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GaN, SiC and all that

The 2013 running of the PCIM – Power Control and Intelligent Motion – exhibition and conference, which took place in Nuremberg in May, provided an update on the progress of alternatives-to-silicon in the fabrication of power semiconductor devices. Gallium nitride and silicon carbide have undergone – and are still undergoing – a long gestation period on their route to volume product availability and application. Their potential attractions for the power sector were identified long ago; fast switching, low switching losses and, especially in the case of silicon carbide, tolerance of operation at high temperatures. For a time, news on developments surfaced mainly from smaller and start-up companies; it was well-known that the larger vendors were working on both, but kept their progress under wraps. Other players appeared to fall into two camps; either they had experience of the material (either one) but struggled to make a convincing switch: or they knew all about making switches but were new to the material. A major impetus to progress, or at least to public revelations of progress, came a few years ago when International Rectifier announced it had stabilised GaN-on-silicon fabrication and set out a programme to bring product to the market.

Over the last two years, successive visits to PCIM have been marked by more and more credible displays and demonstrations of product from both the big names in the power semiconductor business, and from smaller companies and start-ups alike. Fairchild, Infineon, International Rectifier, Mitsubishi figured among the former, and names such as Transphorm and GaN Systems among the latter. There is still a (possibly confusing) variety of device structures for the potential user to make sense of; into a context that had become used to either a MOSFET or IGBT, comes a broad device offering that includes FETs, HEMTs, and BJTs. For a time it looked as though, broadly speaking, SiC was carving a niche in high voltage (1200V+) and high temperature, while GaN's more natural home was at lower voltages (to 600V, say) but typically with very fast switching. "Not so", says Canadian company GaN Systems, mentioning GaN-on-SiC substrate devices at 2kV. There have been casualties along the way; missing since the same event last year was Semi South, closed in October 2012.

The module makers are also gaining confidence; for a long time they have assembled combinations of silicon switches and SiC diodes, and are now moving on. Cree, for example, announced a "six pack" 3-phase high-low switch module with all devices – switches and reverse diodes – in SiC. Vincotech (part of Mitsubishi), which gave a presentation at PCIM promoting the virtues of being semiconductor-vendor independent and able to build modules with any active devices of a customer's choosing, made the observation that, "for next-generation solar inverter [modules], 1200-V SiC will be the preferred [switching] choice."

All the while, however, the "internal combustion engine" phenomenon has been in play among the silicon MOSFETs and IGBTs. That is to say, like the internal combustion engine in cars, the accumulated development and momentum of all those years of research continues to drive performance of established device types to new levels. And, as is the case with the car, the margin by which the new technology must exceed the incumbent to gain acceptance with the engineer/designer presents a continually-moving target. Device performance has, some time ago, passed the point where meticulous attention to the detail of layout, mounting, assembly and driving is essential to fully exploit what the silicon can deliver.

Switch performance is of course about much more than on-resistance, but that headline figure illustrates the point. In announcements at PCIM 2013, power switches with RDS(on) figures of under 1 mΩ could be found from several vendors. Clearly, it is easy to nullify the benefits of adopting a device of that class with only a little excess connection resistance. The same principle is of course true for SiC and GaN – an executive of GaN Systems noted that, "You can't put GaN devices into conventional packages [and expect to achieve their potential performance]." Thus, we have the emergence of new package types such as those reported in the Pulse section of this issue, where lead inductance has become the enemy; and of companies dedicated to producing specialised driver circuits, such as CT-Concept, and Amantys.

The range and performance of devices available to the power management engineer looks like it will continue to grow, in interesting directions: which, considering the pressures to deliver ever-more power density and efficiency, is just as well.

pulse

PCI Express protocol analyser spans full range of PCIe 2.0

Teledyne LeCroy has introduced a cost-effective PCI Express protocol analyser with interchangeable interposers for probing. The compact Summit T24 Protocol Analyser has a small chassis footprint while maintaining the same data analysis features found in the company's Summit T3-16 analyser. The T24 supports PCIe data transmission rates up to 5 GT/sec and data lane widths up to x4 in a single compact unit. "[For] companies that are assembling high-end test labs... Teledyne LeCroy is

from low-cost base units to higher data rates and larger lane size, to protect investment in protocol analysis as product requirements change; this is implemented by a flexible licensing arrangement.

Teledyne LeCroy see increasing numbers of applications using the features of PCI Express technology, in embedded boards for military and telecommunications, storage SSDs or consumer products. At 9 x 6.1 x 1.7 in., the Summit T24 occupies a physical volume less than 50% of its predecessor, the Summit T28. This provides not only cost savings but also increased portability for sharing units within a lab or for field applications. The Summit T24 supports all existing Teledyne LeCroy PCIe 1.0 and 2.0 application-specific interposers and probes, which allow quick and easy connection

The Summit T24 analyser occupies only a small amount of bench space and accesses PCIe signals via interposers.

making it possible with products such as the Summit T24 to reach justifiable price points. The T24 provides a complete range of PCIe 2.0 analysis features at a price point that young, innovative companies can afford," according to Joe Mendolia, Vice President of Marketing, Teledyne LeCroy. "Low cost protocol test equipment will allow more companies to implement effective test plans."

The protocol analyser acquires, records, decodes, analyses and displays complex high-speed serial I/O communication streams, such as PCI Express. The Summit T24 provides a solution for system implementers by providing powerful data capture and analysis at prices starting at €4,890. The T24 also supports upgrade paths

to a wide variety of different physical designs. Embedded board developers working with MicroTCA, ATCA, VPX, CompactPCI serial, XMC and similar form factors will appreciate this portfolio of interposers. Each interposer is designed for reliable data transmission between hosts and devices and for quick set-up times for testing new hosts or new devices. The Summit T24 includes the same powerful PETracer software included with Teledyne LeCroy's most advanced PCI Express protocol analysis systems. PETracer includes important data analysis views such as: LTSSM/Substate; Hierarchical; BitTracer ; Data; Flow Control; and Configuration Space Views.
**Teledyne LeCroy,
teledynelecroy.com/europe**

100mA synchronous buck converter with 150V input eliminates TVS

Linear Technology's LTC3639 is a 150V input-capable synchronous buck converter that delivers up to 100mA of continuous output current. It operates from an input voltage range of 4.5V to 150V, eliminating the need for an external transient suppression device. It uses internal synchronous rectification and a programmable peak current-mode design to optimise efficiency over a broad range of output currents. It delivers efficiency up to 92% and requires only 12 μA of quiescent current, maximising battery run time and eliminating thermal issues. It needs only three external components: typically, input (1 μF) and output (10 μF) capacitors and a 470-μH output inductor. A user-programmable output current limit can set output current from 10mA to 100mA to minimise the need to oversize external components and protect high impedance sources. The LTC3639 can be programmed with fixed output voltages of 1.8V, 3.3V or 5V or a resistor divider can be used to set outputs from 0.8V to VIN. The LTC3639's thermally enhanced MSOP package offers the additional pin spacing required for high voltage inputs. The combination of its MSOP package with only three small external components provides a highly compact solution footprint. The LTC3639's internal high side and synchronous power switches, drawing only 12μA at no load while maintaining output voltage regulation, suit it to always-on battery-powered applications. Due to the inherent stability of the converter, no external compensation is required, simplifying the design and minimising the solution footprint. Additional features include a precise 0.8V +/-1% feedback voltage reference, internal or external soft-start and a feedback comparator output which enables multiple LTC3639s to be connected in parallel for higher current applications.

pulse

Pricing for the LTC3639EMSE starts at $3.65 (1000). An industrial temperature grade version, the LTC3639IMSE is guaranteed to operate from -40°C to 125°C operating junction temperature, and costs $4.02. An automotive temperature grade, the LTC3639HMSE is guaranteed to operate over a -40°C to 150°C operating junction temperature range, at $4.27. And, a high reliability military plastic version, the LTC3639MPMSE, is tested and guaranteed to operate from -55°C to 150°C operating junction temperature, priced at $10.84.
Linear Technology, www.linear.com/product/LTC3639
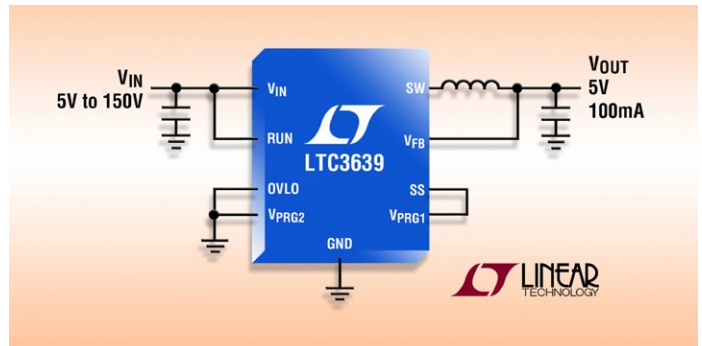
150V, 100mA synchronous buck converter with adjustable output current limit

Select resolution from 8 to 16 bits in a USB oscilloscope

Pico Technology has used reconfigurable ADC technology to offer a choice of resolutions from 8 to 16 bits in a single product; the company says this is the first time this facility has been possible in an oscilloscope. Most digital oscilloscopes achieve their highest sampling rates by interleaving multiple 8-bit ADCs. Pico asserts that, despite careful design, the interleaving process introduces errors that always make the dynamic performance worse than the performance of the individual ADC cores. PicoScope 5000 Series scopes have a significantly different architecture in which multiple high-resolution ADCs can be applied to the input channels in different series and parallel combinations to boost either the sampling rate or the resolution.

In series mode, the ADCs are interleaved to provide 1 Gsample/sec at 8 bits. Interleaving reduces the performance of the ADCs, but the resulting dynamic range (60 dB SFDR) is still much better than oscilloscopes that interleave 8-bit ADCs, the company asserts. This mode can also provide 500 Msamples/sec at 12 bits resolution.

In parallel mode, multiple ADCs are sampled in-phase on each channel to increase the resolution and dynamic performance. Resolution is increased to 14 bits at 125 Msamples/sec per channel (70 dB SFDR). If only two channels are required then resolution can be increased to 15 bits, and in single-channel mode all the ADCs are combined to give a 16-bit mode at 62.5 Msamples/sec.

Pico has been developing high-resolution oscilloscopes for around 20 years, but says that developing a new analogue front end to support an oscilloscope that can be switched between different resolutions was nevertheless a significant challenge. Careful attention was required to support the high-resolution modes (with low noise, low distortion and bandwidth flatness) while maintaining the bandwidth, slew rate and pulse response necessary for the faster 8-bit mode.

As well as flexible resolution, these oscilloscopes have deep memory buffers of up to 512 Msamples to allow long captures at high sampling rates. They also include, as standard, advanced software features such as serial decoding, mask limit testing and segmented memory.

PicoScope 5000 Series Flexible Resolution Oscilloscopes are available from Pico distributors worldwide and from www.picotech.com. Prices range from €846/£699/$1153 for the 2-channel 60-MHz model with built-function generator to €2056/£1699/$2803 for a 4-channel 200-MHz model with built-in arbitrary waveform generator. Prices include a set of matched probes, all necessary software and a 5-year warranty.
Pico Technology, www.picotech.com

The 5000-series oscilloscope communicates via USB to display waveforms on any PC, laptop or portable platform.

18-bit A/D converter is smallest available - Maxim

Maxim's MAX11156 bipolar successive-approximation register (SAR) ADC integrates a reference buffer and internal reference, has excellent AC and DC performance, and is the smallest-available 12-pin, 18-bit SAR ADC, the company says. In a 3 x 3mm TDFN package, the chip integrates an internal reference and reference buffer, saving cost and at least 70% board space over alternative solutions. With 18-bit resolution, it features 'Beyond-the-Rails' technology, which supports a ±5V input from a single positive 5V input rail. This eliminates the need for negative power supplies and simplifies designs. With 18-bit resolution and a 500 ksamples/sec sampling rate, you might use the MAX11156 in automatic test equipment (ATE), industrial control systems, medical instrumentation, and robotics, where high accuracy and tiny size are important.

Due to its monotonic transfer characteristic, fast settling time, and lack of latency, the MAX11156 is suited to fast, high-precision digital control-loop systems. It provides the 18-bit resolution with no missing codes; excellent DC accuracy (0.5 LSB DNL and 2.5 LSB INL (typical)); and excellent AC performance (94.6dB SNR and -105dB THD (typical)). Additionally, it communicates using an SPI-compatible serial interface, which can be used to daisy-chain multiple ADCs in parallel for multichannel applications. This interface can also provide a 'busy' indicator to simplify system synchronisation and timing. Specified over the -40°C to +85°C temperature range, pricing starts at $16.90 (1000).
Maxim Integrated, www. maximintegrated.com

pulse

High density zero-voltage-switching DC/DC converter modules

Vicor has added to its Picor isolated Cool-Power ZVS DC-DC converter modules with high power density (334 W/in³) units; paired with Picor QuietPower active EMI filters they fit space-constrained industrial and aerospace/defence applications. You might use these devices, Vicor suggests, in roles such as provisioning ancillary services in a higher-power industrial supply configuration. In contrast to many applications that Vicor has recently targetted, absolute efficiency may not be the most important parameter in such examples, but power density, where a power rail may have to be placed in a confined space within a host system. The ultra high density Picor Cool-Power PI31xx series of isolated, ZVS-based DC-DC converters is optimised for 24-V industrial, 28-V aerospace/defence and/or demanding wide temperature applications. The Cool-Power PI31xx converters retain the product series' 0.87 x 0.65 x 0.265 in. surface-mount package profile to provide up to 334 W/in³ power density and 2.25 kV input to output isolation. At less than 50% the size of a conventional isolated 1/16th brick, Cool-Power PI31xx converters provide high performance in an IC package to meet that high-density system design limitation. Vicor presents these devices as being complementary to its non-isolated conversion blocks in configuring more complex supply schemes.

Cool-Power PI31xx series converters use a Zero-Voltage Switching (ZVS) architecture and high-performance planar magnetics to enable IC-like density and greater PCB layout flexibility in space-constrained environments. The high-switching frequency (900 kHz) reduces input filter and output capacitance requirements, further reducing space constraints. Programmable features include output voltage trimming, programmable soft-start capability, and remote on/off enable. There is also a temperature monitor function, providing an

These surface-mount modules achieve 50/60W handling in a space less than a 1/16th brick outline.

analogue output voltage proportional to the internal module temperature.

The PI31xx is self-protected against fault conditions including: input over-voltage, under-voltage lockout, over-temperature, and output over-voltage protection. A constant current limit threshold is employed to protect against short circuit and overload conditions. All fault conditions have an auto-restart function.

When paired with 0.98 x 0.49 x 0.18 in. Picor QuietPower EMI filters – the smallest filters in this product category at less than 25% the size of competing offerings – you get a small end-to-end isolated DC-DC conversion and EMI filtering function. QuietPower filters provide up to 99.5% efficiency and are designed for universal compatibility with high frequency switching DC-DC converters from any manufacturer. Example products include the QuietPower QPI-12 filter with high common-mode (better than 40dB) and high differential-mode (better than70dB) attenuation for industrial applications. For aerospace/defence applications, the MQPI-18 offers >45dB and >75dB common-mode and differential-mode attenuation respectively.

