIR SOPHISTICATION WILL EXACT A PRICE IN APPLICATION-DEVELOPMENT TIME.

Within reasonable limits of voltage and current ranges, disparate applications often put remarkably similar demands on power-management subsystems. This initially counterintuitive observation derives from the facts that many applications draw on common core technologies, exploit similar functional partitioning schemes, and operate dominantly on only a few different energy sources. Independently of what you design, declining operating voltages for major subsystems have marked the evolutionary track of many of the technologies you use. The supply tolerances that these technologies impose upon power subsystems have been in decline, too, in rough proportion to the supply voltages. Simultaneously, standing currents have been on the rise, and, disproportionately, dynamic currents have as well.

IN THE LOOP

The typical SMPS (switch-mode-power-supply) control loop modulates the timing of its power switches depending on the subsystem's output voltage (**Figure 1**). Working clockwise from the output, a scaling network samples the output voltage, multiplying it by V_O(ideal)/V_{REF}. The term "error amplifier" is something of a misnomer. The device compares the scaling network's output with the reference voltage and produces a drive signal for the PWM sufficient to force the two input voltages to match. (Some literature describes the error amplifier as developing an output signal proportional to the difference between its two input signals, which is not the case as long as the loop is operating within its linear range.) A compensation network scales the amplifier's dc and low-frequency gain appropriately to the PWM's sensitivity and also provides a local high-frequency feedback path to ensure adequate phase margin for loop stability. This basic structure applies to both isolated and nonisolated supplies. You can provide isolation (not shown) either at the power entry or within the power-switching block.

Beyond the basic issues of voltage regulation, this architecture accommodates

AT A GLANCE

- Recent arrivals of digital power controllers mark the beginning of what many believe is an important new trend in power control. Expect several competing parts to emerge over the coming quarters.
- Digital power controllers allow you to exploit DSP-based filtering methods and build a range of supplies from a common core set of parts with model differentiation managed in software.
- DPWM (digital-PWM) edge placement requires extremely high-speed clocks, which on-chip PLLs generally provide. Though the fastest signals stay on chip, use good high-frequency-layout practices to maintain switching-edge fidelity.

a variety of common ancillary functions with little additional complexity. For example, one additional resistor between the reference's output and the error amplifier's noninverting input provides a tracking option, which allows a regulator to follow another supply rail or voltage source. Here, an external voltage source can take control of the regulator's output target as long as it can adequately source (or sink as necessary) the reference current: $|V_{TRACK}-V_{REF}|\div R_R$. Few functions are implemented so simply, but the architecture accommodates such common features as overvoltage protection, undervoltage protection, overcurrent protection, and current reporting with moderate additional complexity and with little impact on the regulator's loop performance.

Outside the context of a switching regulator, servo circuits similar to this one date back to the days of vacuum tubes and are among the best studied, characterized, and documented control topologies in the literature (**Reference 1**). Considering the levels of performance that modern implementations provide, this loop is a remarkably simple and efficient structure, and, until recently, not easy to replace with a digital equivalent. Indeed, little more than a year ago, Astec Power Vice President Geof Potter stated, "Peripheral functions have long been within the scope of digital-control methods because [the] necessary speed and complexity are not great. On the other hand, digital control of an active feedback loop, including a pulse-modulation process ... has been an elusive prize due to size, cost, and power consumption of components needed for practical operation. To successfully compete with a low-cost analog-control system, a digital equivalent requires data resolution and latency numbers that have been available only in large, expensive DSP and ADC products. To compound the difficulty, there are few, if any, integrated devices on the market ... that contain all the necessary functions to constitute a reasonable [digital] power 'controller'" (**Reference 2**).

BITS OF EMPOWERMENT

The motivation for such devices is multifold: Supplies for product variants within a family can use identical power-management circuits with model-specific tuning and optimization coded in software or by operational coefficients. Onboard self-test programs can reduce, enhance, or eliminate production testing of power-management functions, depending on your organization's design and test-method policies. A digital power-management section can automatically compensate or replace components subject to parametric variation over population, time, or temperature. Product and accessory identification and recognition schemes can fit into a digital-power-management design with little additional hardware and provide enhanced safety, product-tracking, and diagnostic information.

The digitally controlled loop replaces the error amplifier and its compensation network with an ADC and a control-law processor; the processor often implements a PI (proportional-integral) or PID (proportional-integral-derivative) compensator (**Figure 2**). The processor can access stored coefficients that determine the loop dynamics and can modify those coefficients to optimize operation during various normal operating modes, transient events, and faults. The processor's output drives the input to a DPWM (digital PWM), which in turn determines the switching-edge positions by calculating and timing as opposed to exploiting the analog loop's threshold-detection method.

The macroscopic similarities between the analog- and the digital-control-loop topologies mask the complexity of such a replacement. For example, both analog- and digital-control loops must compensate for the phase lags that the forward path imposes between the power-switch inputs and the filter output. The digital implementation must also contend with the additional phase lag due to analog-to-digital-conversion delays and computational latencies through the control-law processor.

In addition to operating as a discrete time circuit, the digital-control loop is a quantizer, whereas the analog-control loop operates in continuous time and amplitude. These distinctions impose structural requirements and performance limitations on the digital loop. These constraints have until recently made high loop bandwidths and tight output tolerances difficult to attain on a large mixed-signal IC. For example, the ADC determines the resolution of the output-voltage setting—the first line item on your output-voltage-error budget. You can calculate your minimum resolution from your nominal output voltage, V_O, and the setting resolution, ΔV_O:

$$\text{RESOLUTION} = \log_2 \frac{V_O}{\Delta V_O} = \frac{\ln \frac{V_O}{\Delta V_O}}{\ln(2)}\ \text{(BITS)}.$$

To prevent limit-cycle oscillations in the output, quantizers that follow the ADC, including the DPWM, must exhibit a greater resolution than the ADC (**Figure 3**). This requirement ensures that a stable output value will exist for each possible ADC quantity. Referring to **Figure 2**,

$$m-n\geq 1.$$

The DPWM essentially translates bits of amplitude into bits of time. The power section's switching rate and the converter's amplitude resolution set the DPWM's minimum timing resolution: The DPWM must fit 2^m bits within the power section's switching interval. For example, in a controller that follows an 8-bit DAC with a 9-bit DPWM controlling a power section with a 1-MHz switching rate, the DPWM timing resolution is

$$\Delta t_{DPWM} = \frac{1}{f_{SW}\,2^{RES_{DPWM}}} = \frac{1}{1\,\text{MHz} \times 2^9} = 1.953\ \text{nSEC}.$$

The reciprocal of the DPWM timing resolution gives the DPWM clock rate, which for this modest example is

$$f_{CLK} = \frac{1}{\Delta t_{DPWM}} = 512\ \text{MHz}.$$

As the voltage-setting resolution increases, the DPWM clock does likewise: one octave per bit. Because some emission is likely at both the system and the DPWM, consider the radiated-noise spectrum of a power supply that uses a digitally controlled loop in the context of your application's signal band before committing to the power-subsystem design. Also, be sure to observe good high-frequency-layout practices, particularly in the regions of the switch-drive and clock signals. Conduction of RF from the regulated dc output, V_O, is unlikely due to the output filter, but radiated RF emissions are still a layout concern (**Reference 3**).

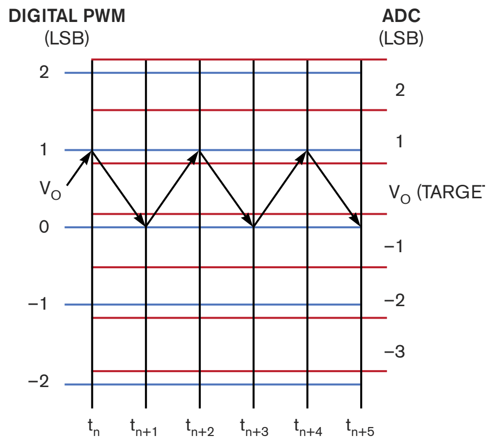


Figure 3 If the DPWM's resolution is coarser than that of the ADC that precedes it, limit-cycle oscillations can result.

POWER IN NUMBERS

The theoretical and technological-development work behind digital power controllers has been ongoing for some years, but this spring brought the announcement of ICs that implement the architecture from Texas Instruments and Silicon Laboratories. The Texas Instruments approach is a two-chip set with several options to accommodate a variety of SMPS topologies (**Figure 4**). ICs from the UCD9k and UCD7k families combine with your power-switching and filter sections to form a complete power subsystem.

The UCD7100 and 7201 single- and dual-channel, low-side MOSFET gate drivers feature microcontroller- and DSP-compatible inputs and can operate at switching rates as fast as 2 MHz. The drivers can typically source or sink 4A and feature maximum rise and fall times of 20 and 15 nsec, respectively, when driving 2.2-nF loads. The maximum input-to-output propagation delay is 35 nsec. Both drivers provide cycle-by-cycle current limiting, programmable limit thresholds, and logic-level limit-status flag outputs. The ICs can operate supplies in the range of 4.5 to 15V and include an on-chip 3.3V regulator rated for 10 mA, which you can use to power external circuits, such as a low-power microcontroller or ASIC. The 99-cent, single-channel and $1.20, dual-channel drivers are available in QFN-14 and QFN-16 packages, respectively. Both parts are also available in HTSSOP-14 packages and are rated for operation at −40 to +105°C.

TI also currently offers four other drivers in the UCD7k family. Various members include a synchronous-buck driver with current sensing, and single- and dual-channel, low-side drivers with 110V start-up capability. The dual-channel ICs are available with either independent or common current sensing. Members of the UCD7k-family drivers mate with a variety of processors, including the UCD9501 and its kin. The 9501, the first of the UCD9k family, comprises a 100-MHz, 32-bit Harvard DSP core; a clock- and timing-control block; a 12-bit, 6.25M-sample/sec ADC; extensive digital I/O, including PWM outputs; and memory.