Vicor, www.vicorpower.com

Gallium nitride delivers 97.5% efficiency in PF-Corrected supply

A reference circuit design using 600-V GaN HEMTs combines a totem-pole PFC circuit with a LLC converter to achieve total conversion losses that are claimed to be half of that possible with silicon.

Transphorm Inc. has announced a high-efficiency off-line 1 kW 48-Vdc power supply that has demonstrated peak efficiency of 97.5%. The power supply design uses Transphorm's JEDEC-qualified GaN-on-silicon 600V high electron mobility transistors (HEMTs) to implement a 99% efficiency totem pole power factor correction (PFC) front end, combined with a 98.6% efficiency LLC converter.

Based on Transphorm's EZ-GaN technology, the TPH3006PS HEMT combines low switching and conduction losses to reduce energy loss by a claimed 50% compared to conventional silicon-based power conversion designs. The TO-220-packaged GaN transistor features low on-state resistance (RDS(on)) of 150 mΩ, low reverse-recovery charge (Qrr) of 54 nanocoulombs (nC) and high-frequency switching capability – all of which result in lower loss, more compact, lower cost systems.

"Transphorm's GaN-based power supply design exceeds the best efficiency results possible with silicon by at least 1%,"
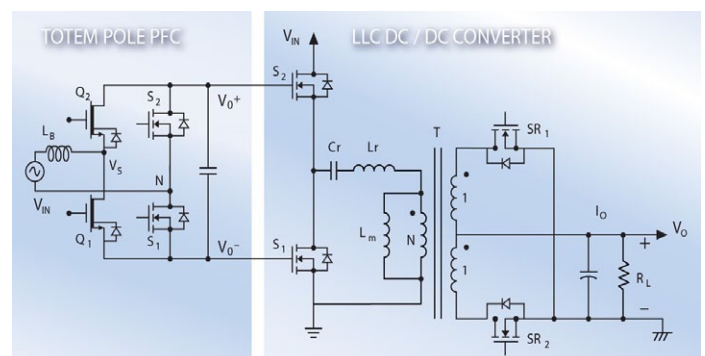
Gallium-nitride power switches cut conversion losses to below that possible with silicon, Transphorm says.

said Umesh Mishra, CEO of Transphorm, "And while recent advances in superjunction silicon devices have reduced their output capacitance by 20% and the Qrr of the intrinsic body diode by 25%, these improvements lag far behind the effective Qrr of the new GaN transistors which reduce Qrr by 95%." Currently being supplied to approved customers, the TPH3006PS and TPH3006PD HEMTs cost $5.89 (1,000). The TPS3410PK and TPS3411PK diodes cost $2.06 and $1.38 (1,000).

Transphorm, www.transphormusa.com

pulse

Synthesised 360° view with approaching-object detection

Fujitsu Semiconductor 's MB86R24 is one of the company's third-generation high-performance graphic SoCs for automotive applications, updating CPU and GPU performance for faster processing and sharper image rendering. The SoC has six full-HD input channels and three display output channels, allowing for greater flexibility in input/output control. Fujitsu says it has, for the first time, been able to incorporate an Approaching Object Detection function, which notifies drivers of nearby people, bicycles and other objects-into the 360° Wraparound View System that allows drivers to check their entire surroundings in 3D from any angle. The chip also enables centralised control of display information for different driving situations. The product will also enable the development of integrated human machine interface (HMI) systems that consolidate and provide centralised control over a variety of onboard vehicle information. Until now, the display of such information on multiple screens has been controlled independently for each screen, Fujitsu says, adding that the new device will help in improving safety, comfort and peace of mind for car drivers, as well as in home and industrial applications.

The 360° Wraparound View System uses cameras facing forward, backward, left, and right to synthesise a 3D model of the environment and then display the surroundings from any perspective. In 2012, Fujitsu Semiconductor developed a 360° wraparound view system that employed a second-generation MB86R10 series graphics SoC and also worked with megapixel cameras. As systems such as this, which give clear visual confirmation of a vehicle's surroundings, grow in popularity, there will be increasing expectations for additional functionality that reduces the likelihood of driver oversights while promoting safer, more confident driving. MB86R24 has roughly double the CPU performance and five times the GPU performance of its second-generation predecessor, delivering sharper images and the ability to view surroundings from any perspective. The Approaching Object proximity detection algorithm was developed jointly with Fujitsu Laboratories, and the company claims it as the first such implementation as part of a 360° wraparound view system.
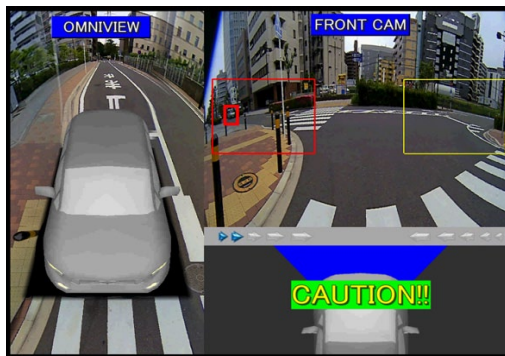
Approaching object detection can issue alerts to developing hazards.

The amount of information shared between drivers, vehicles and the outside world is steadily growing. Such information includes battery information for electric vehicles, camera imagery, navigation information, and connectivity with smartphones and the cloud. Different kinds of information are displayed on different screens, such as central console displays, cluster displays, or heads-up displays, all of which require separate display control. To provide such information in real time to drivers in an easy-to-understand manner, there is a need for technology that can collect information in a single location and centrally control how it is displayed depending on the driving scenario. HMI systems can accomplish this, and MB86R24 is able to control each display to present information that suits the current driving scenario.

The new SoC facilitates the development of modules and platforms for displays that can be incorporated into multiple models, rather than one-off development for each car model. This, in turn, enables a significant reduction in part counts for display systems, while also making it simpler to re-use products in different car models. The chip comes with the software needed to build these systems. This enables one-stop development of high-performance systems with far less work than before.

The CPU employs two ARM CortexT-9 cores along with PowerVRTSGX543 3D graphics. MB86R24 also features Fujitsu Semiconductor's proprietary 2D graphics engine. Since the 3D and 2D graphics engine each run independently of one another, it is possible to obtain even greater graphics processing performance. In addition to a 2D engine, 3D engine, and video capture function, all of which can be run simultaneously, the new SoC features eight rendering layers, making it possible to perform graphics processing on different layers that is optimised to meet the needs of specific applications and content. The 360° Wraparound View System with Approaching Object Detection works with the toolset software for the previous edition of the technology, and software enabling Approaching Object Detection functionality will also be made available. For integrated HMI systems, Fujitsu Semiconductor offers CGI Studio, an authoring tool that allows content designers and engineers to collaboratively design media for the system. MB86R24 'Triton' product samples will be available from August 2013.
Fujitsu Semiconductor Europe (FSEU); http://emea.fujitsu.com/semiconductor

40V automotive-qualified FETs further reduce on-state resistance

International Rectifier has introduced a family of automotive-qualified COOLiRFET MOSFETs optimised for low on-state resistance (Rds(on)) for heavy load applications including electric power steering (EPS), braking systems and other heavy loads on internal combustion engine (ICE) and micro hybrid vehicle platforms. The family of 22 AEC-Q101 qualified 40V N-channel MOSFETs use IR's Gen12.7 trench technology that delivers very low Rds(on) in D2Pak-7P, D2Pak, DPak, TO-262, IPAK and TO-220 packages. The D2Pak-7P AUIRFS8409-7P delivers Rds(on) max as low as 0.75mOhm at 10Vgs with a current rating up to 240A. The new devices offer low conduction losses and robust avalanche performance to deliver higher efficiency, power density and reliability. With this performance, many applications using these new COOLiRFET devices run significantly cooler than with state-of-the-art MOSFETs, IR says. The new devices are AEC-Q101 qualified, which requires that there is no more than a 20% change in Rds(on) after 1,000 temperature cycles of testing.
International Rectifier, www.irf.com

On-resistances under 1 mΩ in some package configurations characterise these automotive-switching FETs.

pulse

Infineon adds package variants for high-power switches

For its range of power semiconductors, Infineon has created two new package variants. One, it terms the TO-Leadless, which the company designed for high current applications up to 300A, and for use at 250V and below. It claims reduced package resistance, significantly smaller size as well as improved EMI behaviour. In the first release, it contains the latest OptiMOS MOSFET generation for applications with high power and reliability requirements such as forklift, light electric vehicles, eFuse, PoL (Point of Load) and telecom systems. Low package resistance enables the lowest RDS(on) in all voltage classes; the 60% smaller package size compared to D2PAK 7pin enables a very compact design. TO-Leadless shows a substantial reduction in footprint of 30% and requires less board space in, for example, forklift applications. You can, the company adds, realise substantial space savings when multiple devices are used in parallel. The 50% reduced height offers a significant advantage in compact applications such as rack or blade servers. Moreover low package parasitic inductances result in an improved EMI behaviour, Infineon says, and the thermal solder pad area is larger, leading to efficient heat transfer. It hosts what the company says is the first 0.75mΩ 60V MOSFET, which reduces the number of parallel MOSFETs in a forklift application and increases power density. A 50% bigger solder contact area which leads to lower current density. This helps to avoid electro migration at high current levels and temperatures, resulting in improved reliability. Unlike other leadless packages TO-Leadless offers an optical inspection due to tin plated grooved leads. Samples of TO-Leadless are available now in 30V (0.4 mΩ max.), 60V (0.75 mΩ max.), 100V (2.0 mΩ max.) and 150V (5.9 mΩ max.) with production devices available in the third quarter 2013. More at; www.infineon.com/toll.

4-lead TO-247

Together with ST Microelectronics, Infineon has also developed a custom TO 247-4 pin package for its CoolMOS MOSFETs; the added fourth pin acts analogously to a Kelvin measurement point, but rather than eliminating the effect of lead resistance the intention is to reduce the effects of parasitic inductance of the source lead of the power MOSFET. It connects directly to the transistor source but bypasses the high-current source lead itself.

The efficiency benefit will be highest in various hard switching topologies such as Continuous Conduction Mode Power Factor Correction (CCM PFC), Boost and Two Transistor Forward (TTF).

The new package offers improved efficiency by reducing switching losses by up to 8%. This equates to 5W lower power dissipation on the MOSFET in a CCM PFC running at 1.2KW, which means 0.4% extra full load efficiency compared to the same MOSFET in the standard 3-pin TO 247 package. The new TO 247-4 is available from both Infineon and ST, as an alternative source.

"The latest generation of Superjunction MOSFETs is able to switch several hundreds of volts and several tens of amperes within a few nanoseconds. To reach the full benefit of the chip technology the package is an important factor to set up an appropriate system environment which is crucial to reach the next level of energy efficiency," said Jan-Willem Reynaerts, Product Segment Head of High Voltage Power Conversion at Infineon Technologies.

An additional benefit of the Kelvin source configuration in the TO 247-4 is the ease of use for the PCB layout due to its new pin arrangement with the exposed drain and the source between gate and drain. This reduces the critical drain to gate coupling, which often causes gate oscillations at turn off with high dv/dt rates of the Drain-Source Voltage (V DS). Furthermore, the increase of creepage distance between drain and source improves system reliability. The new package is optimised for high power applications such as server, telecom and solar energy.

CoolMOS C7 – the latest generation of Infineon's Superjunction power transistors, which has been announced recently – will be the first Infineon MOSFET family using the TO 247-4 pin package.

ST will first use the package to house an MDmesh V Super-Junction MOSFET: the new TO247-4 4-lead package provides, ST comments, "a direct source connection used only for switching control, whereas conventional packages provide one connection for both switching and power. The extra lead increases switching efficiency, which reduces energy losses and allows higher-frequency operation for more compact power supplies. The TO247-4 is highly cost-effective and requires only minimal modification of the PCB layout when replacing a standard TO-247 device, which simplifies adoption in power systems." Up to 60% of switching losses can be eliminated and designers can use higher switching frequencies that require smaller filtering components. The specific device from ST is theW57N65M5-, priced from $10.00 (1,000).

Infineon, www.infineon.com/c7
ST Micro, www.st.com/to247-4-pr

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WHAT MAKES INDUSTRIAL SENSORS
GO AWRY?

SENSORS THAT MEASURE PARAMETERS SUCH AS PRESSURE, TEMPERATURE, TOXIC GAS, AND PH ARE ABUNDANT AND MAKE INDUSTRIAL PROCESSING SAFER, MORE EFFICIENT, AND LESS COSTLY. EACH SENSOR TYPE, HOWEVER, HAS ITS OWN SET OF UNIQUE CHARACTERISTICS, RESULTING IN VARIOUS AND COMPLEX DESIGN CHALLENGES.

BY JASON SEITZ • TEXAS INSTRUMENTS

One of the most popular measurements in industrial processes is temperature. Temperature can be measured by a variety of sensor types, including thermocouples, resistance-temperature detectors (RTDs), and thermistors.

To measure the largest temperature range, a system designer often uses a thermocouple. For example, a Type C thermocouple has a measurement temperature range between 0 and 2320°C. The thermocouple's principle of operation is based on the Seebeck effect, where, if two dissimilar metals are placed together, a voltage is produced that is proportional to the temperature at the junction. Thermocouples are bipolar devices that produce a positive or negative voltage, depending on the sensing, or "hot" junction, temperature relative to the reference, or "cold" junction, temperature. First, you need a bias to the thermocouple so it won't rail against ground in a single-supply system. Next, measure the cold-junction temperature to obtain the temperature being measured. One drawback to thermocouples when compared with other temperature sensors is limited accuracy, which is typically worse than ±1°C.

If the system requires greater precision over a reduced temperature range—say less than 660°C—a designer can implement the measurement with an RTD, which can be as accurate to below ±1°C. RTDs are resistive elements whose resistance depends on the ambient temperature in which they are placed. They come in two-, three-, and four-wire configurations. Increasing the number of wires increases accuracy. RTDs require an excitation in the form of a current source. Current-source values often are 100 µA to 1 mA to handle PT100 (100Ω at 0°C) and PT1000 RTDs (1000Ω at 0°C).

For accuracy up to ±0.1°C, with the trade-off of an even smaller temperature range (less than 100°C), you can use thermistors. Similar to RTDs, thermistors' resistance also changes with temperature. Thermistors typically are connected in a resistor-divider configuration where the other resistor in the divider is the same as the nominal value (value at room temperature, 25°C) of the thermistor. One end of the thermistor is connected to the supply voltage; the other end is connected to the other resistor, which in turn is connected to ground (**Figure 1**). To determine temperature, measure the voltage at the divider's center point. You would expect +V/2 at 25°C. For any deviations from this, you can calculate the thermistor's resistance and use a look-up table to determine the ambient temperature being measured.

In summary, temperature sensors need bias (voltage or current). When it comes to thermocouples, cold-junction compensation is needed. The Texas Instruments LMP90100 is a 24-bit sensor analog front end (AFE) with four differential or seven single-ended inputs, two matched programmable current sources, and continuous background calibration (**Figure 2**). This integrated configurable chip is suitable for addressing the various design challenges associated with temperature sensors.
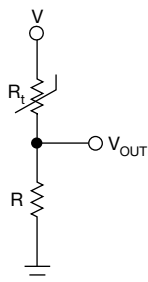
Figure 1 *A thermistor circuit is shown with one end connected to the supply voltage and the other to the other resistor and the ground.*

AT A GLANCE

- Temperature, an important measurement in industrial processes, can be determined using thermocouples, resistance-temperature detectors, and thermistors.
- Strain gauges and load cells that utilize the Wheatstone-bridge circuit are popular for measuring pressure, force, and weight.
- Electrochemical cells typically are used to measure various gases. An alternative is nondispersive infrared technology.
- Using an appropriate analog front end improves measurement accuracy while reducing design complexity.