The ADC features a 16-channel multiplexer and a sample-and-hold amplifier and operates over a 3V unipolar range. You can program the ADC to synchronize with the PWM outputs or initiate a conversion by either software command or hardware interrupt. A built-in sequencer can take as many as 16 samples with one command. You can program the sequencer to take each sample from any of the 16 input channels. The converter's INL (integral nonlinearity) and DNL (differential nonlinearity) are typically 1.5 and 1 LSBs, respectively, at 6.25M samples/sec; the manufacturer provides no limit specs. Similarly, ac-converter specifications are available only as typical values: 76-dB SFDR (spurious-free dynamic range), 67-dB SNR, and 10.6-bit ENOB (effective number of bits), all at 100 kHz, suggest that the converter is largely noise-limited but at sufficiently low values for power-management applications. When the device is operating with a 100-MHz system clock, on-chip timers can set the

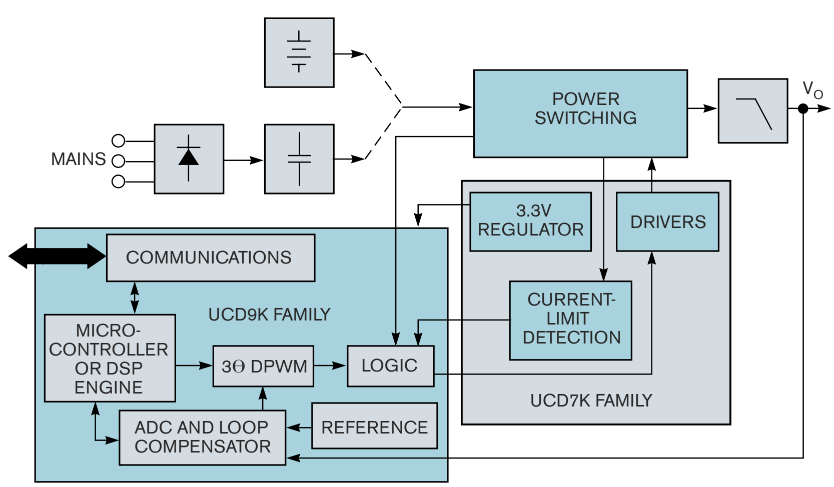
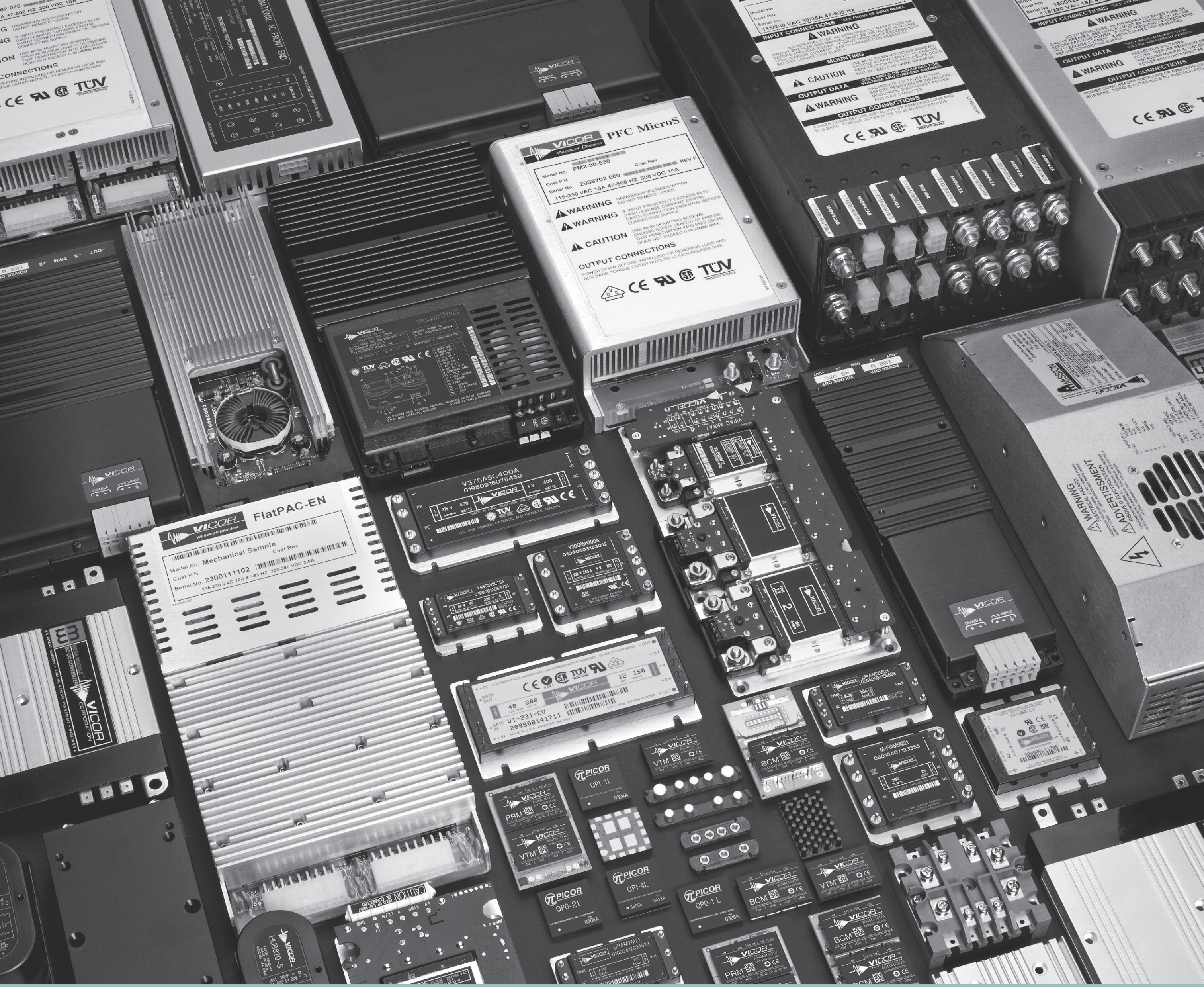


Figure 4 Texas Instruments' UCD9k and UCD7k ICs combine to form a digital power controller.



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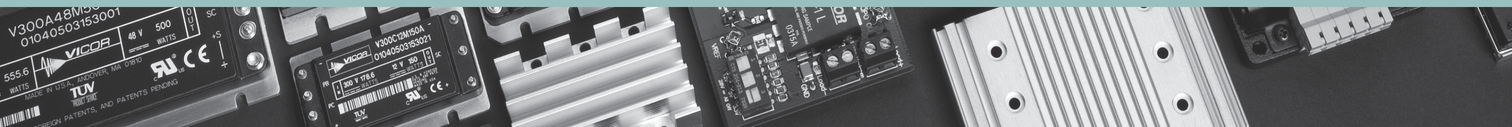

output edge positions of the three high-resolution PWM channels to a nominal granularity of 150 psec. At a 1-MHz power-switching rate, errors due to the PWM's finite-edge-placement resolution fall below the converter's noise floor.

TI offers the $5.79 (1000) digital power controller in an LQFP-100 package with three temperature-range options extending to 125°C. The IC operates on 3.3 and 1.8V supplies and typically dissipates ½W. Support tools include a $495 eZdsp starter kit, a C/C++ compiler/assembler/linker, TI's Code Composer Studio IDE, evaluation modules, JTAG controllers, and TI's DSP/BIOS.

Silicon Labs takes a dual-processor approach that separates all of the communication and housekeeping activities from the primary task of loop control (**Figure 5**). At the block-diagram level, the Si8250 digital-power-controller family performs the functions of TI's UCD9k family, though their internal architectures significantly differ. That fact leaves you to provide the driver and current sensing that the TI UCD7k family provides. However, a cursory search reveals some 15 reputable vendors of power-MOSFET drivers, so it is reasonable that Silicon Labs didn't reinvent the wheel when developing its first power-controller ICs.

One advantage of the Si8250 that is evident at first glance is its size: The dual-processor controller fits into QFN-28 and LQFP-32 packages. In exchange for the reduced pinout, the SiLabs part does without some of the ADC's multiplexer width—eight rather than 16 channels—and the 8250 family provides a somewhat more modest complement of digital-I/O facilities than does the UCD9k, which devotes more pins that function—35—than does the entirety of the 8250's package. (Ironically, perhaps, the Si8250 manages to fit in six PWM outputs—the business end of these devices—compared with the UCD9k's three.) If you can do with the more modest facilities of the $2.49 (1000) Si8250, another benefit in addition to its relatively reduced girth is a maximum dissipation of 69 mW.

The 8250 operates with an internal 25-MHz system clock. An internal PLL-based clock multiplier derives 50-, 100-, and 200-MHz clocks for the loop-control ADC, DPWM, and some peripherals. Programmable options include operation with an external clock with an on-chip, 3-bit programmable prescaler and an integrated 80-kHz, low-frequency clock, which is useful for certain low-power, nonoperational modes.

Silicon Labs provides a dedicated 10-MHz, 6-bit loop-control ADC and a separate 12-bit ADC with an eight-channel multiplexer for current, temperature, and other housekeeping measurements. The loop-control ADC meets 2- and 1-bit

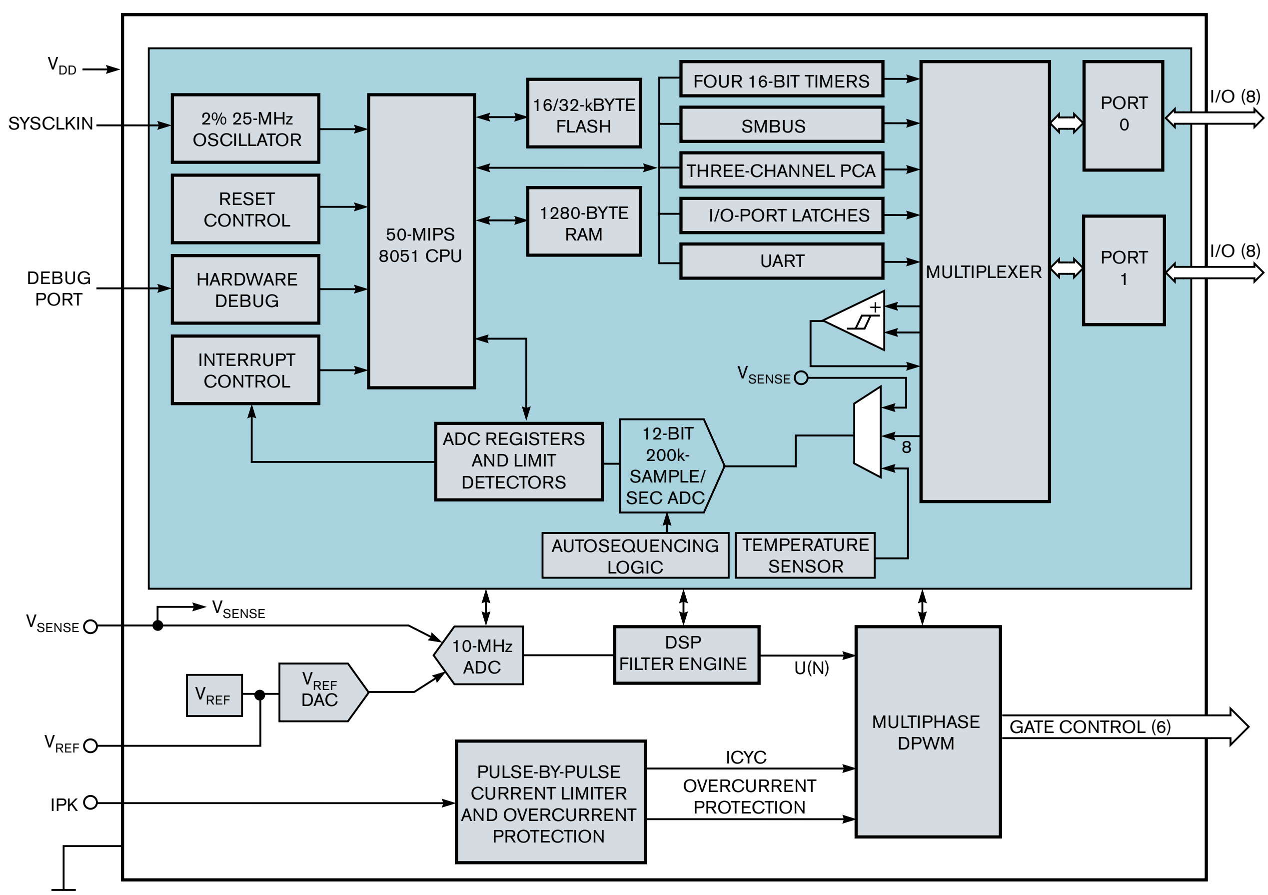

Figure 5 The Silicon Laboratories Si8250 commits a dedicated ADC and DSP-filter engine to loop control. A separate ADC and 8051 attend to such housekeeping duties as temperature measurement and system communications.

INL- and DNL-limit specs, respectively—a bit chubby for a 6-bit converter from a specsmanship perspective, perhaps, but adequate for many power-controller applications. A reference DAC allows you to program the LSB size from 2 to 20 mV for a dynamic range of 128 mV to 1.28V. As yet, SiLabs has neither specified the loop-control ADC's ac performance, nor announced an intention to do so.

One unusual "feature"—in the "it's-not-a-bug-it's-a-feature" sense of the word—of the Si8250's 300-page data sheet is that the specification table does not exist in a single section. Instead, the document tucks away pieces of the table at the end of each table segment's relative text. This approach distributes information critical to the part-selection process and early-design phases throughout the book-sized data sheet. In many cases, you'll find spec-table fragments under subparagraphs that you might otherwise hardly notice. Although this organization may be useful for those who assembled the data-sheet source materials, it can be cumbersome for users of the resultant document. You may, therefore, wish to have the data sheet in PDF form on a laptop for quick text searches, particularly if you are developing your first application using the 8250. Alternatively, you can arm yourself with a healthy supply of Post-it Notes.

Among the support tools for the Si8250 family is a $199 IDK, which features a GUI-based design interface and timing design wizard. The tool set comprises a real-time firmware kernel with C source code, microcontroller-configuration software, and a USB debugging adapter. EDN

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3 Israelsohn, Joshua, Gary Levy, and Ron Gatzke, "A circuit board layout guide for RFICs," EOEM Design Expo, June 2005, www.eoemdesignexpo.com.

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MORE AT EDN.COM

+ **This just in:** We did not receive information about Primarion's or Zilker Labs' power converters in time for *EDN*'s print edition, but you can read about them and news about an upcoming related conference in the online version of this article at www.edn.com/072105df1.

+ **Politically correct power:** Power-semiconductor vendors ease OEM's efforts to comply with international power-factor-correction requirements. See www.edn.com/article/CA608153.

+ Digitally controlled power-controller methods and challenges are in some ways reminiscent of those that Class-D amplifiers face. Read **Class D Gen 3** at www.edn.com/article/CA408383 to make the comparison and note the differences.

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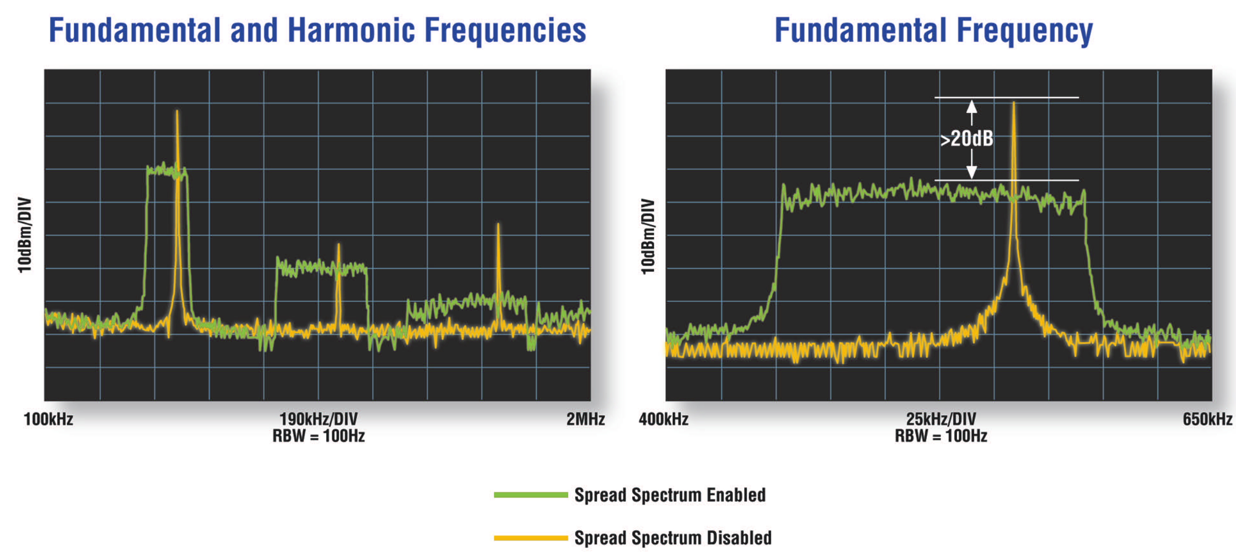

Eliminate Noise Problems with On-Chip Spread Spectrum

Built-in spread spectrum modulation in Linear Technology's new family of DC/DC regulators reduces peak radiated and conducted energy at any frequency by at least 20dB. This improvement significantly suppresses peak electromagnetic interference (EMI), reducing the need for metallic shielding or expensive filtering. Many of our future switching regulators will incorporate this technology – see the table below for our current offering.

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LTC®3736-1	2-Phase, Dual Synchronous Controller	2.75 to 9.8	1: 0.6 to V_{IN} 2: 0.6 to V_{IN}	5	✓	-	300, 550 or 750	450 to 580	QFN-24 SSOP-24
LTC3808	Synchronous Controller	2.75 to 9.8	0.6 to V_{IN}	5	✓	✓	300, 550 or 750	460 to 635	DFN-14 SSOP-16
LTC3776	DDR Memory Dual Controller	2.75 to 9.8	1: 0.6 to V_{IN} 2: $V_{DDQ}/2$	5	✓	✓	300, 550 or 750	450 to 580	QFN-24 SSOP-24
LTC3809	Synchronous Controller	2.75 to 9.8	0.6 to V_{IN}	5	-	✓	300, 550 or 750	450 to 580	DFN-10 MSOP-10
LTC3252	Inductorless, Dual, 2-Phase	2.7 to 5.5	1: 0.9 to 1.6 2: 0.9 to 1.6	0.25	-	-	-	1,000 to 1,600	DFN-12
LTC3251	Inductorless, 2-Phase	2.7 to 5.5	0.9 to 1.6	0.5	-	-	1,600	1,000 to 1,600	MSOP-10
LTC3445	Monolithic, I²C, Triple Output	2.5 to 5.5	1: 0.85 to 1.55 2, 3: ≥ 0.3	1: 0.6 2,3: 0.05	✓	-	1,500	Adjustable Spread 0% to 22.4%	QFN-24
LTC3415	Monolithic, PolyPhase, Stackable	2.5 to 5.5	0.6 to V_{IN}	7 x n	✓	✓	2,000	1,000 to 3,000	QFN-38

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12-Bit	LTC2290	LTC2291	LTC2292	LTC2293	LTC2294
10-Bit	9mm x 9mm	LTC2286	LTC2287	LTC2288	LTC2289
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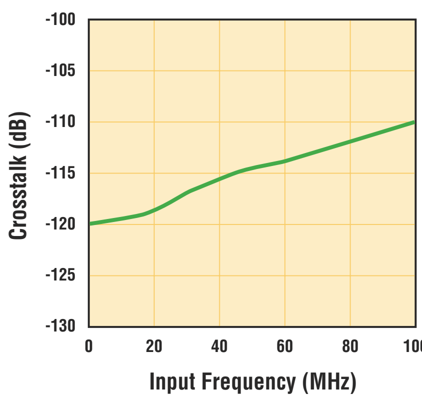
Crosstalk vs Input Frequency



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Power-supply interrupter fights ESD-induced device latch-up

Emerson Segura, Lifescale Global Diagnostics Inc, Toronto, ON, Canada

Under certain conditions, ESD events can damage digital circuits by causing latch-up. For example, when ESD triggers them, parasitic transistors normally formed as parts of a CMOS device can behave as an SCR (silicon-controlled rectifier). Once ESD triggers, the SCR presents a low-resistance path between portions of the CMOS device and conducts heavily. Damage to the device can result unless you immediately remove power from the circuit. ESD from human interaction presents a significant problem for mobile industrial and medical devices. For adequate ESD protection, most medical and industrial devices require a grounded return path for ESD currents. In the real world, mobile devices may serve in environments in which properly grounded power outlets are unavailable.

To protect expensive equipment from latch-up failures even when no ESD ground is present, you can add the power-interruption circuit shown in **Figure 1** to prevent damage when ESD-induced latch-up occurs. Under normal conditions, current drawn by ESD-susceptible devices develops a small voltage across sense resistor R_6. A voltage divider formed by R_4 and R_5 defines a reset-current threshold for the LED portion of optoisolator IC_1, and, under normal operational current consumption, the LED remains dark.