Strain gauges and load cells that utilize the Wheatstone-bridge circuit are popular implementations for measuring pressure, force, and weight. Any strain or stress on the gauge causes a resistance change and subsequent voltage differential change on the sensor output (**Figure 3**). The voltages that come out of these sensors are low, typically in the millivolt range. To make the most accurate measurements, amplify this small voltage up to the data converter's full dynamic range. A programmable-gain-amplifier (PGA) stage allows for interfacing with multiple sensors as well as optimum flexibility. This stage should have low noise, low offset, and low-offset drift to ensure the best system performance.

These types of sensors also require excitation in the form of a bias voltage. A common failure mode for pressure sensors is incorrect measurements due to opens or shorts in the bridge. Even harder to detect are out-of-range signals caused by sensor damage or degradation over time. A way to catch all of these failure modes is to incorporate a diagnostic circuit. This circuit injects a small current, sometimes referred to as "burnout" current, into the resistor ladder of the Wheatstone bridge and then measures the resulting voltages.

If, for example, the bridge outputs are at the same potential (+V/2), is it because there is no pressure on the gauge or because you have a failure in the system that is shorting the outputs? Injecting current into one of the differential outputs and measuring the differential voltage between the outputs can answer this question. In normal operation, the differential voltage will be the voltage drop across the resistors in the bridge. However, if there is indeed a short, there will be little or no voltage drop.

In short, Wheatstone-bridge sensors require an excitation voltage, a low-noise/offset PGA, and diagnostics. The LMP90100 also mates well with these types of sensors. Its continuous background sensor diagnostics allow detection of open-circuit, short-circuit, and out-of-range signals. By injecting burnout currents into a channel after it has undergone a conversion, it avoids burnout-current injection from interfering with the channel's conversion result. Diagnostics provide continuous noninvasive failure detection, aid in root-cause analysis, and minimize system downtime.

Electrochemical cells typically are used to measure a wide variety of toxic and nontoxic gases, such as carbon monoxide, oxygen, and hydrogen. They are based on the principles of chemical oxidation and reduction, and produce a current in proportion to the measured gas. Most cells comprise three electrodes: working (WE), counter (CE), and reference (RE). The WE oxidizes or reduces the target gas and produces a current proportional to the gas concentration. The CE balances the generated current, and the RE maintains the working electrode potential to ensure the proper region of operation. Electrochemical cells are intended to interface with a potentiostat circuit. This potentiostat circuit provides current (and biasing, if required) to the CE. It maintains the WE at the same potential as the RE and converts the output current from the WE into a voltage using a transimpedance amplifier (TIA).

Electrochemical sensors, like many sensors, have a dependence on temperature. To enable the best performance, measure the cell's temperature. Make appropriate temperature corrections based on that cell's performance versus temperature plots, which can be found in the data sheet.

The sensor, gas type, and gas-concentration level dictate how much current will be output at the sensor's working electrode. To handle this variability, use a TIA with adjustable gain. Currents in the level between one to hundreds of microamperes are possible, so having a TIA gain in the one to hundreds of kilohms range is sufficient.

Different sensors require different biasing; some require a zero bias. Be aware of these requirements so that the current produced by the sensor meets specifications. Whether the cell goes through an oxidation (CO) or reduc-
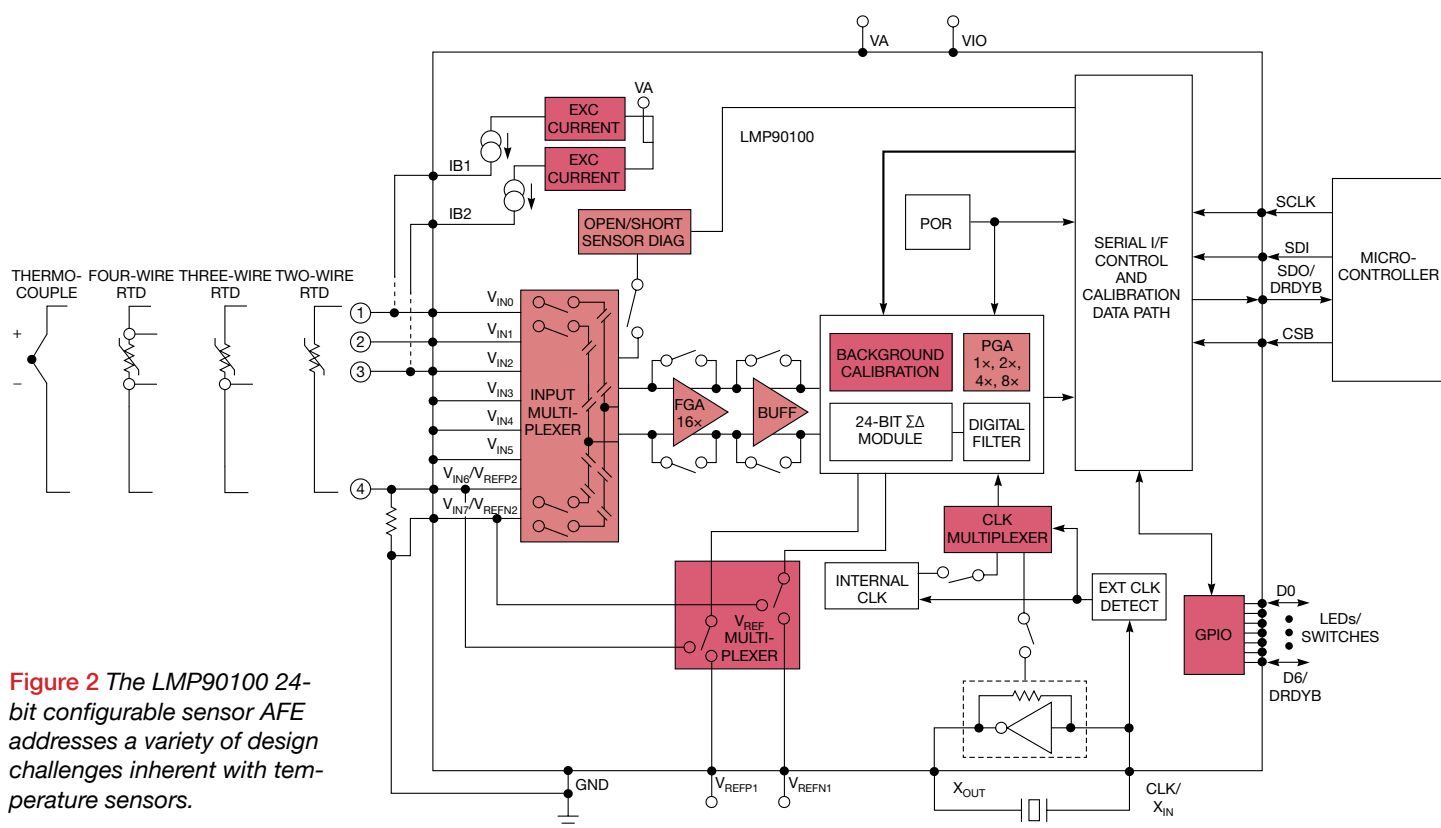
Figure 2 *The LMP90100 24-bit configurable sensor AFE addresses a variety of design challenges inherent with temperature sensors.*

tion (NO_2) reaction to the measured gas determines if the cell produces a current into or out of the WE, respectively. The voltage at the TIA's noninverting pin should be level-shifted appropriately to ensure maximum gain without saturating the amplifier's output in single-supply systems. For example, the TIA produces an output voltage governed by the equation $V_{OUT}=-I_{IN}\times R_{FEEDBACK}$, where I_{IN} is current going toward the TIA across the feedback resistor. If the current into the TIA is positive (reduction reaction), V_{OUT} will be negative in reference to the noninverting pin voltage. That voltage should be raised to avoid railing the output to the negative supply.

Basically, it is essential that electro-chemical cells have temperature correction and a potentiostat circuit that provides current sinking/sourcing, voltage biasing, current-to-voltage conversion, and level shifting. The TI LMP91000, a configurable AFE potentiostat, satisfies these functions. It contains a complete potentiostat circuit with sink and source capability along with programmable TIA gain, electrochemical-cell bias, and internal zero voltage. Moreover, this sensor AFE contains an integrated temperature sensor and comes in a small 14-pin, 4-mm² package that allows positioning the device directly under the electrochemical cell for accurate temperature compensation and improved noise performance.

Not all gases can be accurately measured with an electrochemical cell. An alternative is to use nondispersive infrared (NDIR) technology, a type of IR spectroscopy. IR spectroscopy is based on the principle that most gas molecules absorb IR light. (Absorption occurs at a specific wavelength.) The amount of light absorbed is proportional to the gas concentration. Specifically, NDIR passes all IR light through the gas sample and uses an optical filter to isolate the wavelength of interest.

Typically, a thermopile with a built-in filter is used to detect the amount of a specific gas. For instance, because CO_2 has a strong absorbance at a wavelength of 4.26 µm, a bandpass filter is used to remove all light outside of this wavelength. Along with CO_2 and alcohol detection, NDIR gas sensors also can be used to detect greenhouse gases and refrigerants such as Freon.

A major obstacle with NDIR systems is accurately determining, over time, whether changes in the light transmitted to the detector are actually due to absorption from gas rather than deterioration of the light source or chamber contamination. Calibration is possible at the beginning of the NDIR system operation. To combat light-source deterioration and chamber contamination over time, however, ongoing calibration is required.

This calibration can be expensive and time-consuming and is just not feasible in long-term field operation.

One way to solve this problem is to employ a reference channel in your system. This reference channel contains a detector that measures the light source in a range where no absorption occurs. Gas concentration now is determined by the ratio of the two transmitted light quantities. Any errors due to the light source's deviating are now cancelled out. This deviation results in long-term drift, which occurs over long periods of time. Hence, there is no need to simultaneously sample both the reference and active channel. You can use an input multiplexer to switch between the two channels, reducing system cost and complexity while maintaining accuracy.

Thermopiles used as IR detectors in NDIR systems produce a voltage based on the amount of incident light they receive in watts. The measured gas type, its absorption coefficient, and the gas-concentration range all affect the amount of incident light on the thermopile detector. The result is thermopile output voltages, typically in the range of tens of microvolts. Therefore, you need to design supporting electronics with the ability to amplify the thermopile output voltage with different gains. This can be handled by an AFE with a built-in PGA. Gain settings in the range of hundreds
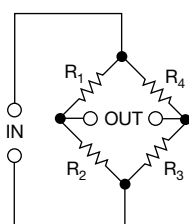
Figure 3 *A Wheatstone-bridge circuit is shown. Any strain or stress on the gauge causes a resistance change and subsequent voltage differential change on the sensor output.*

to thousands of V/V are required to amplify the small thermopile signal to the system's full-scale ADC, and achieve maximum system accuracy.

Another factor in NDIR system design is knowing how to handle the significant offset voltages associated with thermopile sensors. The thermopile is expected to have an offset component larger (up to 1 mV) than the actual signal, which limits the system's dynamic range. A way to minimize this problem is to integrate offset compensation into the system's electronics. One solution is to use a DAC to compensate for the measured offset. The system microcontroller can capture the level of offset and remove the offset by programming the DAC to shift the output toward the negative rail, zero scale. This solution utilizes the ADC's complete dynamic range, minimizing ADC resolution requirements.

Also, due to the thermopile's offset voltage, you need to bias the thermopile

above ground. You can do this with a common-mode generator, which applies a common-mode voltage to the sensor. This approach level-shifts the thermopile sensor signal away from the negative rail, allowing for accurate sensing in the presence of sensor offset voltages.

Again, NDIR systems need a reference channel, adjustable amplification, offset compensation, and biasing. The LMP91051 configurable sensor AFE can handle this task for NDIR sensing applications (**Figure 4**). It has a dual-channel input to support an active and reference channel, PGA, adjustable offset cancellation DAC, and common-mode generator. The LMP91051's ability to integrate these important NDIR system blocks reduces design time, board space, power, and cost.

A pH electrode measures hydrogen-ion (H+) activity and produces an electrical potential or voltage. The pH electrode operates on the principle that an electric potential develops when two liquids of different pH come into contact at opposite sides of a thin glass membrane. These pH electrodes use the same principle to measure pH in a variety of applications, including water treatment, chemical processing, medical instrumentation, and environmental test systems.

The pH electrode is a passive sensor, which means no excitation source (voltage or current) is required. However, it's a bipolar sensor whose output can swing above and below the reference

point. Therefore, in a single-supply system, the sensor needs to be referenced to a common-mode voltage (often half-supply) to prevent it from railing to ground.

The source impedance of a pH electrode is very high because the thin glass bulb has a large resistance, typically in the range of 10 to 1000 MΩ. This means that only a high-impedance measurement circuit can monitor the electrode. Furthermore, the circuit should have low-input bias current since even the smallest current injected into the high-impedance electrode creates a significant offset voltage and introduces measurement error into the system. Also, it is possible that current drawn from the pH electrode, while the system is shut down, can degrade the sensor over time. It is important, therefore, to keep the input bias current low, even when power is not supplied to the measurement circuit.

The pH electrode produces a voltage output that is linearly dependent upon the solution's pH being measured. The transfer function and pH scale in **figures 5** and **6** show that as the solution's pH increases, the voltage produced by the pH-measuring electrode decreases. Note that a pH electrode's sensitivity varies over temperature. Looking at the pH electrode transfer function shows that the sensitivity linearly increases with temperature. Due to this behavior, it is critical to know the solution's temperature being measured and compensate
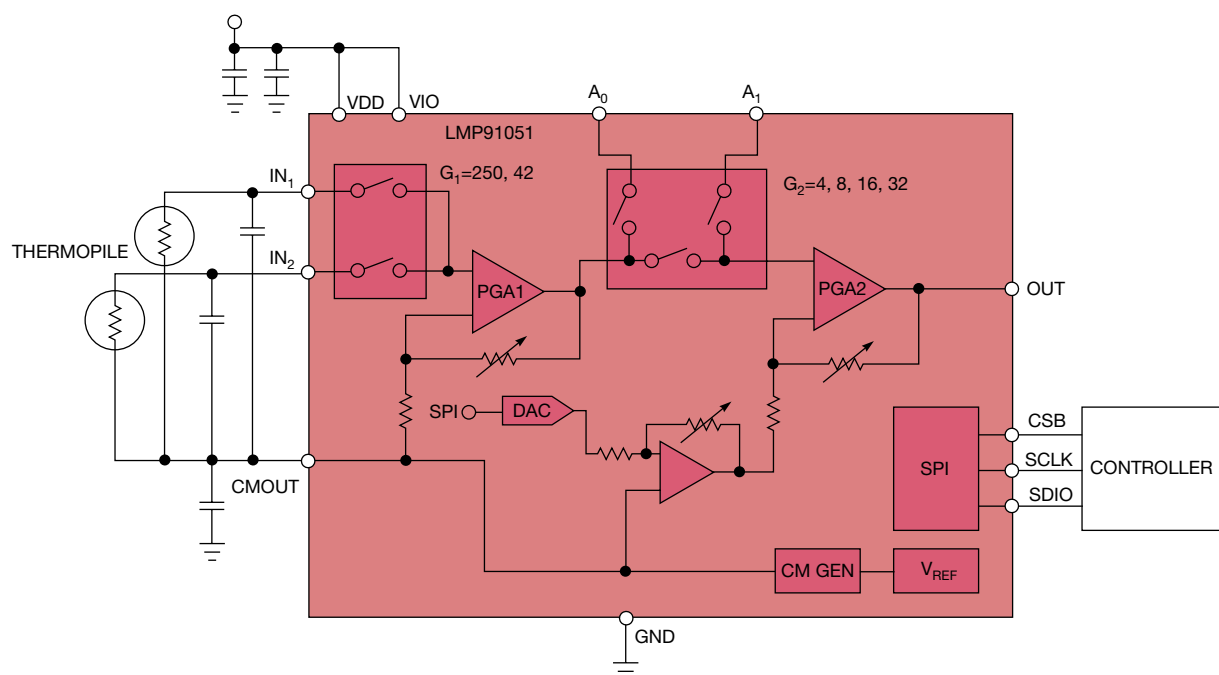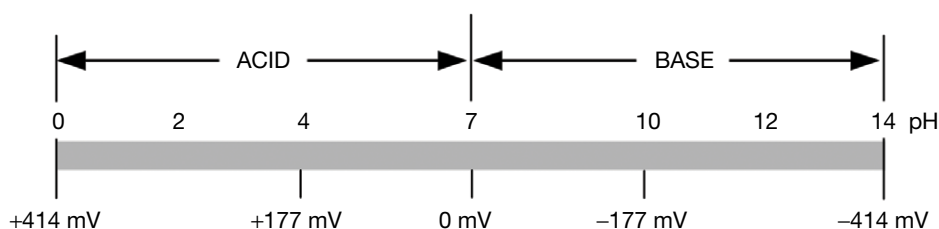

Figure 4 *The level of integration provided by the LMP91051 configurable sensor AFE for NDIR sensing reduces design time, board space, power, and cost.*
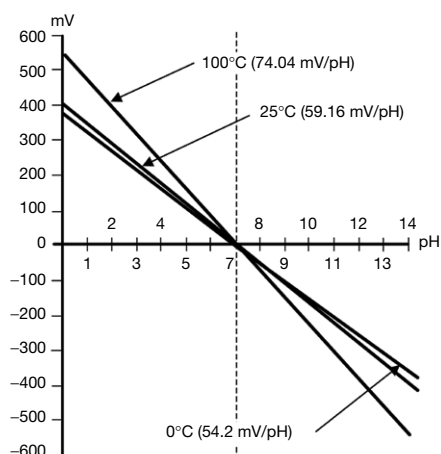
Figure 5 *A pH electrode produces a voltage output that is linearly dependent upon the solution's pH being measured.*

Figure 6 *As the pH increases, the voltage produced by the pH-measuring electrode decreases.*

the measurement accordingly.

In the end, pH sensors require a high-impedance, low-input bias current interface, common-mode voltage, and temperature-compensation ability. The LMP91200 sensor AFE for chemical sensing addresses these functions (**Figure 7**). You can interface easily with RTDs with its programmable current source. Temperature-measurement accuracy is further enhanced with the multistep temperature-measurement feature, which removes error in the tem-

perature signal path. The device's input bias current is in the range of only tens of fA at 25°C, minimizing error when connecting to a high-impedance pH electrode. Finally, the bias current is just hundreds of fA when the device is powered off, minimizing electrode degradation due to current draw over time.

Some of the design challenges associated with industrial sensors include the need for excitation, gain, temperature compensation, offset cancellation, current-to-voltage conversion, high-impedance interface, and diagnostics. Using an appropriate AFE improves measurement accuracy while reducing design complexity.EDN

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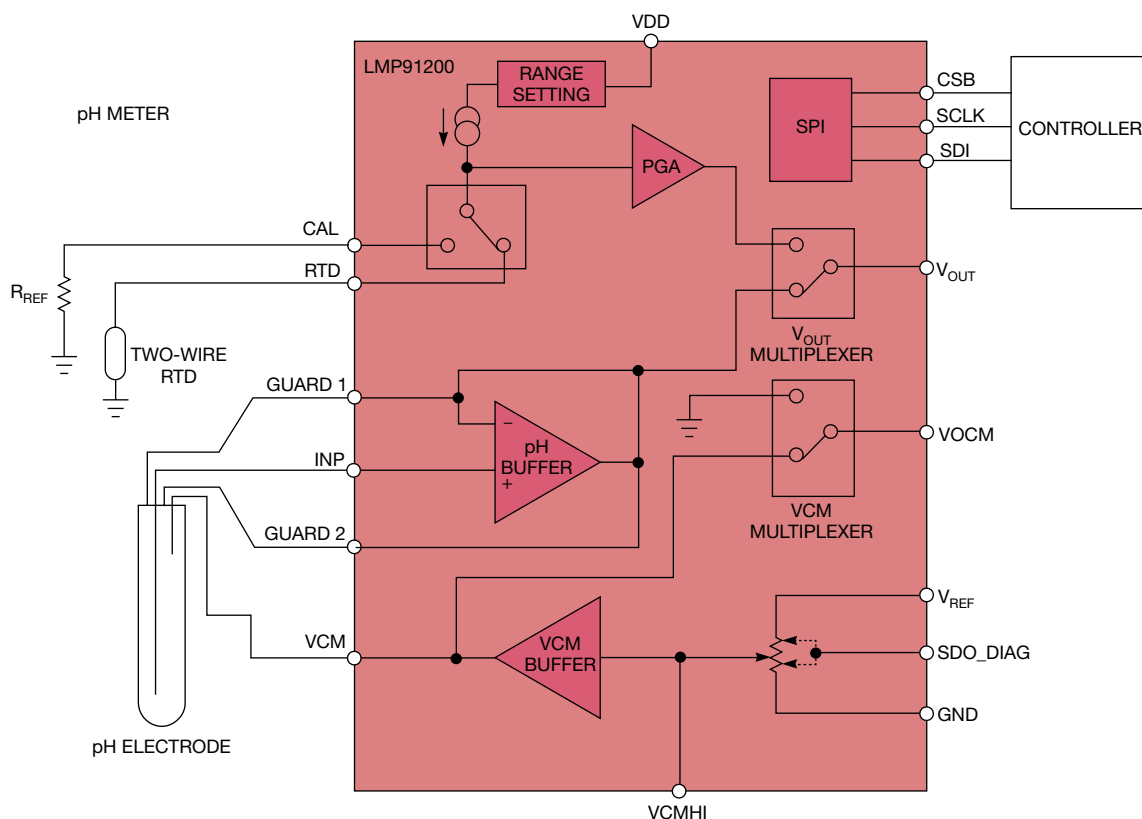
Figure 7 *The LMP91200 configurable sensor AFE for chemical sensing addresses the need for high impedance, a low-input bias current interface, common-mode voltage, and temperature compensation.*

BY HOWARD JOHNSON, PHD

WHY REFLECTIONS HAPPEN

Throw a rubber ball hard against a concrete wall. The ball bounces. You have just experienced a reflection. Reflections happen in propagating systems at those points where the conditions of propagation change.
The best way to understand reflections is to track the movement of energy. When the ball reaches the wall, it cannot continue on its original course. Neither can the ball simply stop, because the energy associated with its incoming path cannot just disappear; it must go somewhere.

Nature solves this problem by dividing the incoming energy among the available outgoing modes of propagation. Those modes include the ball's retreating along its incoming direction, an acoustic wave (bonk!) generated in the air, a slight movement of the concrete wall, and a residual thermal agitation of both rubber and concrete.

The proportions of energy contained in each outgoing mode are determined by the law of conservation of momentum in combination with the various properties, called boundary conditions, of each individual outgoing mode. The reflecting-ball problem is tricky, because the ball can arrive at any incident angle, it can carry spin, and there are multiple avenues for energy dissipation.

A transmission line supports only two modes of operation: A signal either goes straight down the line in one direction or comes back in the other. That's it.

In a typical digital application, no other modes of operation are possible. When a traveling wave encounters a load at the end of a transmission structure, only three entities are involved: the incoming power, the fraction of that power that is dissipated in the load, and the remaining power, all of which reflects back toward the source.

The solution to the problem of allocating power among those three modes is the highly vaunted "reflection coefficient" formula, which is used to predict the size of a reflected signal:

$$\frac{V_R}{V_I} = \frac{Z_L - Z_C}{Z_L + Z_C}.$$

The reflection formula expresses the ratio of reflected voltage to incident voltage, as observed at the end of a transmission line, computed as a function of the load impedance at the end, ZL, and the characteristic impedance of the transmission line, ZC.

If the end of a transmission structure is left open-circuited, making an infinite load impedance, that load draws no current and therefore dissipates zero power. In that case, 100% of the incident power reflects, creating a reflected signal just as large as the incident waveform. If you imagine electrical current as being loosely analogous to physical velocity in the rubber-ball example, the concrete wall did the same thing. When struck, the wall hardly moved, absorbing very little energy, and thereby reflecting almost perfectly.

If you reduce the endpoint load impedance to successively lower values, the load begins to draw more current, dissipating more power and creating a progressively weaker reflected signal. In the physical world, you can test that idea by throwing your ball at three things: a wooden fence, a wall of hay bales, and a wet sheet hanging out to dry. When the mechanical impedance of the wall best matches the physical properties of the ball, the ball reflects least strongly.

Electrically, a load impedance that completely absorbs all incoming power creates zero reflection. That is the ideal arrangement for an end terminator. That particular impedance, if you can find it, is defined as the characteristic impedance of the transmission structure. There is no other definition. All formulas for characteristic impedance are merely approximations of this ultimate meaning. **EDN**

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.
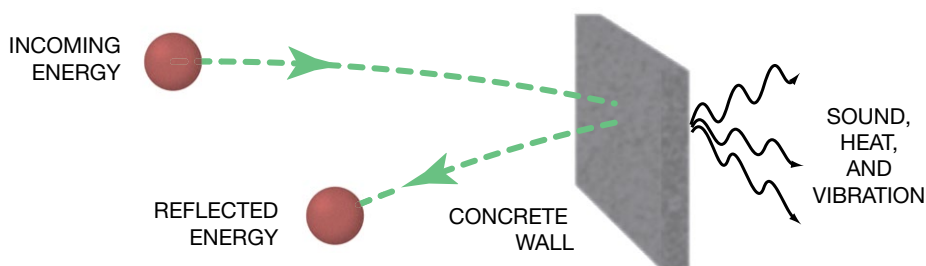
Figure 1 *The wall converts a portion of the incoming energy into sound, heat, and vibration.*

INCOMING ENERGY

REFLECTED ENERGY

CONCRETE WALL

SOUND, HEAT, AND VIBRATION

DESIGN FOR
MANUFACTURING
&YIELD

WITHOUT INCREASINGLY SOPHIS-
TICATED SOFTWARE, MANUFAC-
TURING AT 28 NM HAS BECOME
HIGHLY PROBLEMATIC AND
YIELDS UNECONOMICALLY
LOW. WHAT CAN BE DONE TO
ENABLE THIS AND SMALLER
NODES TO REACH THE
DESIRED YIELDS?

BRIAN BAILEY ● CONTRIBUTING
TECHNICAL EDITOR

A s designs move to the 28-nm and smaller nodes, the likelihood of a design being manufactured without defects trends toward zero unless a rapidly growing set of rules is adhered to. Those rules are increasing in number and complexity. The absence of extreme ultraviolet light sources means that double patterning has become essential and new devices, such as 3-D transistors, are being adopted. But it does not stop with just manufacturability. Lithographic features affect functionality and performance in such a way that yield has also become a primary concern.

Here we examine the problems and the ways in which increasingly sophisticated software can be used to overcome the limitations of technology. Representatives from five different companies discuss, from their own perspectives, these issues as well as solutions.

IMAGE: SHUTTERSTOCK
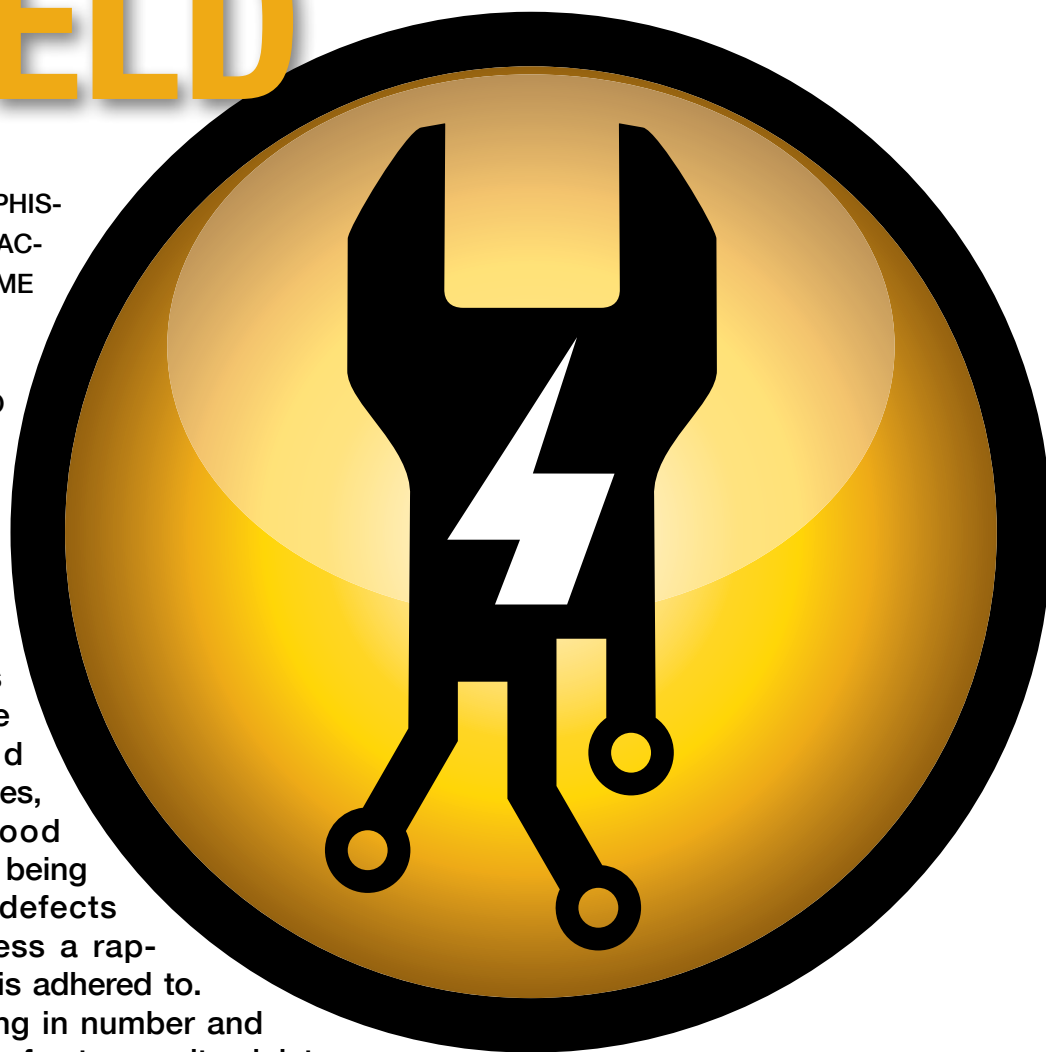
WHY HAS IT BECOME SUCH AN IMPORTANT TOPIC?
Shrikrishna Mehetre, Director of Engineering,
Open-Silicon
Major contributors to yield loss are:
• Geometric variations during the manufacturing process may result in performance variations that can push the device out of the allowed 3-Sigma variation, causing parametric yield loss.
• Specific patterns on the die may not get manufactured as desired because of diffractions that happen during the lithography process, causing catastrophic failures on the dies.
• Random defects may induce shorts or opens on the wafer, resulting in yield loss.
• The wafer goes through chemical mechanical polishing (CMP) after every interconnect and dielectric layer is deposited. Metal-density variations result in the thickness varia-

AT A GLANCE

■ Identifying a manufacturable design within the bounds of performance, reliability, and cost requirements is becoming ever more challenging.