The output of IC_1 controls the gate bias applied to MOSFET Q_1, which is normally on. When latch-up occurs, power-supply current drain rapidly increases by an order of magnitude or more. The large voltage drop developed across R_6 forward-biases IC_1's LED, which in turn drives IC_1's phototransistor into conduction and shuts off Q_1, interrupting dc power to ESD-susceptible devices for several milliseconds. In addition, the system's firmware design must allow for automatic recovery from a power interruption.

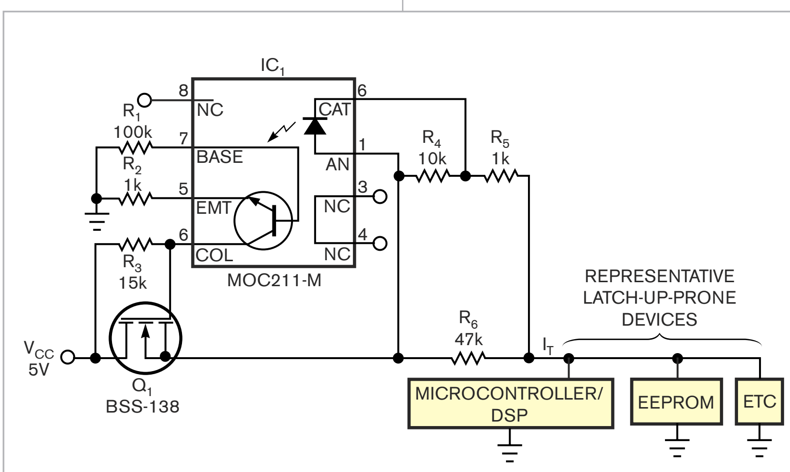

Figure 1 Upon sensing an overcurrent spike, this circuit interrupts power and enables the circuit's recovery from ESD-induced latch-up.

The following describes the relationship between the reset-current threshold and the values of R_4 and R_5: $(R_4+R_5)/R_4=(I_T\times R_6)/V_{LED}$, in which $I_T\geq(V_{LED})/R_6$, and $V_{CC}>V_{LED}$.

The ESD-induced fault threshold current, I_T, is greater than or equal to the optoisolator LED's conducting forward-voltage drop divided by the value of sense resistor R_6. Also, the raw power-supply voltage must exceed the LED's forward-voltage drop. Resistor R_1 provides a path for IC_1's base-leakage current, and resistors R_3 and R_2 determine Q_1's gate-shutoff bias.

In **Figure 1**, the optoisolator presents an LED forward-voltage drop of 1.2V. For the component values shown, the circuit momentarily interrupts V_{CC} when ESD-induced power-supply current exceeds approximately 300 mA. Total cost of the six resistors, one MOSFET, and one optoisolator is approximately $1 (production quantities). EDN

DIs Inside

High-impedance FET probe extends RF-spectrum analyzer's usable range

Steve Hageman, Windsor, CA

Current models of spectrum analyzers routinely offer frequency responses that begin as low as 10 Hz. When you combine them with 1-Hz or narrower band FFT software, expanded low-frequency performance makes the modern spectrum analyzer an invaluable tool for designing and debugging high-performance analog circuits. Unfortunately, a spectrum analyzer that's primarily for RF typically presents an input impedance of 50Ω, a heavy load when you apply it to most high-impedance analog circuits. You can improvise a somewhat higher impedance probe by adding a 953Ω resistor in series with the 50Ω input, but this approach provides only a 1-kΩ input impedance and reduces the measured signal by 26 dB.

In addition, most RF-spectrum analyzers lack ac coupling, and, thus, any dc-input component directly reaches either the internal terminating resistor or the front-end mixer. To maintain a 10-Hz, low-frequency response, you must connect a coupling capacitor with a value of at least 2 μF in series with the 953Ω input probe. Although oscilloscopes' input circuits can withstand accidental probe contacts and capacitive-transient overloads, using a low-impedance, ac-coupled probe with a spectrum analyzer can lead to destruction of the analyzer's expensive and possibly hard-to-replace front-end mixer.

Although high-impedance probes are commercially available, they're expensive to purchase and repair. This Design Idea offers an alternative: an inexpensive and well-protected unity-gain probe that presents the same input impedance as a basic bench oscilloscope and can drive the spectrum analyzer's 50Ω input impedance. The probe has a gain of 0±0.2 dB at 100 kHz. Input impedance is 1 MΩ, 15 pF, and maximum input is 0.8V p-p. Load impedance is 50Ω, and frequency response is 10 Hz to 200 MHz at −3 dB. Passband ripple is less than 1 dB p-p. Input noise at 1 MHz is less than 10 $nV/\sqrt{Hz}$. Distortion for 0.5V p-p input at 10 MHz is less than −75 dBc for second-order distortion and less than −85 dBc for third order. Power requirements are ±5V at 16 mA.

You can assemble the circuit in **Figure 1** in an afternoon from readily available and inexpensive components. The circuit's input presents the same characteristics as a bench oscilloscope—a 1-MΩ resistance in parallel with 15 pF of capacitance. You can also use this active probe in place of standard 1-to-1 or 10-to-1 oscilloscope probes, thus extending the design's applicability. The back-to-back silicon diodes in the D_1 clamp the input signal to plus or minus one forward-voltage drop, which limits signal excursions you apply to the spectrum analyzer's front end, thus protecting the input mixer from damage due to overloads and ESD. Because most users employ the probe and spectrum analyzer to measure small-amplitude signals and noise,

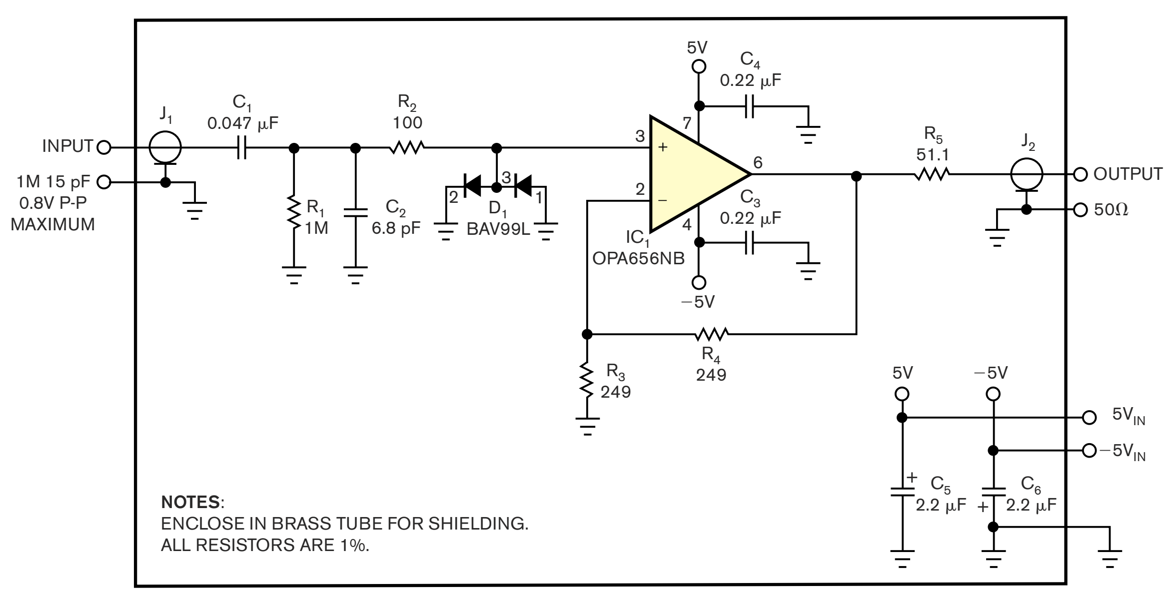

Figure 1 Just a handful of parts can help extend a spectrum analyzer's performance. This unity-gain probe emulates a standard oscilloscope probe's 1-MΩ and 15-pF input characteristics and easily drives 50Ω loads.

the limited large-signal response does not affect most applications.

High-performance FET input operational amplifier IC_1, a Texas Instruments OPA656, provides a voltage gain of two. This configuration yields a bandwidth of approximately 200 MHz (**Figure 2**). The OPA656 can drive 50Ω back-matched loads for a total load of 100Ω, which results in a 6-dB gain loss for which IC_1's gain of two compensates for a net gain of unity. The OPA656 also introduces lower noise and distortion than that of most commercially available, active FET-based probes.

The probe in **Figure 3** fits into a small section of brass hobby tubing. The input connector comprises a small SMA edge-launch connector that you can easily adapt to other connectors, including the BNC and its many accessories. The probe requires 5 and −5V at approximately 18 mA each, which you can obtain from an instrument's probe-power connector if available or from a linear supply designed around an ac wall transformer. For best results, use 78L05 and 79L05 voltage regulators to stabilize the supply voltages.

Standard miniature 50Ω coaxial cable connects the probe to the measuring instrument. For the flattest frequency response and uniform gain, terminate the probe's output with 50Ω; the circuit requires no dc-output-blocking capacitor. EDN

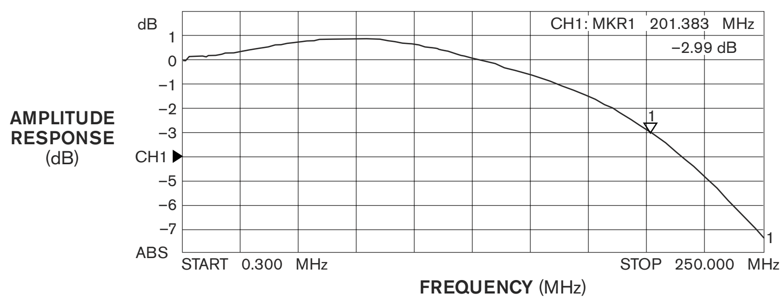

Figure 2 The probe's measured −3-dB frequency response extends from 10 Hz to 200 MHz with slightly less than 1-dB passband ripple, which compares favorably with the ±2-dB response of many commercial active-FET probes.