■ Logic designers can add additional test or diagnosis logic and implement redundancy for sensitive circuits.

■ At 20 nm, double-patterning technology adds yet another dimension to the impact of silicon printability and connectivity.

■ To derive the underlying root causes, you need to apply machine learning and design statistics.

tions during the CMP process, which can accumulate errors and alter interconnect parasitics, causing yield loss.

Engineers can take precautions during the design process that would help reduce these effects. Logic designers can add either redundant logic or memory cells. These can be used to repair faults, which will increase yield even though the die is partly defective. There are tools and techniques used in the diagnosis of failures seen on silicon to ascertain the cause of the failures. This information can be used to correct layouts to improve the yield.

Additional steps are required in the physical and logic design flow. Logic designers can add additional test or diagnosis logic and implement redundancy for sensitive circuits, such as memory bit cells. Physical design engineers can ensure planarity of metals, litho-friendly design, redundant vias, and wire spreading to reduce failures on the die. Parametric yield loss can be addressed by using additional on-chip variation guard banding.

As the steps are added to the ASIC design flow for DFM/DFY, cost increases. The additional cost comes from the additional time required to plan, execute, and correct for these issues. There are additional EDA tools necessary to perform logical and physical checks for the design. It is important to see the ROI of such investments for a product. If the cost advantage from the increased yield is not significant compared with the investment done to achieve better yield, it is not worth spending those additional efforts. If 5% yield improvement can be obtained on a 28-nm design by implementing such DFM techniques, the investment may be worthwhile.

Another approach that can be considered is to do partial fixes. Addressing effects that affect yield the most, such as memory redundancy, redundant vias, litho-friendly routing, and pattern corrections, may have a greater impact compared with other DFM solutions. Designers can choose to selectively fix the DFM issues that provide the highest gains.

THE ROLE OF PACKAGE MODELING IN DFM OF ELECTRONIC DEVICES

Siva P Gurrum and Manu Prakuzhy, Design for Manufacturing, Semiconductor Packaging,
Texas Instruments

Semiconductor packaging is evolving from an enabling role to a differentiator in today's electronic devices. Identifying a manufacturable design within the bounds of performance, reliability, and cost requirements is becoming ever more

challenging. Advances in package modeling are providing means to predict a multitude of parameters related to performance, reliability, and cost.

Predictions from package modeling can be broadly categorized into performance and reliability. The cost of a packaging solution is typically derived from the design specification and manufacturing process flow. Performance parameters include thermal, such as thermal resistance values, and electrical, such as parasitics. In reliability, predictions typically cover risks and trends for the identified fail modes in a package family or package lifetime based on some of the fail modes. Predictions of both performance and reliability require correlations between model values and physical evaluations (Figure 1).

Modeling correlations are typically empirical relations between output parameters resulting from a model and physical parameters. Examples include: (a) the relationship between a model evaluation of the fatigue damage in solder joint and the physical number of temperature cycles to electrical failure, and (b) the relationship between electrical

PACKAGE DESIGN
PERFORMANCE
RELIABILITY
COST

MODELING CORRELATIONS
THERMAL, THERMO-MECHANICAL, ELECTRICAL

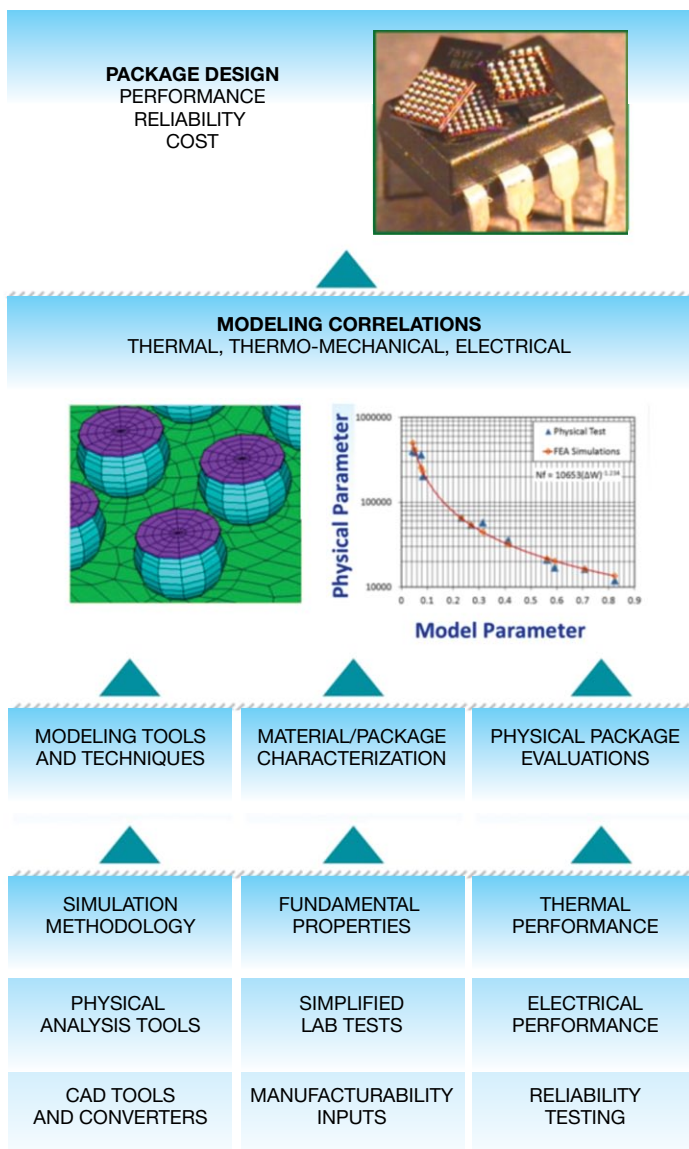| MODELING TOOLS AND TECHNIQUES	MATERIAL/PACKAGE CHARACTERIZATION	PHYSICAL PACKAGE EVALUATIONS
SIMULATION METHODOLOGY	FUNDAMENTAL PROPERTIES	THERMAL PERFORMANCE
PHYSICAL ANALYSIS TOOLS	SIMPLIFIED LAB TESTS	ELECTRICAL PERFORMANCE
CAD TOOLS AND CONVERTERS	MANUFACTURABILITY INPUTS	RELIABILITY TESTING

Figure 1 *Building blocks of modeling correlations enable package design for manufacturing.*

model prediction for the current density profile in a trace and the electromigration lifetime from physical tests. In some cases, physical parameters are directly predicted by a model, such as the junction-to-air thermal resistance of the package, or bond wire electrical parasitics. In these instances, correlations serve as a validation of the chosen approach for derivative designs.

For good modeling correlation, it is essential to incorporate the best modeling tools and techniques, accurate properties from material characterization, and the wealth of data from physical evaluations. Analysis tools are maturing, with customized tools now available for thermal and electrical, whereas the majority of mechanical tools are more general purpose, with longer cycle times. Material characterization must include bulk properties as well as properties sensitive to the physical structure and assembly of a package, such as the interfacial thermal resistance of a die attach material or the adhesion strength between interfaces. Also important is package characterization to bound manufacturing tolerances on critical parameters. An example is the die attach bond line thickness in a leadframe package, which critically affects delamination risk. Physical evaluations needed to complete a correlation include thermal resistance measurements, electrical testing on evaluation boards, and reliability testing according to standard specifications.

Some examples of design for manufacturing in packaging are:
• Bond wire pattern to eliminate shorts during mold flow for high wire density molded packages
• Lead finger design to minimize warpage and stress concentration near the bond wire stitch
• Layout of silicon chips on a die pad in a multichip module to minimize delamination stresses
• Thick metal content to reduce wafer warpage, which affects handling in assembly
• Metal content balancing in a substrate to reduce warpage, which affects assembly to PCBs
The role of modeling will grow to influence design, materials, and processes used in packaging.

DFM AT ADVANCED NODES AND ITS IMPACT ON DESIGN FLOWS: A REALITY CHECK

Manoj Chacko, Product Marketing Director, Custom IC and Sign Off, Cadence Design Systems
Manufacturing improvements via novel materials, processes, and new technologies aren't keeping up with the market demand for ever-shrinking feature dimensions, increasing performance, and low-power requirements. Software is now, and will remain, the new key enabler, as long as there's a growing gap between design and manufacturing.

At 28 nm, the impact of manufacturing variability on performance, power consumption, and yield has become disproportionately larger and more complex. Software analysis is critical for effectively quantifying and mitigating the impact on both the physical integrity and parametric performance of the designs.

Physical DFM checks are the final step after DRC, especially lithography process check analysis. Litho analysis can be run on blocks, post route in a design flow, and as the final step after DRC. The value of litho checks is clearly evident at the beginning of a process technology ramp-up. At 28 nm, for better predictability of physical and parametric yield, the lithography complexity has moved upstream to parasitic extraction with changes in the multi orders effects range, and in physical verification in the form of

recommended DFM rules or litho yield detractor patterns in the design rule manuals (Figure 2). At 20 nm, double-patterning technology adds yet another dimension to the impact of silicon printability and connectivity.

The increase in design density and use of third-party IP bring additional challenges associated with CMP-induced metal thickness variation. For example, model-based, rather than rule-based, CMP analysis is key to identifying thickness variations of the complete metal stack set. Also, as more design teams integrate third-party IP, the metal fill thickness variations around the border of the IP are increasing. The IP designer follows the design rules and the density requirements. However, making blocks that are easily integrated into different SoC environments without iterations to address CMP density issues is ineffective.

The impact of layout-dependent effects (LDE) variability on the design is well acknowledged. LDE variability comes primarily from manufacturing challenges, lithography effects, CMP, and stress, which significantly affect device behavior. Varying methods are used to mitigate the LDE issues because of the inability to qualify and quantify variability impact at the specific transistors. LDE cannot be analyzed by considering devices in isolation. A common method is to over-margin the transistors with dummies to minimize the impact of context problems on device performance. Designers need software to help quantify delay and leakage due to LDE, improve their traditional methods, and locally optimize the devices deviating from the specifications

TRADITIONAL STA: A→B 80ps
DELAY ANALYSIS IGNORING REAL CONTEXT EFFECTS
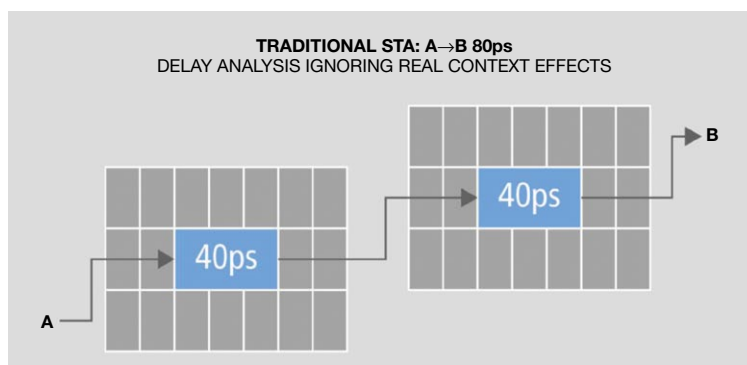
CRITICAL PATH AND TIMING DELAYS WITHOUT CONSIDERING THE IMPACT OF LDE ASSUMES STANDARD NEIGHBORING CONTEXTS.

CONTEXT-AWARE STA: A→B ?ps
DELAY ANALYSIS SHOULD INCLUDE REAL CONTEXT EFFECTS
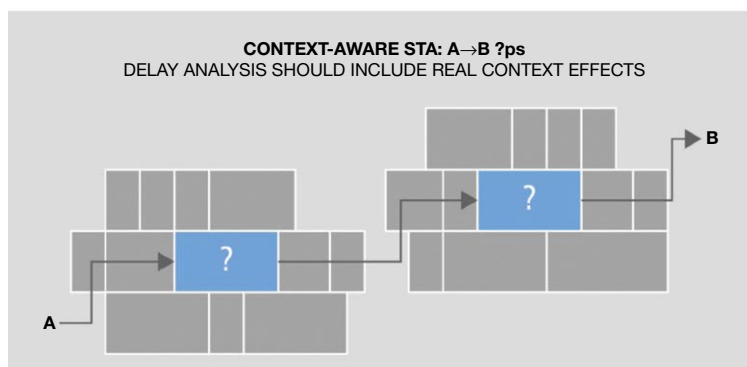
CRITICAL PATH DELAY VARIATION TAKING INTO ACCOUNT LDE IMPACT SHOULD SHOW VARIATION BECAUSE OF REAL CONTEXTS.

Figure 2 Lithography complexity has moved upstream to parasitic extraction.

(Figure 3). Timing and power variability are becoming more significant at each new process node, affecting margins, silicon utilization, silicon failure, and timing closure.

Consequently, advanced-node designers must optimize chip manufacturability along with area, speed, and power. This trend will increase exponentially as technology advances to 14 nm.

IDENTIFY CRITICAL DESIGN FEATURES USING DIAGNOSIS-DRIVEN YIELD ANALYSIS

Geir Eide, Product Marketing Manager, Silicon Test Solutions Group, Mentor Graphics
During the transition to the 28-nm node, several leading semiconductor companies struggled with supply: They couldn't ship enough of their products. Part of the problem was lower-than-expected yield. This situation illustrates how traditional yield learning methods are running out of steam, largely because of the dramatic increase in the number and complexity of design-sensitive defects and longer failure analysis cycle times. These factors have forced fabless semiconductor companies to arm themselves with new technologies such as diagnosis-driven yield analysis (DDYA), which can rapidly identify the root cause of yield loss and effectively separate design- and process-oriented yield loss.

Software-based diagnosis of test failures is an established method for localizing defects during failure analysis for digital semiconductor devices. Diagnosis software determines the defect type and location for each failing device based on the design description, scan test patterns, and tester fail data. Using statistical analysis, diagnosis results from a number of failing devices can be used to effectively determine the underlying root causes.

The primary challenge for yield analysis is dealing with the ambiguity in the results. For example, more than one location could explain the defective behavior, and each suspect location often has multiple possible root causes associated with it. To better derive the underlying root causes represented in a population of failing devices from test data alone,

you need to apply machine learning and design statistics, such as tested critical area for each layer and total number of gates tested of any given type[1].

Another way to expand the scope of DDYA is to include data from DFM analysis (Figure 4). One key motivation behind this approach is to be able to prove that a defect found in failure analysis is a systematic critical feature, and then to learn what about that feature relates to the defect's rate of occurrence. Without a DDYA methodology that can automatically incorporate DFM information, you would need a team of experts and a lot of experimentation to accomplish this. However, by first identifying all locations in a design with a suspected feature through DFM analysis, any diagnosis results (that is, actual silicon defects) that overlap these locations can easily be identified and analyzed to determine whether this correlation also presents causation. A second motivation behind this approach is to determine whether a potential design fix could cure the problem. By identifying design locations that contain the planned fix, a similar correlation can be performed before actually implementing the fix, and the failure rates can be combined[2].

Diagnosis-driven yield analysis appears particularly promising for the 20- and 16-nm nodes in spite of the inherent limitations of immersion lithography.

SPICE SIMULATION CHALLENGES FOR DFY APPLICATIONS

Dr Bruce W McGaughy, Chief Technology Officer and Senior Vice President of Engineering, ProPlus Design Solutions
Process variations, especially local random variations, are making DFY a must-have methodology for sub-65-nm design. A DFY methodology comprises three critical components: statistical transistor model extraction, yield prediction and analysis, and a powerful statistical simulation engine. An integrated solution with all three components provides added efficiency and consistency.
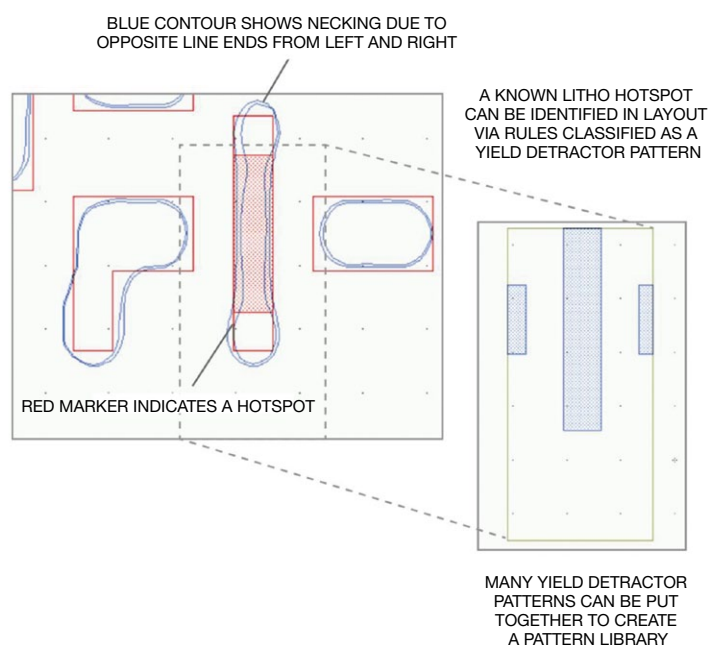
The heart and soul of DFY is the simulation engine. Until recently, most simulators have not been well suited as the core engine of a DFY solution. First, it needs to be built from the ground up with specially designed data structures and algorithms for statistical analysis and simulation. Second, the simulator needs to have tight integration into a yield-prediction tool with the ability to massively parallelize simulations on server farms. Third, the simulator needs to have full compatibility with foundry model libraries and consistency with the extraction process from silicon measurement.

Given the tremendous computational demands of DFY analysis (Figure 5), the simulator needs to have high accuracy, capacity, and performance.

Designers have had to choose between two types of circuit simulators. Either they can choose high accuracy and good usability available in SPICE simulators, but sacrifice performance and capacity, or designers can choose FastSPICE with high performance and capacity but with poor accuracy and usability. Neither is suitable as a DFY simulation engine.

FastSPICE simulators employ aggressive partitioning, event-driven multi-rate schemes, transistor table models, hierarchical array reduction, and the like. All of these techniques are "tuned" for typical circuit types and operating conditions and, in most cases, require further "tuning" with special options by the designer.

With yield prediction, designers track circuit behavior at the margins of the design and process space where

BLUE CONTOUR SHOWS NECKING DUE TO OPPOSITE LINE ENDS FROM LEFT AND RIGHT

A KNOWN LITHO HOTSPOT CAN BE IDENTIFIED IN LAYOUT VIA RULES CLASSIFIED AS A YIELD DETRACTOR PATTERN

RED MARKER INDICATES A HOTSPOT

MANY YIELD DETRACTOR PATTERNS CAN BE PUT TOGETHER TO CREATE A PATTERN LIBRARY

Figure 3 *Software helps quantify problems due to LDE and to locally optimize the devices deviating from the specifications.*
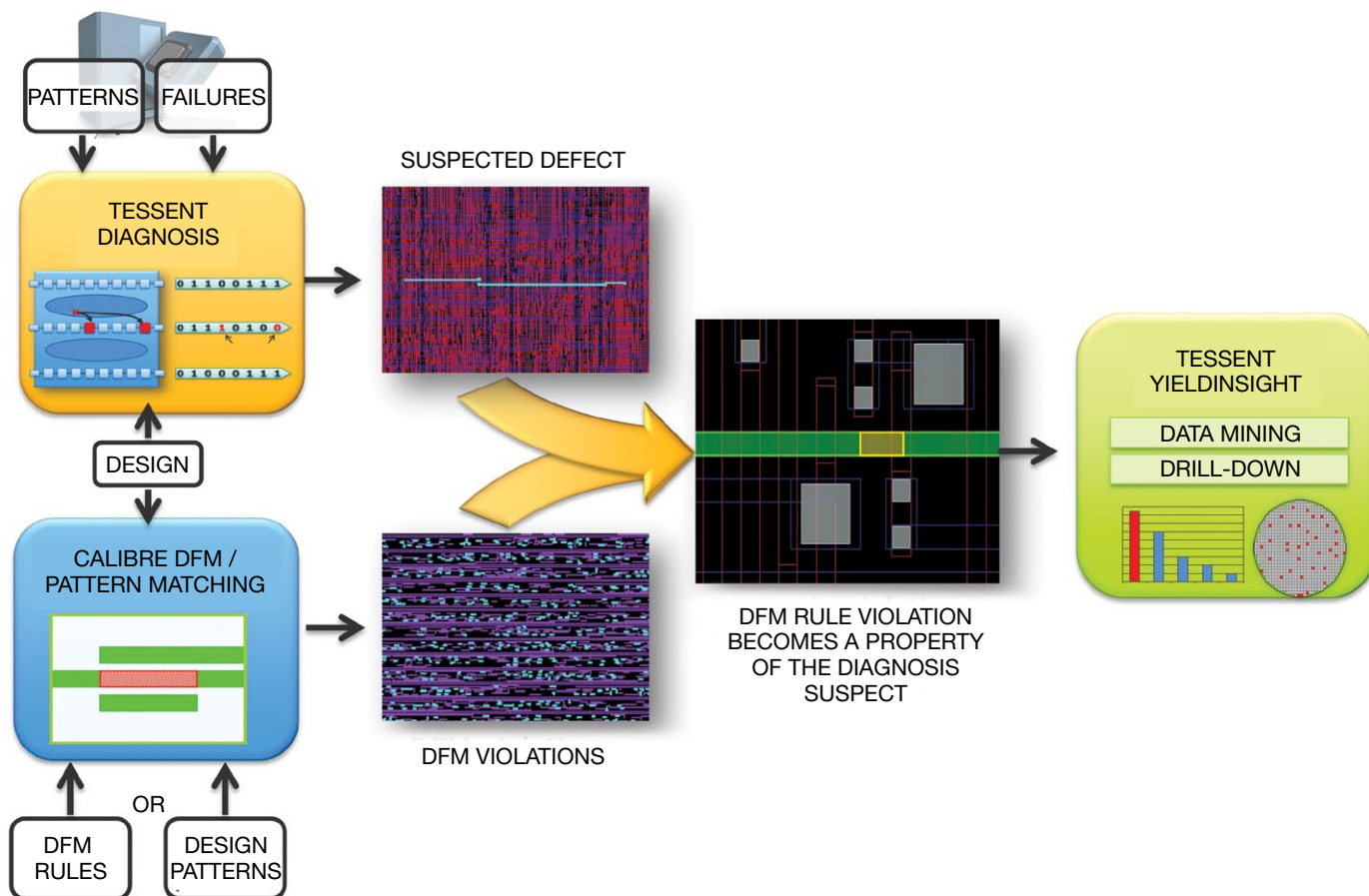
Figure 4 *DFM analysis meets diagnosis-driven yield analysis in new methodologies and software tools such as these from Mentor Graphics.*

built-in tuning may not apply, leading to accuracy problems. Furthermore, the designer cannot manually tune the options for marginal operating conditions during statistical simulation. Finally, techniques such as table models and hierarchical array reduction will not work when every transistor in the circuit has a different variation.

The ideal solution would be to extend the capabilities of SPICE to cover the performance and capacity provided with FastSPICE. Parallel SPICE simulators have taken over some of the space covered by FastSPICE with 10x or more speedup over traditional SPICE.

Advancement for giga-scale simulators is coming from highly optimized data structures and core algorithms built for high-performance parallelization and capacity. Giga-scale SPICE is the principle behind ProPlus's NanoSpice, the simulation engine of its DFY solution built around NanoYield, yield prediction and improvement, and BSIMProPlus, statistical model extraction.EDN

REFERENCES

1 Benware, B, et al, "Determining a Failure Root Cause Distribution From a Population of Layout-Aware Scan Diagnosis Results," IEEE D&T of Computers, Volume 29, Issue 1.

2 Schuermyer, C, et al, "Identifying Systematic Critical Features Using Silicon Diagnosis Data," ASMC 2012, http://bit.ly/ZmV2PD.
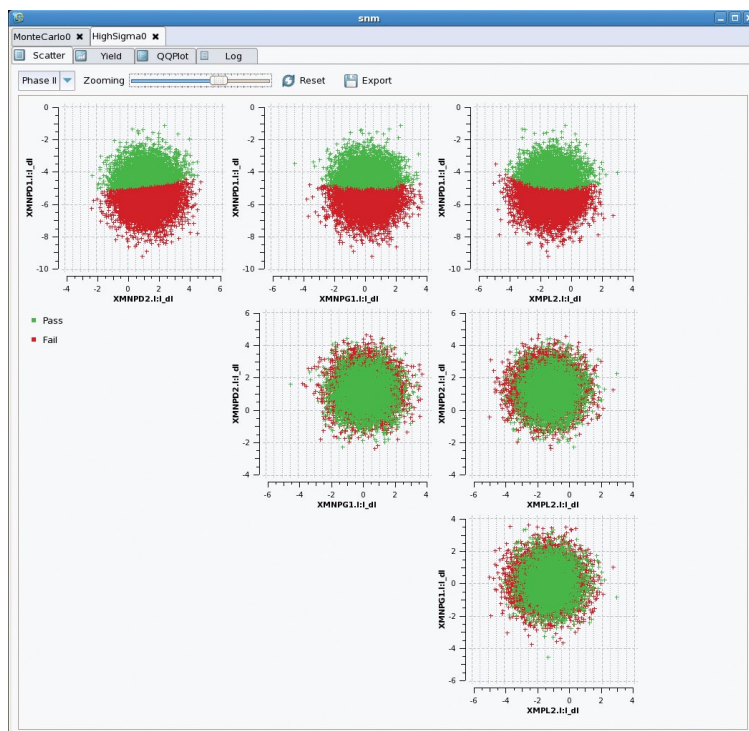
Figure 5 *DFY analysis places tremendous computational demands on the simulator.*

MECHATRONICS
IN DESIGN

FRESH IDEAS ON INTEGRATING
MECHANICAL SYSTEMS,
ELECTRONICS, CONTROL SYSTEMS,
AND SOFTWARE IN DESIGN
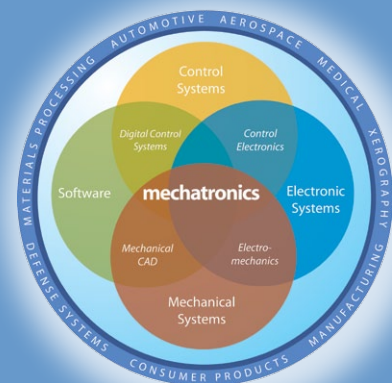
Frequency response: the gold standard

Engineers predict real-world response and identify model parameters.

By Kevin C Craig, PhD

What do engineers "see" when they look at a real system or conceive a new design? They will look past the hardware and visualize the flow of energy, where it is stored, and where it is dissipated. They will identify the kinetic energy of moving fluids and solid masses; the potential energy of compressible fluids, elastic hoses and tanks, and deformable solids; the energy stored in electric and magnetic fields; and the energy lost through friction generating heat. But they will also "see" how the system might respond to real-world inputs by understanding the frequency response of the system and the frequency spectrum of the probable inputs.

A real system often can be modeled, over some range of motion and time duration, as stable, linear, and time invariant. If the input to this system is a sine wave, the steady-state output (after the transients have died out) is also a sine wave with the same frequency, but with an amplitude and phase angle that are both frequency dependent. Plots of the input-output amplitude ratio versus frequency and the phase angle versus frequency are called Bode plots.

If the system being excited were nonlinear or time varying, the output might contain frequencies other than the input frequency, and the amplitude ratio might be dependent on the input magnitude. Any real-world device or process will need to function properly for only a certain range of frequencies; outside this range, we don't care what happens. When one has the frequency-response curves for any system and is given a specific sinusoidal input, it is easy to calculate the sinusoidal output. What is not obvious, but extremely important, is that the frequency-response curves are really a complete description of the system's dynamic behavior and allow one to compute the response for any input, not just sine waves.

Two hundred years ago, Jean Baptiste Fourier showed that any periodic waveform that exists in nature can be generated by adding up sine waves. By picking the amplitudes, frequencies, and phases of these sine waves, one can generate a waveform identical to the desired signal. A periodic function, $q_i(t)$, can be represented by an infinite series of terms called a Fourier series. Figure 1 shows a square wave and a plot of the first few terms of the Fourier series. The more terms used in the series, the better the fit.