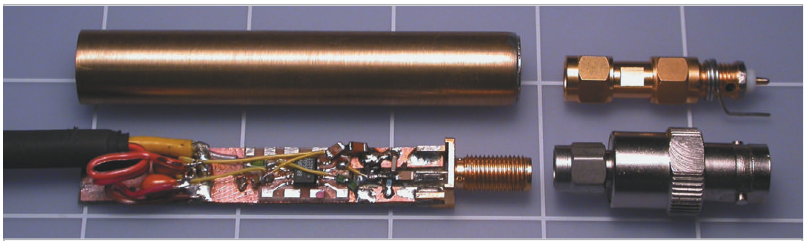

Figure 3 You can assemble the probe on a piece of breadboard that fits into a section of brass tubing from model and hobby shops. An SMA input connector matches a multitude of adapters and probe tips, a few of which are shown. Use a rubber grommet to close the probe's output end.

Watchdog circuit protects against loss of battery charger's control signals

Andy Fewster, Maxim Integrated Products Inc, Hampshire, UK

Recharging a mobile phone's internal battery usually occurs under control of a proprietary charging algorithm that resides in the baseband controller. The charger connects to the internal battery through a P-channel-MOSFET switch of low on-resistance (**Figure 1**). A baseband controller supplies a PWM signal that drives the switch. To minimize power dissipation and consequent thermal problems in the phone, the charging supply—usually a plug-in transformer assembly—features internal current limiting and has specifications that correspond to the battery's chemistry and charge-recovery requirements.

However, if the baseband processor stalls for any reason, the nearly direct charger-to-battery connection could damage the battery. To circumvent the problem, another circuit monitors the charger's PWM input and disables the series power switch after a predetermined delay interval (**Figure 2**). The circuit operates independently of the baseband unit's processor and allows charging to resume when the PWM signal returns.

In this circuit, microprocessor supervisor IC_1, a Maxim MAX6321 that includes a watchdog circuit that can monitor software execution, drives IC_2, a normally open SPST analog switch. Components R_4, D_2, and C_1 protect IC_1 and IC_2 by limiting V_{CC} to a maximum of 5.1V. Resistor R_4's value isn't critical because the protection circuit's quiescent current is low at approximately 30 μA. Select R_4 to provide just enough current—for example, 0.5 mA—to bias zener diode D_1 into the "knee" of its characteristic V-I curve.

(continued on pg 76)

DESIGN NOTES

Tiny Versatile Buck Regulators Operate from 3.6V to 36V Input

Design Note 367

Hua (Walker) Bai

Introduction

Linear Technology offers two new buck regulators that operate from a wide input voltage range (3.6V to 36V) and take so little space that they easily solve many difficult power supply problems. The LT®1936 and LT1933 are perfect for applications with disparate power inputs or wide range input power supplies such as automotive batteries, 24V industrial supplies, 5V logic supplies and various wall adapters. Both parts are monolithic current mode PWM regulators which provide excellent line and load regulation and dynamic response. They operate at a 500kHz switching frequency, enabling the use of small, low cost inductors and ceramic capacitors, resulting in low, predictable output ripple.

Small Size and Versatility

The LT1936 regulator includes a 1.9A power switch in a tiny, thermally enhanced 8-lead MSOP. The LT1933 regulator includes an internal 0.75A power switch in a tiny 6-lead ThinSOT™ package, which occupies less than $0.15in^2$ board space. The LT1936 offers the option of external compensation for design flexibility or internal compensation for compact solution size. Both parts offer soft-start via the $\overline{SHDN}$ pin, thus reducing maximum inrush currents during start-up. Both parts also have a very low, 2µA shutdown current which significantly extends battery life in applications that spend long periods of time in sleep or shutdown mode. During short circuit, both parts offer frequency foldback, where the switching frequency decreases by about a factor of ten. The lower frequency allows the inductor current to safely discharge, thereby preventing current runaway.

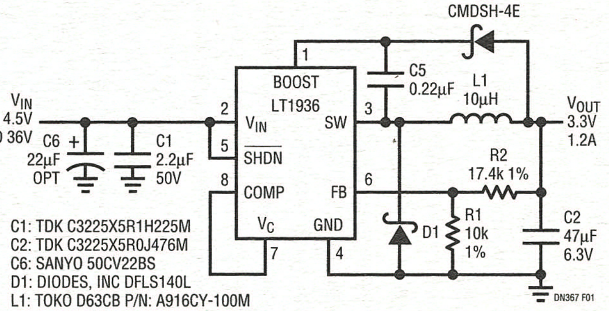

Figure 1. Typical Application of LT1936 Accepts 4.5V to 36V and Produces 3.3V/1.2A

LT1936 Produces 3.3V at 1.2A from 4.5V to 36V

Figure 1 shows a typical application for the LT1936. This circuit generates 3.3V at 1.2A from an input of 4.5V to 36V. With the same input voltage range, the LT1933 circuit can supply 500mA. The typical output voltage ripple of the Figure 1 circuit is less than 16mV while efficiency is as high as 89%. Excellent transient response is possible with either external compensation or the internal compensation; this circuit uses internal compensation to minimize component count. A high ESR electrolytic capacitor, C6 in Figure 1, is recommended to damp overshoot voltage in applications where the circuit is plugged into a live input source through long leads. For more information, refer to the LT1933 or LT1936 data sheet.

Producing a Lower Output Voltage from the LT1936

In order to fully saturate the internal NPN power transistor of the LT1936, the BOOST pin voltage must be at least 2.3V above the SW pin voltage. A charge pump comprising D2 and C5 creates this headroom in Figure 1. Nevertheless, when the output voltage is less than 2.5V, different approaches are needed. Figure 2 shows one example. It allows V_{IN} to go up to 36V and generates 1.4A at 1.8V. In this circuit, Q2 serves as an inexpensive Zener. The emitter-base breakdown voltage of Q2 gives a stable 6V reference. The charging current for the BOOST capacitor, C5, passes through the follower, Q1. R4, Q1 and Q2 limit the BOOST pin voltage below its maximum rating of 43V. If the maximum V_{IN} in an application is less than 20V, simply tie V_{IN} to D2 to allow a lower minimum input voltage.

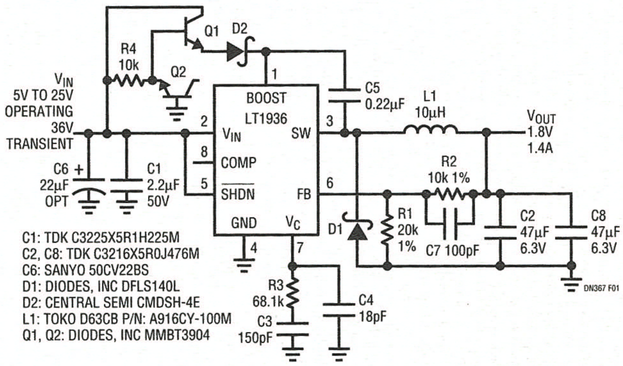

Figure 2. This Circuit Generates Lower Output Voltage While Allowing Maximum Input Up to 36V

Negative Output from a Buck Regulator

The circuit shown in Figure 3 can generate a negative voltage of –3.3V from a buck regulator such as the LT1933. This circuit effectively sets the ground reference of the LT1933 to –3.3V. The average inductor current of this circuit is the summation of the input and output current. The available output current is a function of the input voltage as shown in Figure 4.

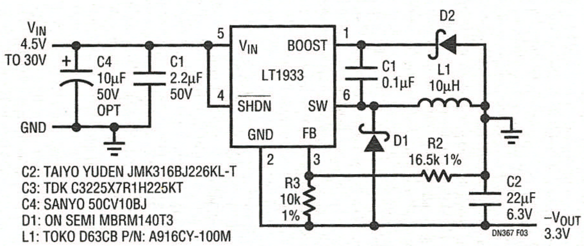

Figure 3. This Circuit Produces –3.3V from 4.5V to 30V

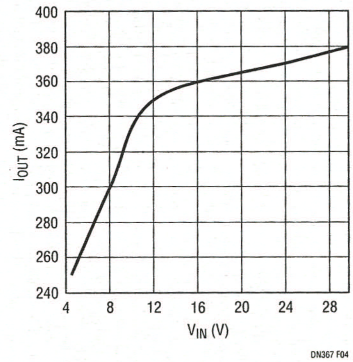

Figure 4. Maximum Output Current of the Circuit in Figure 3 as a Function of the Input Voltage

Tiny Circuit Generates 3.3V and 5V from a Minimum 4.5V Supply

The circuit in Figure 5 is capable of generating two output voltages from a minimum 4.5V supply. One output is 3.3V at 300mA, the other 5V at 50mA. The circuit is especially useful in automotive cold crank conditions when the battery voltage drops below 5V but both the 3.3V and 5V outputs need to be alive. If more current is needed, the circuit can also be implemented using the LT1936. Even though the input of the LT1761-5 is unregulated, the 5V output is regulated by the LT1761-5 LDO. To maintain regulation, the 3.3V output current should be always well above the 5V output current, especially when V_{IN} is low.

Conclusion

The LT1933 and LT1936 step-down switching regulators accept a wide variety of input sources as well as offer compact, efficient and versatile solutions to many otherwise hard-to-solve problems.

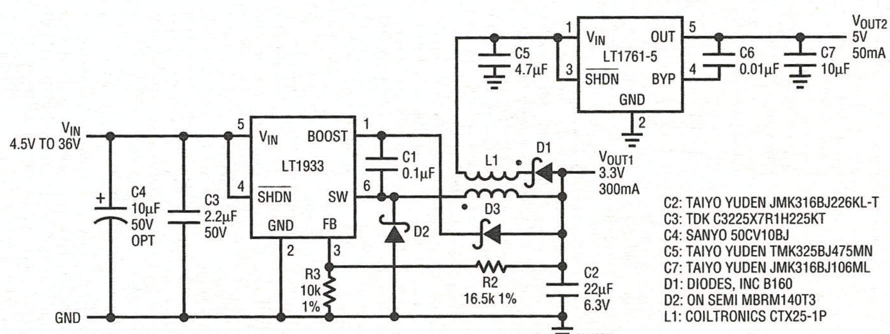

Figure 5. From a Minimum 4.5V, This Circuit Produces Two Outputs at 3.3V/300mA and 5V/50mA

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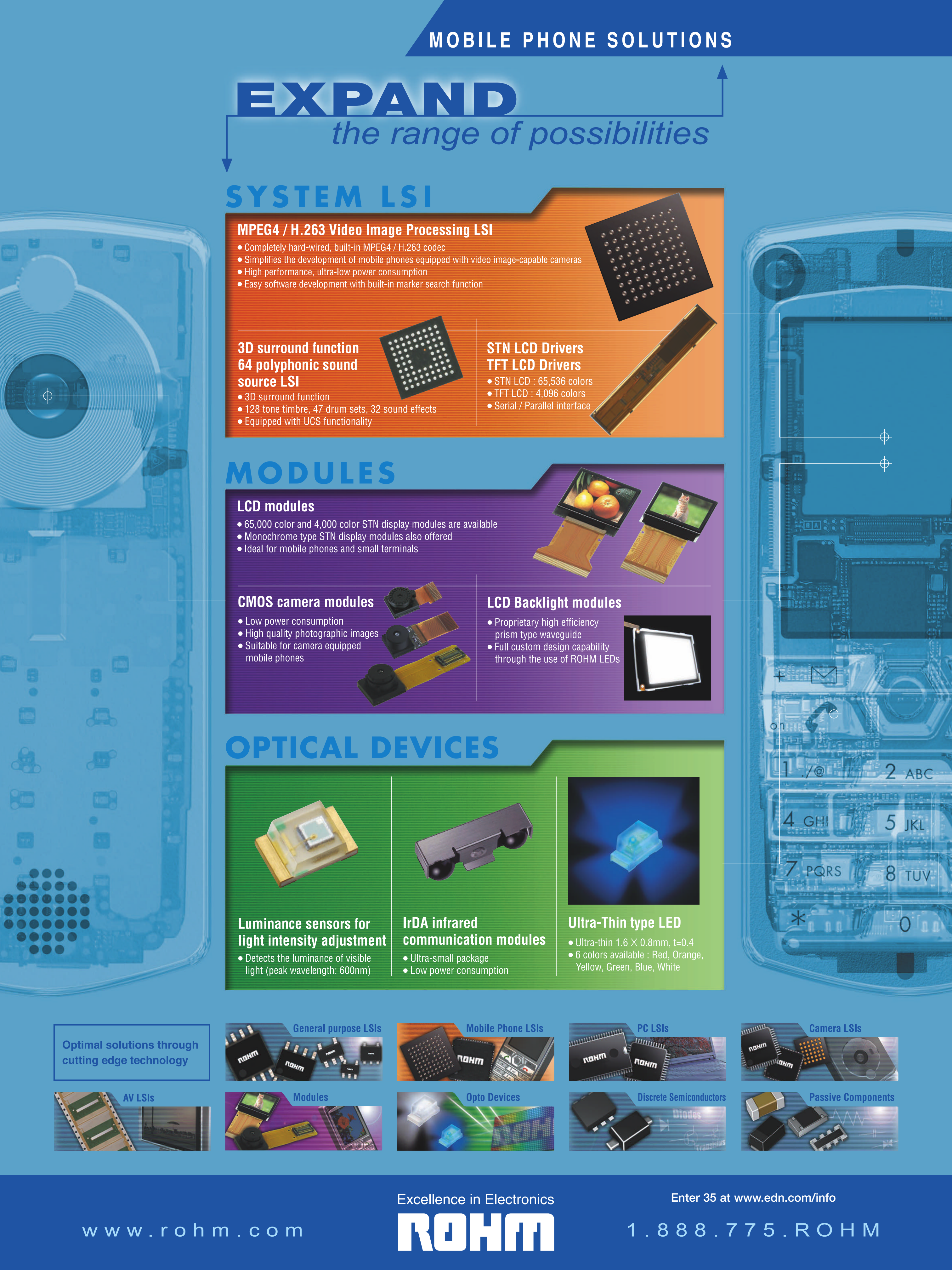

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The protection circuit consumes no power except when the battery undergoes charging and therefore doesn't burden the battery. Supervisor IC_1 provides a $\overline{RESET}$ output that can serve as a charger-ready interrupt input to the baseband-controller CPU. The $\overline{RESET}$ output's open-drain structure allows its connection to other circuits that operate from different supply voltages. Supplying power to the watchdog and PWM circuits only during charging also prevents reverse current from flowing into the IC_1's $\overline{RESET}$ output and discharging the battery via a sneak path.

The timing diagram illustrates the circuit's operation when an active

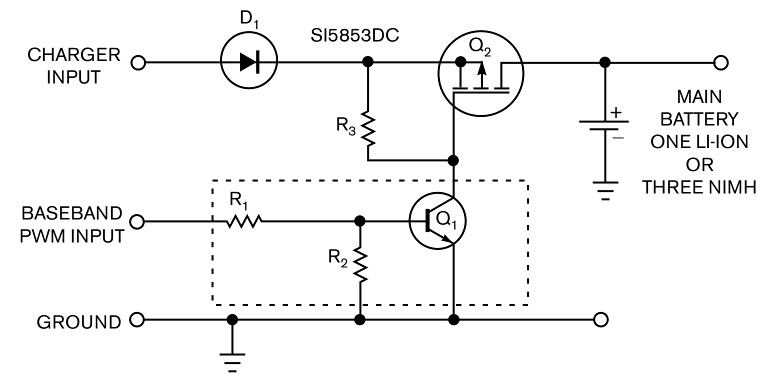

Figure 1 A typical mobile phone's battery-charger input circuit comprises a series switch controlled by a PWM signal.

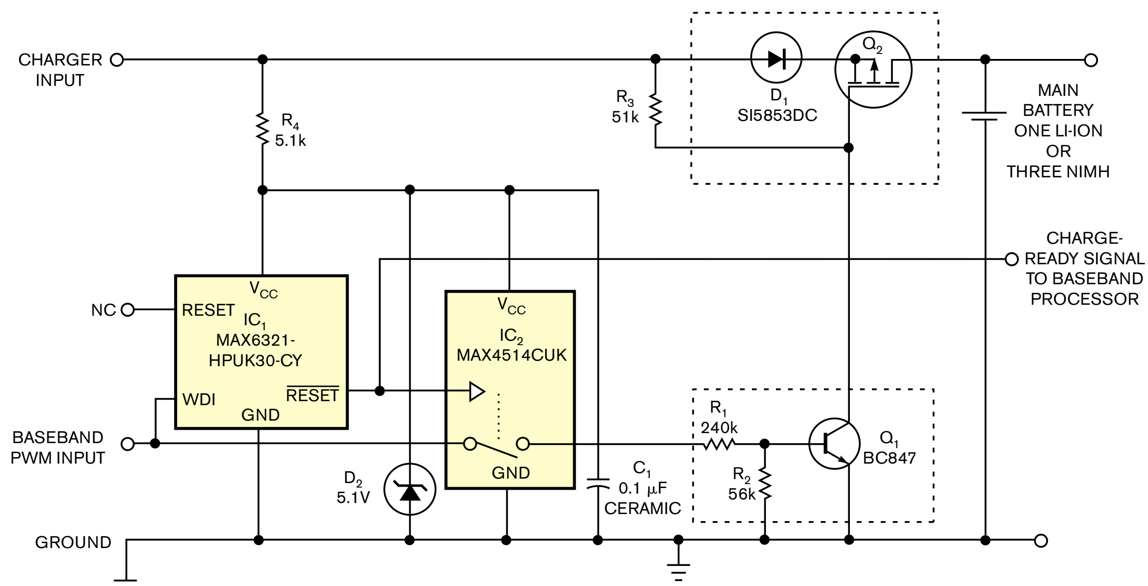

Figure 2 Adding watchdog protection to the circuit of Figure 1 guards against battery damage when the baseband processor stalls or ceases software execution.

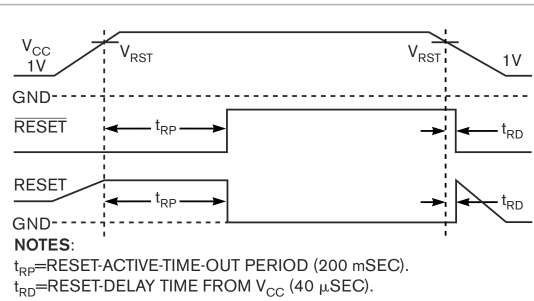

Figure 3 Reset-timing relationships for the circuit of Figure 2 illustrates its power-on behavior.

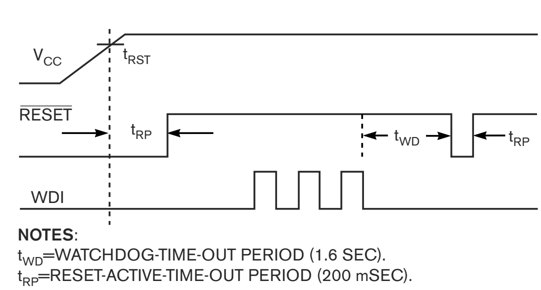

Figure 4 When PWM pulses cease, the watchdog circuit disables the charger after a 1.6-sec interval.

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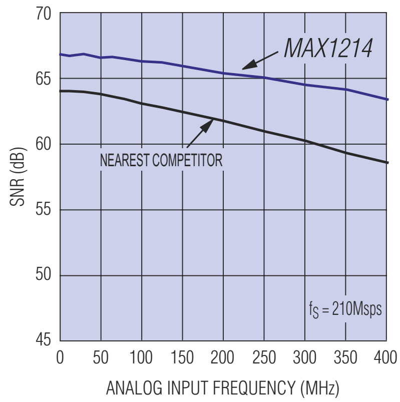

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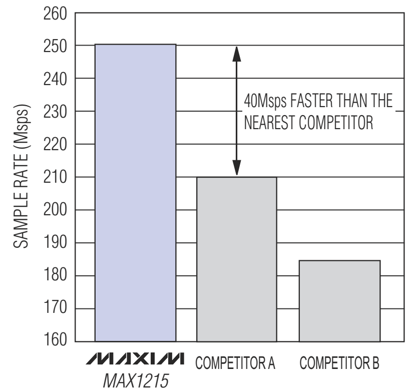

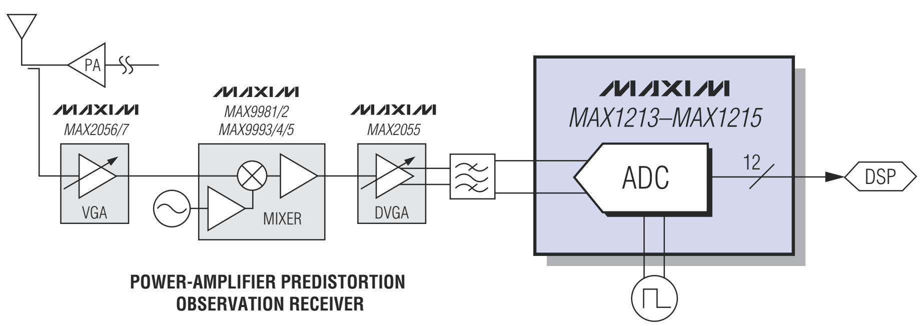

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charger connects to the phone's charger-input socket (**Figure 3**). In this example, the MAX6321-HPUK30-CY that IC_1 uses is factory-trimmed for a 3V reset threshold, and the -CY suffix indicates complementary reset outputs and a 1.6-sec delay interval. The reset interval begins when V_{CC} reaches 3V±45 mV. After 200 msec, RESET goes low, and $\overline{RESET}$ goes high.