Using the principle of superposition for linear systems, we can combine the frequency spectrum of a real-world signal with the system's frequency response and calculate the time response. A dynamic signal analyzer is the device used to experimentally determine a system's frequency response. Many excellent application notes on its use are available. EDN

(a)

$$q_i(t) = 0.5 + \frac{4}{\pi}\sin(100\pi t) + \frac{4}{3\pi}\sin(300\pi t)$$

(b)
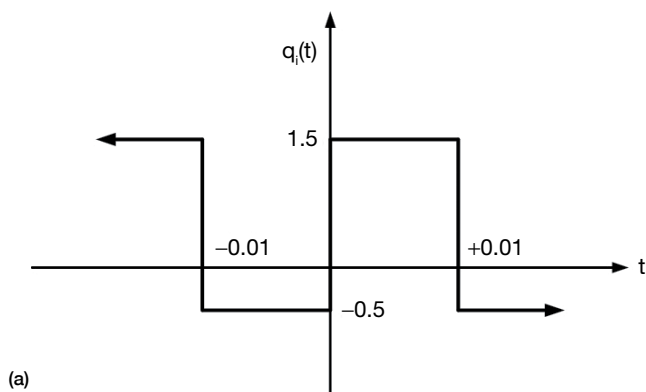
Figure 1 *A periodic function, $q_i(t)$, can be represented by an infinite series of terms called a Fourier series; shown are a square wave (a) and a plot of the first few terms of the Fourier series (b).*

VICOR
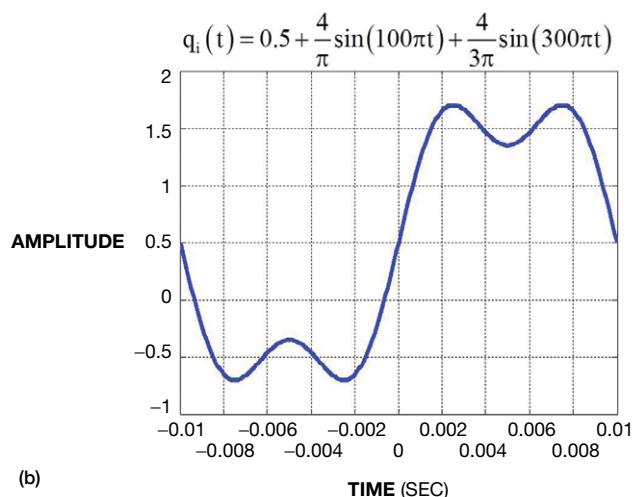
Solutions from **AC to Point of Load**

Our Latest Products
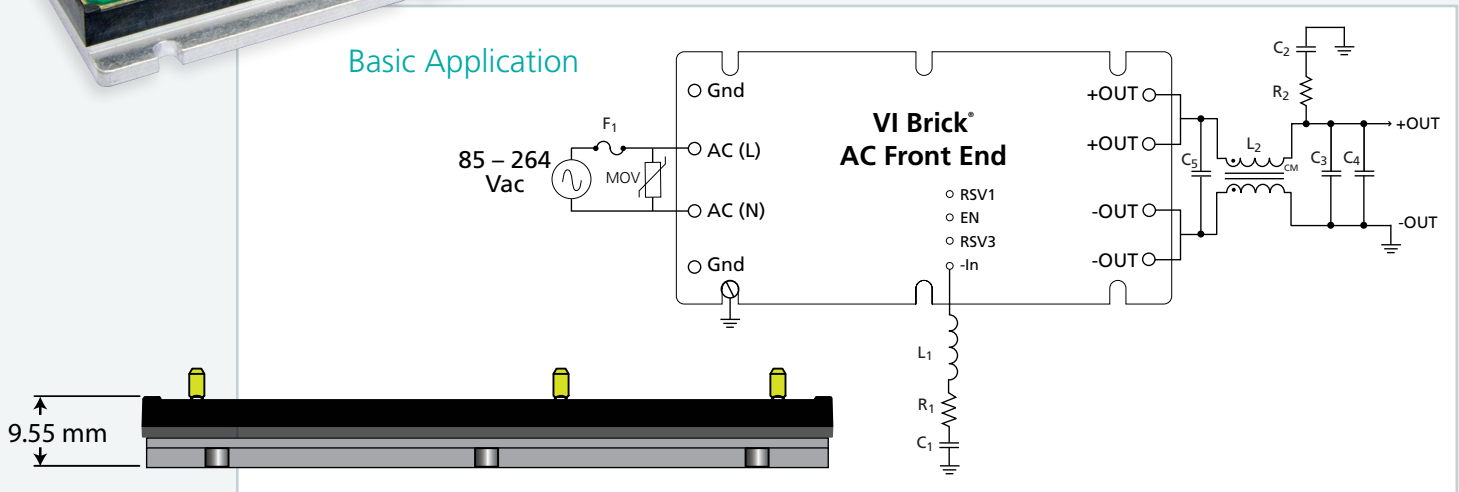
AC Front End

Overview

- Universal Input: 85 – 264 Vac
- Output: 48 Vdc - isolated, regulated (SELV)
- Power: 330 W - over entire input voltage range
- Isolated AC-DC converter with active Power Factor Correction (PFC)
- Integrated rectification, filtering and transient protection
- Peak efficiency: >92%
- EN55022, Class B EMI conducted emissions with a few components
- EN61000-3-2 harmonic limits
- -55 to 100°C baseplate operation

Features

- Low profile, 9.55 mm height above board
- Small footprint, size of a business card
- Flanged aluminum package for secure mounting and thermal management
- Consistent high efficiency across the worldwide mains (flat efficiency curve)
- Reduced power loss and cooling requirements
- Module includes PFC, regulation, isolated 48 V output (SELV), filtering, rectification, transient protection, agency approvals, simplified thermal management
- Simple design, requires few external components
- Module power density, 121 W/in³
- Complete solution including hold-up capacitors, 54 W/in³

Basic Application

$85 – 264$ Vac

VI Brick® AC Front End

Gnd
AC (L)
AC (N)
Gnd
F_1
MOV
RSV1
EN
RSV3
-In
+OUT
+OUT
-OUT
-OUT
C_5
L_2 CM
C_2
R_2
C_3
C_4
+OUT
-OUT
L_1
R_1
C_1

9.55 mm

Resources

- ▶ An Introduction to the Vicor AC Front End Module
- ▶ High Performance AC-DC Power System Webinar
- ▤ AC Front End Product Information

Consistent High Efficiency
Over Line, Load, Temperature

Part Number	Input Voltage	Output Voltage	Output Power	Operating Temperature
FE175D480C033FP-00	85 – 264 Vac	48 Vdc	330 W	-20 to 100°C
FE175D480T033FP-00	85 – 264 Vac	48 Vdc	330 W	-40 to 100°C
FE175D480M033FP-00	85 – 264 Vac	48 Vdc	330 W	-55 to 100°C

Replace the "–00" suffix in the part number with "–CB" to order an evaluation board.
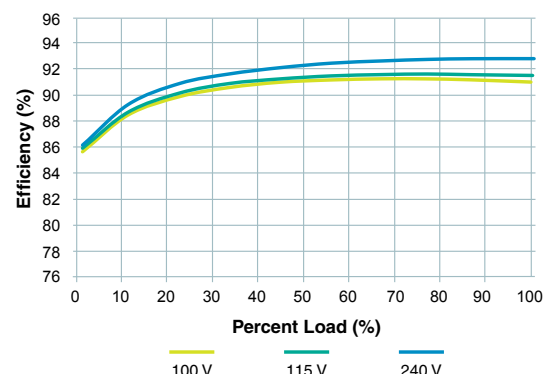
Picor Cool-Power ZVS Buck Regulators

Wide Operating Range

- Wide V_{IN} (8 – 36 V) and wide V_{OUT} (1 – 16 V)
- 12 V-optimized performance with PI34xx Series
- -40°C to 125°C operating range

## Simple to Use; Fast Development Time

- Internal compensation - few external components
- No additional design or additional settings required

High Efficiency

- Up to 98% peak efficiency (19 V_{IN} to 15 V_{OUT})
- PI34xx Series optimized for 12 V_{IN} with even higher efficiency
- Light and full load high-efficiency performance

Flexible and Rich Feature Set

- Paralleling and single wire current sharing
- Frequency synchronization
- User adjustable soft-start & tracking
- Power-up into pre-biased load
- Optional I²C functionality & programmability
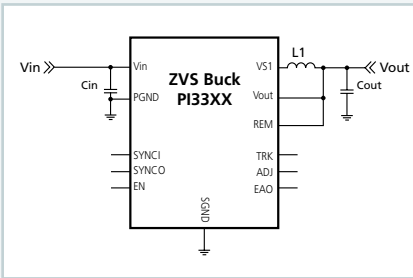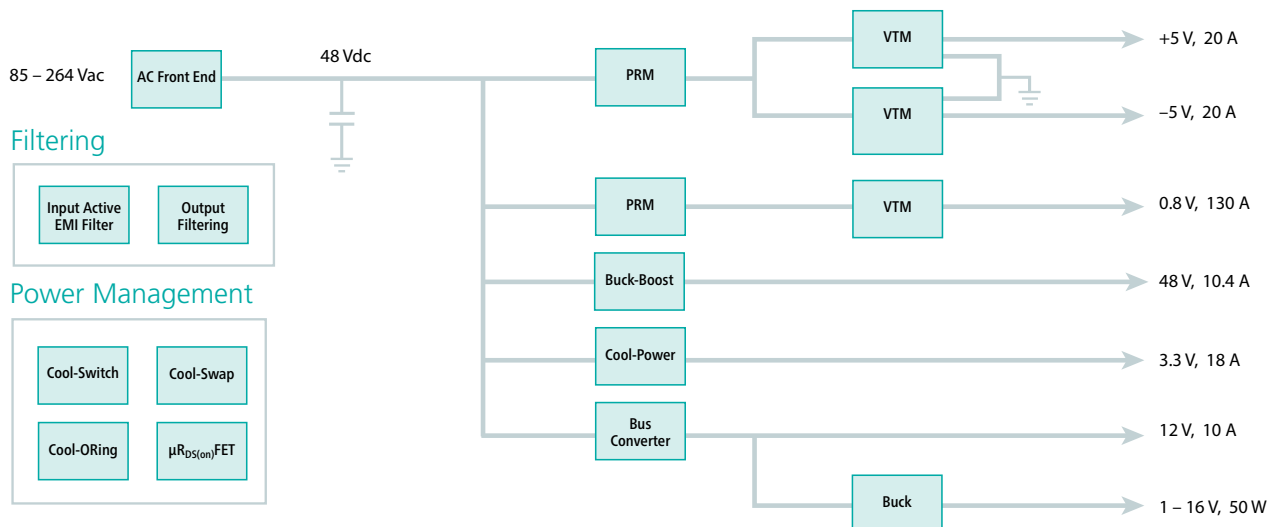
NEW: Isolated ZVS DC-DC Converters

Resources

- ▶ Interview with ECE Europe about ZVS Regulators
- ▶ ZVS Point-of-Load Regulation Webinar
- ▶ High Performance On-Board Power Design Webinar
- 🗎 Cool-Power ZVS Buck Regulators Product Information

| Cool-Power | Output Range | | I_OUT |
Model Number	Set	Trim Range	Max
PI3311-00-LGIZ	1.0 V	1.0 V to 1.4 V	10 A
PI3318-00-LGIZ	1.8 V	1.4 V to 2.0 V	10 A
PI3312-00-LGIZ	2.5 V	2.0 V to 3.1 V	10 A
PI3301-00-LGIZ	3.3 V	2.3 V to 4.1 V	10 A
PI3302-00-LGIZ	5.0 V	3.3 V to 6.5 V	10 A
PI3303-00-LGIZ	12 V	6.5 V to 13.0 V	8 A
PI3305-00-LGIZ	15 V	10.0 V to 16.0 V	8 A
Higher Current Versions			
PI3311-01-LGIZ	1.0 V	1.0 V to 1.4 V	15 A
PI3318-01-LGIZ	1.8 V	1.4 V to 2.0 V	15 A
PI3312-01-LGIZ	2.5 V	2.0 V to 3.1 V	15 A
PI3301-01-LGIZ	3.3 V	2.3 V to 4.1 V	15 A
I²C Functionality and Programmability			
PI3311-20-LGIZ	1.0 V	1.0 V to 1.4 V	10 A
PI3318-20-LGIZ	1.8 V	1.4 V to 2.0 V	10 A
PI3312-20-LGIZ	2.5 V	2.0 V to 3.1 V	10 A
PI3301-20-LGIZ	3.3 V	2.3 V to 4.1 V	10 A
PI3302-20-LGIZ	5.0 V	3.3 V to 6.5 V	10 A
PI3303-20-LGIZ	12 V	6.5 V to 13.0 V	8 A
PI3305-20-LGIZ	15 V	10.0 V to 16.0 V	8 A
PI3311-21-LGIZ	1.0 V	1.0 V to 1.4 V	15 A
PI3318-21-LGIZ	1.8 V	1.4 V to 2.0 V	15 A
PI3312-21-LGIZ	2.5 V	2.0 V to 3.1 V	15 A
PI3301-21-LGIZ	3.3 V	2.3 V to 4.1 V	15 A
12 V Optimized Option			
PI3420-00-LGIZ	1.0 V	1.0 V to 1.4 V	15 A
PI3421-00-LGIZ	1.8 V	1.4 V to 2.0 V	15 A
PI3422-00-LGIZ	2.5 V	2.0 V to 3.1 V	15 A
PI3423-00-LGIZ	3.3 V	2.3 V to 4.1 V	15 A
PI3424-00-LGIZ	5.0 V	3.3 V to 6.5 V	15 A

(Left bracket labels: 8 – 36 Vin for PI3311-00 through PI3301-21; 8 – 18 Vin for PI3420-00 through PI3424-00)

I²C is a trademark of NXP Semiconductors

Solutions from **AC to Point of Load**

85 – 264 Vac → AC Front End → 48 Vdc

Filtering
- Input Active EMI Filter
- Output Filtering

Power Management
- Cool-Switch
- Cool-Swap
- Cool-ORing
- μR_DS(on)FET

- PRM → VTM → +5 V, 20 A
- → VTM → −5 V, 20 A
- PRM → VTM → 0.8 V, 130 A
- Buck-Boost → 48 V, 10.4 A
- Cool-Power → 3.3 V, 18 A
- Bus Converter → 12 V, 10 A
- → Buck → 1 – 16 V, 50 W

VI Chip PRM Module

Simple to Use

- Point-of-load, Buck-Boost regulation
- Factorized Power Architecture
- Minimal external components

High Density

- Up to 1,700 W/in³, with 500 W in 1.1in² package
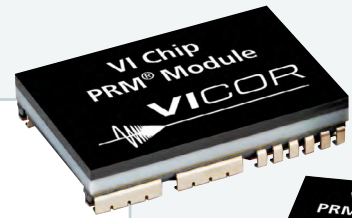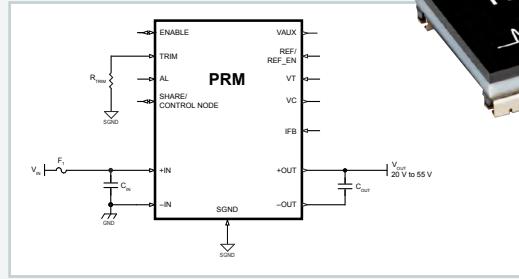
Wide Vin Optimized for 48 Vout

- 24 Vin, 18 – 36 Vin range
- 36 Vin, 18 – 60 Vin range
- 45 Vin, 38 – 55 Vin range
- 48 Vin, 36 – 75 Vin range

High Efficiency

- Full 500 W: 97.8%
- Half 250 W: 96.7%

Flexible

- Regulation: Remote sense, local loop, adaptive loop
- Parallel capabilities

PRM Modules Model Number	Input Voltage Nom. (V)	Range (V)	Output Voltage Voltage Range (V)	Output Power Max.	Output Current Max.	Package Size
P024F048T12AL	24 V	18 – 36 V	26 – 55 V	120 W	2.5 A	Full
P036F048T12AL	36 V	18 – 60 V	26 – 55 V	120 W	2.5 A	Full
P045F048T17AL	45 V	38 – 55 V	26 – 55 V	170 W	3.5 A	Full
P045F048T32AL	45 V	38 – 55 V	26 – 55 V	320 W	6.67 A	Full
P048F048T12AL	48 V	36 – 75 V	26 – 55 V	120 W	2.5 A	Full
P048F048T24AL	48 V	36 – 75 V	26 – 55 V	240 W	5.0 A	Full
PRM48BH480T200A00	48 V	38 – 55 V	5 – 55 V	200 W	4.17 A	Half
PRM48BF480T400A00	48 V	38 – 55 V	5 – 55 V	400 W	8.33 A	Full
PRM48AH480T200A00	**48 V**	**36 – 75 V**	**20 – 55 V**	**200 W**	**4.17 A**	**Half**
PRM48AF480T400A00	**48 V**	**36 – 75 V**	**20 – 55 V**	**400 W**	**8.33 A**	**Full**
PRM48BH480T250A00	**48 V**	**38 – 55 V**	**20 – 55 V**	**250 W**	**5.21 A**	**Half**
PRM48BF480T500A00	**48 V**	**38 – 55 V**	**20 – 55 V**	**500 W**	**10.42 A**	**Full**

These PRM modules can be further configured to meet your exact needs.