The $\overline{RESET}$ output releases the SPST analog switch, IC_2, which enables the PWM input. Meanwhile, the active WDI (watchdog input) monitors the PWM input signal. If no signal transitions occur within 1.6 sec, the RESET and $\overline{RESET}$ outputs become active, disabling the PWM input and pausing the charger algorithm using a CPU interrupt that the charger-ready signal conveys (**Figure 4**). All active and passive components for the circuit are available in surface-mount packages. Pass transistor Q_2, a Siliconix-Vishay SiS5853, includes an integrated Schottky diode, D_1.**EDN**

Circuit adds foldback-current protection

Rafael García-Gil and JM Espí, Electronic Engineering Department, University of Valencia, Spain

For many applications that require power-supply currents of a few amperes or less, three-terminal adjustable-output linear voltage regulators, such as National Semiconductor's LM317, offer ease of use, low cost, and full on-chip overload protection. The addition of a few components can provide a three-terminal regulator with high-speed short-circuit current limiting for improved reliability. The current limiter protects the regulator from damage by holding the maximum output current at a constant level, I_{MAX}, that doesn't damage the regulator (**Reference 1**). When a fault condition occurs, the power dissipated in the pass transistor equals approximately $V_{IN} \times I_{MAX}$. Designing a regulator to survive an overload requires conservatively rated—and often overdesigned—components unless you can reduce, or fold back, the output current when a fault occurs (**Reference 2**).

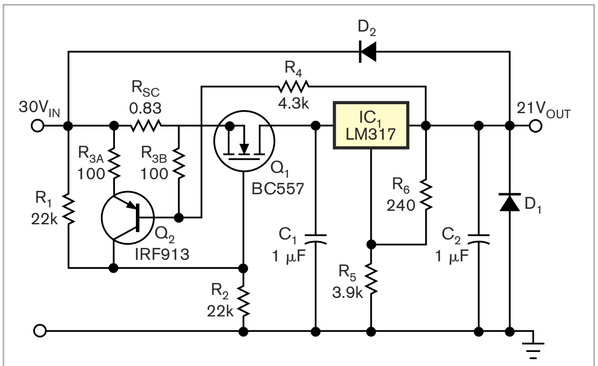

Figure 1 This circuit adds foldback-overcurrent protection to a linear regulator.

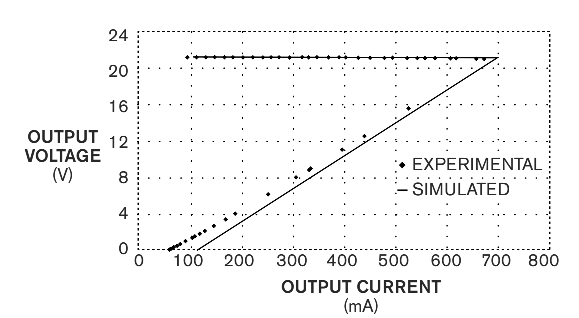

Figure 2 Simulated and measured foldback-current responses to a load resistance that varies from 200 to 0.01Ω show close agreement.

The circuit in **Figure 1** incorporates foldback-current limiting to protect the pass transistor by adding feedback resistor R_4. Under normal conditions, transistor Q_2 doesn't conduct, and resistors R_1 and R_2 bias MOSFET Q_1 into conduction. When an output overload occurs, Q_2 conducts, reducing the on-state bias applied to Q_1 and thus increasing its drain-source resistance and limiting the current flowing into regulator IC_1, an LM317. Adding R_4 makes Q_2's bias current dependent on the output voltage, V_{OUT}, which decreases under overload conditions.

For the circuit in **Figure 1**, you can calculate the maximum foldover and short-circuit currents, I_{KNEE} and I_{SC}, respectively, as follows:

$$I_{KNEE}=\frac{(R_3+R_4)\times V_{SENSE}}{R_{SC}\times R_4}-(V_{IN}-V_{OUT})\times\frac{R_3}{R_{SC}\times R_4}. \quad (1)$$

$$I_{SC}=\frac{(R_3+R_4)\times V_{SENSE}}{R_{SC}\times R_4}-V_{IN}\times\frac{R_3}{R_{SC}\times R_4}. \quad (2)$$

In a practical design, you select values for I_{KNEE} and I_{SC} and equal values for R_{3A} and R_{3B} and then use **equations 1** and **2** to calculate resistors R_{SC} and R_4. For the circuit in **Figure 1**, the output's maximum and short-circuit currents are fixed at 0.7 and 0.05A, respectively. With R_{3A} and R_{3B} set to 100Ω, solving the equations yields values of 0.73Ω for R_{SC} and 4.3 kΩ for R_4. You can demonstrate the circuit's performance by applying a variable-load resistor that's adjustable from 0 to 200Ω. As **Figure 2** shows, the output's simulated and measured voltage-versus-current characteristics, V_{OUT} and I_{OUT}, respectively, are in close agreement.**EDN**

REFERENCES

1 Hulseman, Herb, "MOSFET enhances voltage regulator's overcurrent protection," *EDN*, March 3, 2005, pg 74.

2 Galinski, Martin, "Circuit folds back current during fault conditions," *EDN*, Nov 28, 2002, pg 102.

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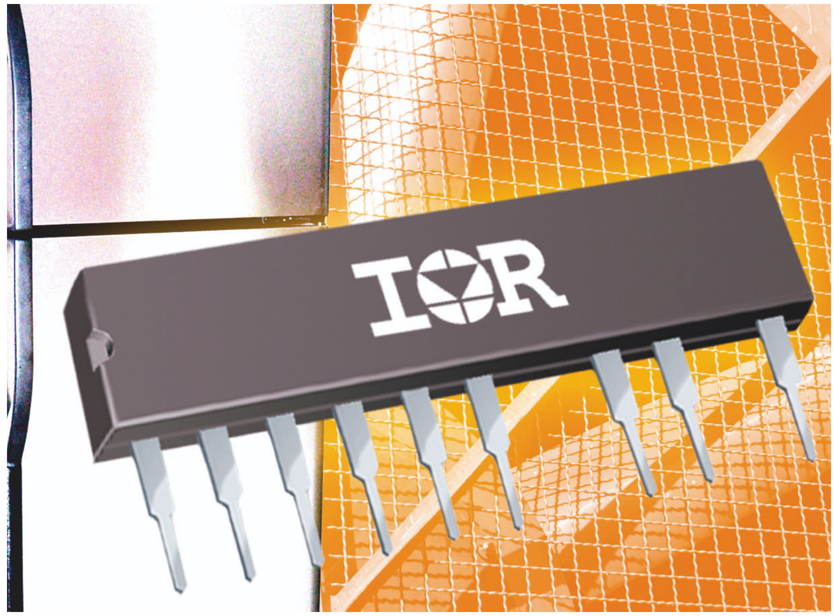


Motor-drive IC comes with a demonstration kit

Requiring no heat sink for electronic-motor-drive applications requiring operation at power as high as 180W, the IR3103 motor-drive half-bridge FredFET includes a gate-driver IC. The miniSIP-11 package features isolation ratings of 1500V rms/minute, enables shorter intercomponent connections, and reduces EMI emissions. Able to operate at a maximum input-voltage rating of 500V, at temperatures as high as 150°C, the device also supports ESD protection and includes a bootstrap diode for the high-side-driver section. The IRADK31 demonstration kit includes a three-phase, 250W motor-drive system and software that compares several motor-control-drive strategies for ac induction motors and advanced brushless dc motors. The IR3103 costs $1.25 (10,000).

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

Diode series has extensive selection

These L-Flat surface-mount packages for high-power rectifier diodes use a lead-clamp structure to provide a 32-mm^2 mounting area, measuring 4×8.2×1.8 mm. Targeting circuit-protection applications in devices such as motor drivers, ac/dc converters, and switch-mode power supplies, the series has an IFAV (average-forward-current) rating of 3 to 10A. The L-Flat series includes general-purpose, fast-recovery, high-efficiency, Schottky-barrier, and zener diodes. L-Flat series diodes cost 30 cents each.

▷**Toshiba America Electronic Components Inc, www.toshiba.com/taec/**

MOSFETs feature low on-resistance and high switching speeds

Targeting power supplies for computer servers, telecom equipment, and flat-panel displays, the CoolMOS CS Server series of power MOSFETs has an on-resistance of 99 mΩ in a TO220 package or 45Ω in a TO247 package with switching speeds of 150V/nsec and

DISCRETE SEMICONDUCTORS

a 600V voltage blocking. The 99-mΩ device costs $4 (10,000).

▷**Infineon**, **www.infineon.com/power**

Schottky diodes come in SOT-563 package

In an SOT-563 case, the CMLSH-05-04DO dual, low-forward-voltage Schottky diodes use 55% less board space than two SOD-523 devices. The vendor configures the product as two isolated diodes with an opposing anode/cathode pinout; each product features a peak repetitive reverse voltage of 40V, continuous forward current of 500 mA, and a forward voltage of 0.35V at 100 mA. The CMLSH05-04DO devices cost 16 cents each (3000).

▷**Central Semiconductor Corp**, **www.centralsemi.com**

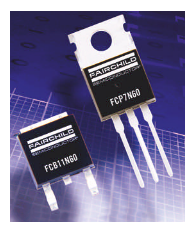
Power-MOSFET family comes in variety of packages

A family of P-channel power MOSFETs targeting active-clamp configurations features 150 and 200V options. The 150V Si1411DH and 200V Si1419DH have on-resistance values of 2.6 and 5Ω, respectively, and both come in SC-70 packages. The 150V Si2325DS and 200V Si2327DS have on-resistance values of 1.2 and 2.35Ω, respectively, and both come in SOT-23 packages. The 150V Si7439DP and 200V Si7431DP have on-resistance values of 0.09 and 0.174Ω, respectively, and both come in SO-8 packages. The devices cost 20 cents (100,000).

▷**Vishay Intertechnology**, **www.vishay.com**

MOSFETs suit PFC circuitry, lighting, and ac/dc power-supply systems

Aiming at withstanding high-speed voltage- and current-switching transients, these eight high-voltage MOSFETs target transient-prone HID (high-intensity-discharge) lighting-ballast applications and power supplies for PDP (plasma-display-panel) televisions. The devices reduce conduction losses and increase switching performance by lowering RDS_{ON} and gate charge; they also feature a gate-to-source voltage of ±30V. Available in TO-220, TO220F, D2-PAK, TO247, and TO-3P packages, the MOSFETs' cost ranges from $1.54 to $5.36.



▷**Fairchild Semiconductors**, **www.fairchildsemi.com/superfets**

EMBEDDED SYSTEMS

10-Gbps packet-processing module has high-bandwidth throughput

With high-bandwidth throughput from a single AdvancedTCA slot, the Promentum ATCA-7010 packet-processing module allows designers to implement a security gateway that filters and monitors incoming traffic for intrusion or security breaches at wire speed. The module features duel Intel IXP28xx network processors with a 1.4-GHz core processor and a 700-MHz Xscale processor, which designers can configure as single or dual and parallel or pipelined. With 10-Gbps Ethernet interfaces connecting through an RTM (rear transition module), the device supports PICMG-3.0 and PICMG3.x. The module also includes three independent banks of 256-Mbyte RDRAM per network processor at 533 MHz, four banks of 8-Mbyte DRII SRAM per network processor, and an optional 18-Mbit TCAM (ternary content-addressable memory) in place of an SRAM bank. Compatible with the Intel IXP SDK 4.x, the ATCA-

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7010 comes with the vendor's software-development kit and Montavista Professional Edition 3.1 support as well as with a full complement of diagnostics and debugging support. The module costs $10,582 for a fully loaded memory configuration.

▷**RadiSys Corp, www.radisys.com**

Serial controller targets 3U CompactPCI systems

The high-density, 3U, 32-bit TCP460 CompactPCI serial-communications controller features 16 channels of RS232, RS422, or mixed RS232/422 serial-interface-channel configurations. The RS232 channels support RxD, TxD, RTS, and CTS, and the RS422 channels support RxD± and TxD± with connection through front-panel I/O using an HD68 SCSI-3-type connector or through the rear-panel I/O using P14. Each serial channel has a 64-byte receiving and transmitting FIFO with programmable FIFO trigger levels and programmable baud rates as high as 921.6 kbps for RS232 and 5.5296 Mbps for RS422 channels. Operating in extended-temperature ranges of −40 to +85°C, the TCP460 costs $860.

▷**Tews Technology, www.tews.com**

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Intersil Battery Charger ICs

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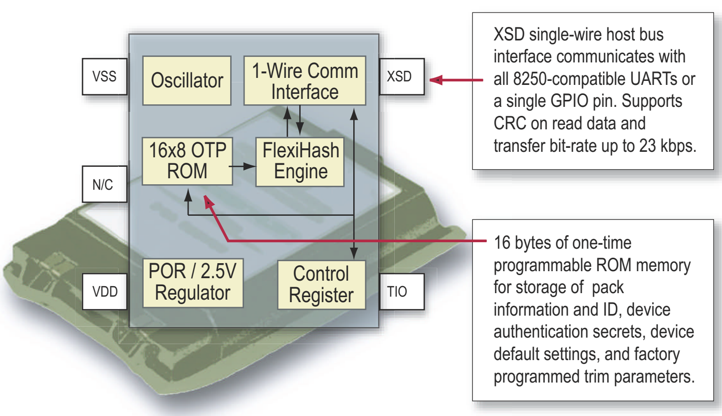
Don't Get Burned by Cheap Imposters

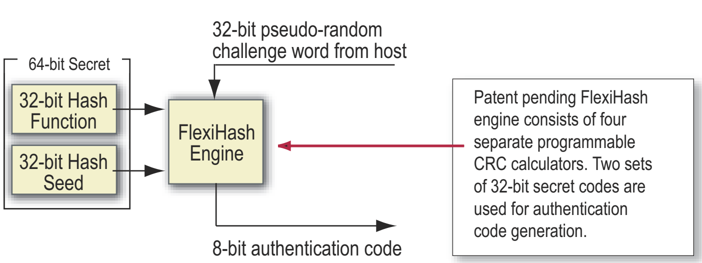
Protect your designs from counterfeit battery packs with Intersil's ISL6296. We've integrated our FlexiHash™ technology to deliver a simple, robust and inexpensive battery authentication solution for 1-cell Li-Ion/Li-Polymer or 3-cell NiMH series battery packs.

Intersil's ISL6296 offers the same level of effectiveness as other significantly more expensive, high maintenance, monetary-grade hash algorithm and authentication schemes. This device supports a wide range of operating voltages and is customized for low-cost applications.

ISL6296 Functional Block Diagram



Device Authentication Process



Key Features:

- Patent pending challenge-response authentication scheme using 32-bit challenge code word and 8-bit authentication code.
- Fast single-step authentication process
- Supports 1-cell Li-Ion/Li-Polymer and 3-cell series NiMH battery packs (2.6V-to-4.8V operation)
- Compatible for use with serial ports offered by all 8250-compatible UARTs or a single GPIO pin
- "Zero Power" sleep mode after bus inactivity time-out period
- 64-bit user-programmable secret for security
- Can also be used in a variety of accessories such as printer ink cartridges where authenticity needs to be verified.
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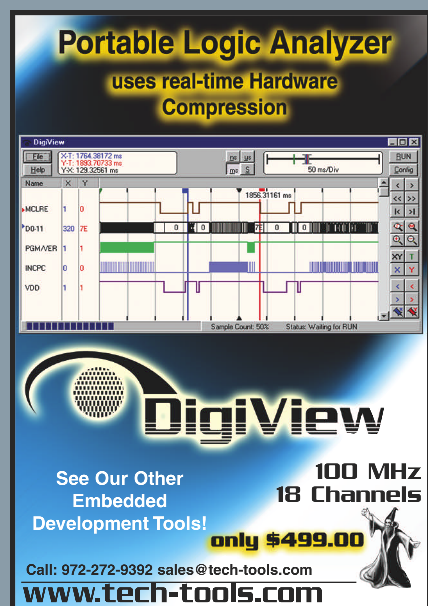

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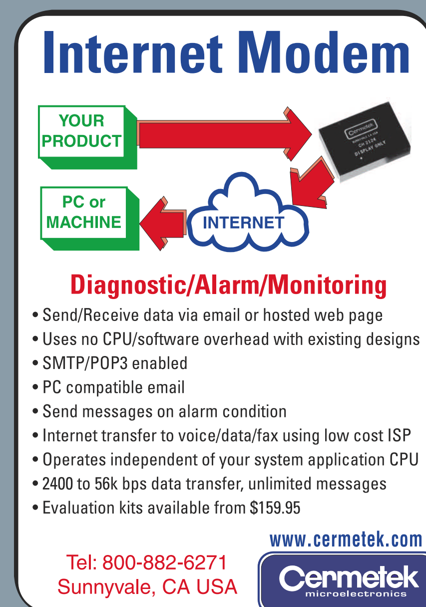

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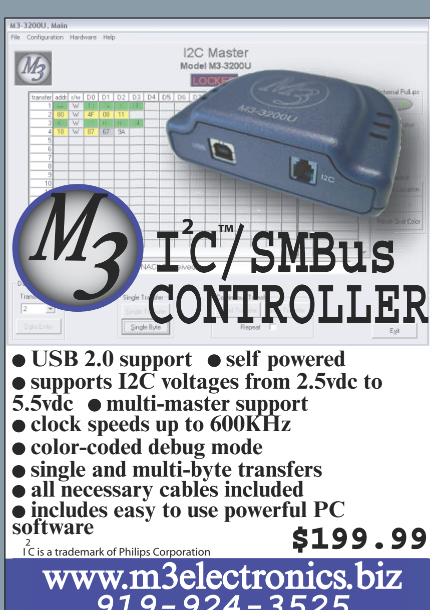

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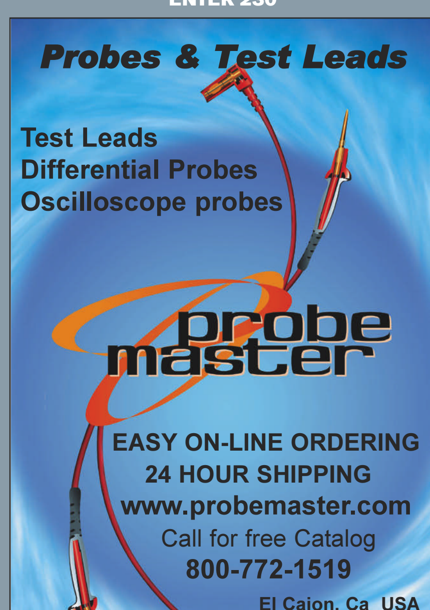

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Segway press coverage zooms, but sales falter

Segway LLC in December 2001 released the self-balancing Segway HT (human transporter) with a brilliantly executed "teaser" public-relations campaign; major print and broadcast press coverage followed. Noted inventor Dean Kamen claimed that the device would "transform the way people work and live" and "provide a solution to short-distance travel." The Segway includes multiple DSPs, sophisticated motor control, and gyroscopes functioning as tilt sensors, all monitoring the user's center of gravity 100 times/sec. Weighing 85 lbs, the Segway can carry as much as 260 lbs at a maximum speed of 12.5 mph, with a range of 15 to 24 miles with a lithium-ion battery pack or 8 to 12 miles with an nickel-metal-hydride pack.

The vendor hoped to sell 50,000 to 100,000 units in the first year at around $5000 each. But, according to papers filed with a recall notice, initiated by a software problem with the battery-charging circuit, the company sold only 6000 units in the first 21 months. Furthermore, industry analysts estimate that the company sold only about 10,000 units through 2004. In hindsight, analysts attribute the poor sales to the Segway's high price, limited applicability, and legal issues. (It's illegal for street use and, in many cities, for sidewalk use.)

—by Bill Schweber, Executive Editor