Resources

- An Overview of Vicor's VI Chip PRM Module
- PRM Product Information
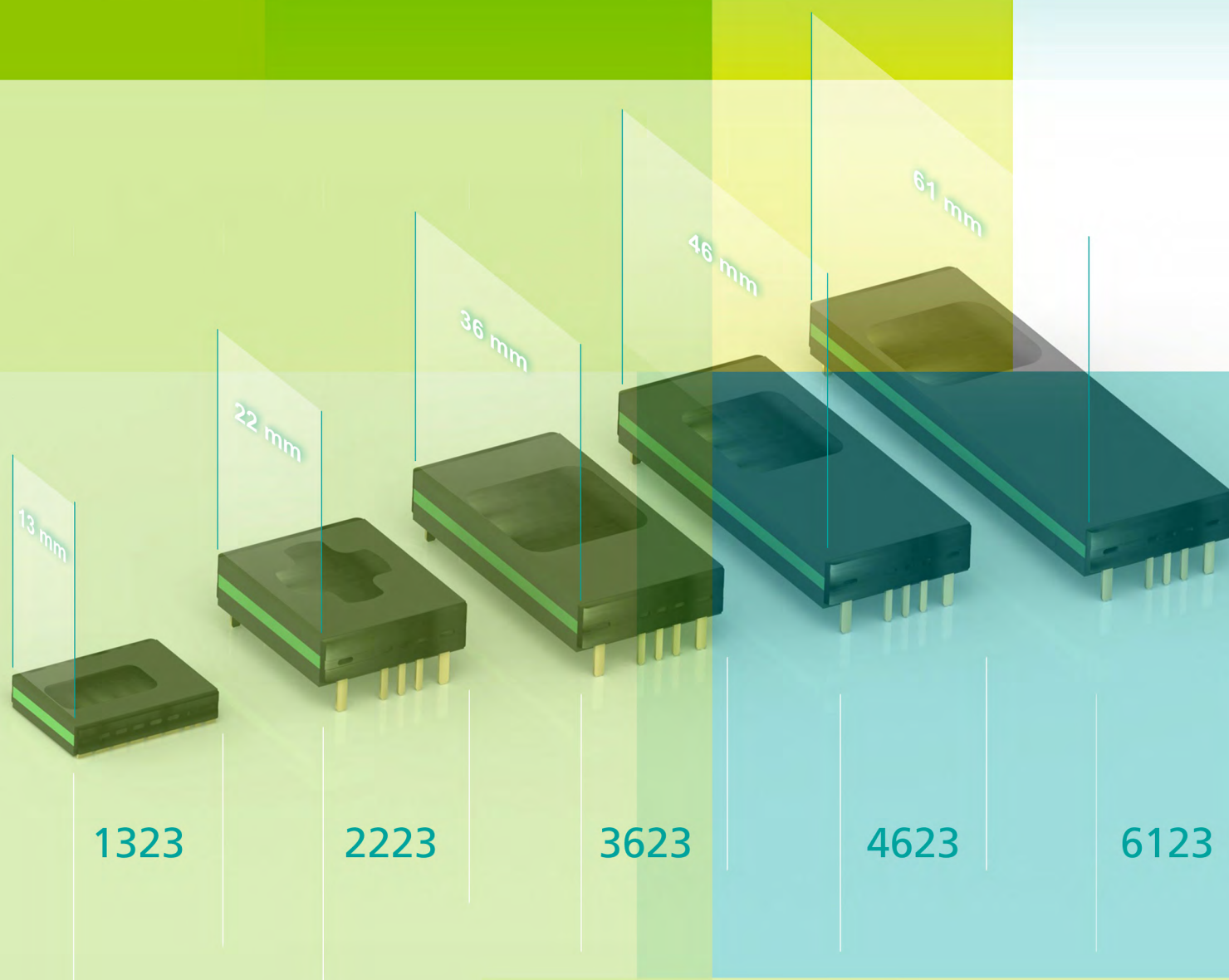- Configure a PRM for your application's requirements
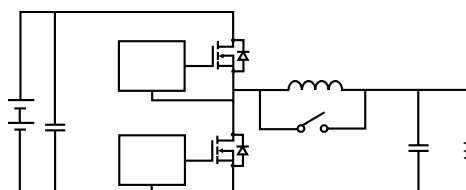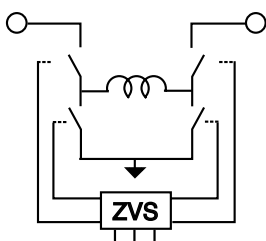
Reduces Q1 turn-on losses
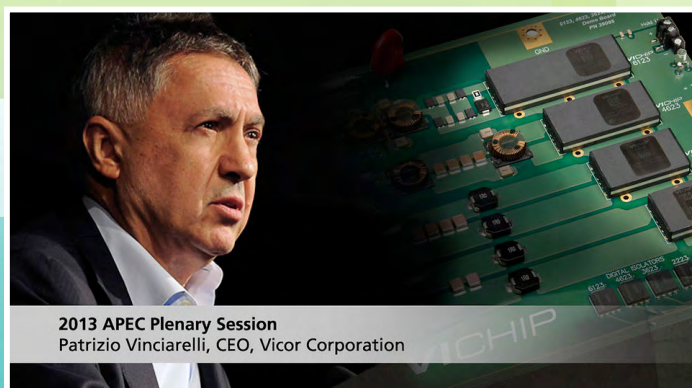Reduces gate drive losses
Reduces body diode conduction

Benefits of **Zero-Voltage-Switching Topology**

Introducing... The Growing ChiP Lineup

"Converters housed in Package" Technology

13 mm

22 mm

36 mm

46 mm

61 mm

1323

2223

3623

4623

6123

Resources

2013 APEC Plenary Session
Patrizio Vinciarelli, CEO, Vicor Corporation

▶ Vicor's CEO discusses ChiP technology at APEC

▶ An introduction to ChiP technology

Configure Your Product

PowerBench™ online design center

- Design your own DC-DC converters to meet your application's requirements
- Or use hundreds of predefined designs
- Online registration allows designs to be saved

VI Chip® PRM® Module

- Point-of-Load Buck-Boost regulation with remote sense
- Full Chip (up to 500 W in 1.1 in²)
- Half Chip (up to 250 W in 0.57 in²)

Other DC-DC Converters

- Maxi, Mini, Micro Series: Full (160–600 W), Half (100–300 W), Quarter (50–150 W)
- VI-200 / VI-J00 Series: Full brick (50–200 W), Half brick (25–100 W)
- ComPAC, VIPAC Arrays and chassis-mount MegaMods

AC-DC Converters

- VIPAC - Autoranging input with filtering, multiple output, cold plate chassis,
- FlatPAC - Multiple output and autorange input with heat sink or conduction-cooled models

Complete power systems

- Westcor custom AC-DC
- High power density, small size, high efficiency
- Fan-cooled, slide-in assemblies

Resources

- PowerBench tools
- Register for PowerBench account
- Modeling, Simulation, and Selection Techniques in Power Design

Efficiency Graphs Calculated Automatically

Typical Performance Characteristics

The following figures present typical performance at T_C = 25ºC, unless otherwise noted. See associated figures for general trend data.
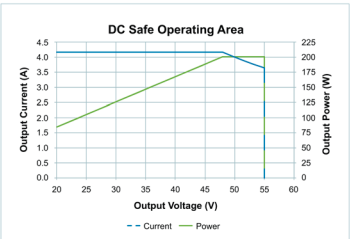

Figure 1 — DC Safe Operating Area (SOA)

Figure 4 — Total efficiency and power dissipation vs. V_{IN} and I_{OUT} Low Trim, T_{CASE} = -40ºC

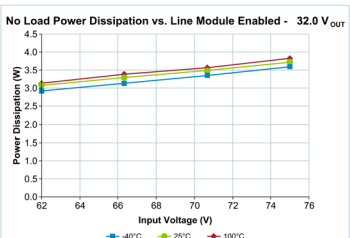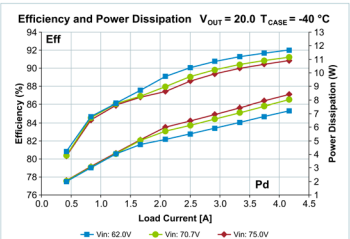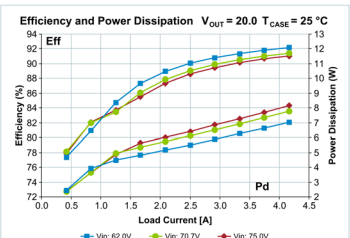Figure 2 — No Load Power Dissipation vs. V_{IN}, module enabled

Figure 5 — Total efficiency and power dissipation vs. V_{IN} and I_{OUT} Low Trim, T_{CASE} = 25ºC

Data Sheet for Custom Products
Generated Automatically

VICOR

PRM® Regulator
PRM2A04-000599

☑ ⓒ CE

High Efficiency Converter

Features

- 69.2 V input (60.6 V to 75.0 V), non-isolated ZVS buck-boost regulator
- 20.0 V to 55.0 V adjustable output range
- 134 W output power in 0.57 in² footprint
- 94.1% typical efficiency, at full load
- 894 W/in² (55 W/cm²) Power Density
- 5.29 MHrs MTBF (MIL-HDBK-217 Plus Parts Count)
- Pin selectable operating mode
  - Adaptive Loop
  - Remote Sense / Slave
- Half VI Chip® Package
  - 22.0mm x 16.5mm x 6.73mm
  - Surface Mount Pin Style
  - T Grade

Typical Applications

- High Density Power Supply DC-DC rail outputs
- High Density ATE system DC-DC power
- Telecom NPU and ASIC core power
- Communications Systems
- Non-isolated and isolated power converters

Product Ratings		
V_{IN} = 60.6 V to 75.0 V		P_{OUT} = 134 W
V_{OUT} = 31.8 V (20.0 V to 55.0 V Trim)		I_{OUT} = 4.20 A
Operating Temperature		Package & Pin Style
T Grade -40ºC to 125ºC		Half VI Chip, Surface Mount

Product Description

The VI Chip® PRM® Regulator is high efficiency converter, operating from a 60.6 to 75.0 Vdc input to generate a regulated 20.0 to 55.0 Vdc output. The ZVS buck-boost topology enables high switching frequency (~1.03 MHz) operation with high conversion efficiency. High switching frequency reduces the size of reactive components enabling power density up to 894 W/in³.

The Half VI Chip® package is compatible with standard pick-and-place and surface mount assembly processes with a planar thermal interface area and superior thermal conductivity.

In a Factorized Power Architecture™ system, the PRM and downstream VTM® current multiplier minimize distribution and conversion losses in a high power solution, providing an isolated, regulated output voltage.

The PRM2A04-000599 has two selectable modes of regulation depending on the application requirements.

In Adaptive Loop Operation, the PRM2A04-000599 utilizes a unique feed-forward scheme that enables precise regulation of an isolated POL voltage without the need for remote sensing and voltage feedback.

In Remote Sense Operation, the internal regulation circuitry is disabled, and an external control loop and current sensor maintain regulation. This affords flexibility in the design of both voltage and current compensation loops to optimize performance in the end application.

PRM® Regulator
Page 1 of 40   05/2013   vicorpower.com   800 735.6200   VICHIP
High Performance Power Modules

VI Chip **PRM Module Configurator**

User Defined Module

Specify a User Defined PRM Module   **All PRM Module**

Designer's Reference [   ]   (This text is for reference in M

Input Voltage

Voltage Range Platform
1. ○ Wide (36-75 V) ○ Narrow (38-55V)

		Selection Range
Vin Low Line	[ ] V	
Vin Nominal	[ ] V	
Vin High Line	[ ] V	
Undervoltage Lockout	[ ] %	
Undervoltage Lockout Hysteresis	[ ] %	
Overvoltage Lockout	[ ] %	
Overvoltage Lockout Hysteresis	[ ] %	

Output Voltage

		Selection Range
Vout Set Point	[48.0] V	26.0 - 52.0 V
Maximum Trim	[55] V	52.8 - 55 V
Overvoltage Limit	N/A %	
Overvoltage Limit Hysteresis	N/A %	
Turn On Delay	[1] ms	1 - 4 ms
Output Rise Time	[1] ms	1 - 4 ms

Output Power, Package, and Product Grade

2. Package Size ○ Half (0.65 x 0.57 in) ○ Full (1.28 x 0.87 in)

		Selection Range
Load Current	[ ] A	
Current Limit Setpoint		

3. Pin Style Select your Package Size above to show Pin Style options.

4. Product Grade ○ T-Grade ○ M-Grade

Requests / Results

[SIMULATE]   [GET PART NUMBER, PRICE AND DELIVERY]

Online Design Tools

Online Simulator

- Simulate electrical and thermal behavior
- Supports VI BRICK IBCs, BCMs and PRMs
- User defines line and load conditions, input and output impedance and filters
- Simulations include start-up, steady state, shutdown, Vin step and load step, as well as thermal.
- Electrical and thermal performance showed in charts and tables

Design Calculators

- Determine trim resistors for fixed and variable output voltage trimming
- Calculate required bus capacitance for VI-ARM, FARM, and ENMod modules
- Thermal calculator for heat sink selection

Filter Design

- Select attenuation and frequency
- Choose from five different topologies
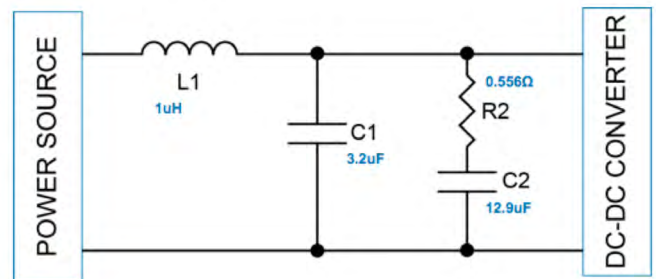- Supports regulated and unregulated converters

Resources

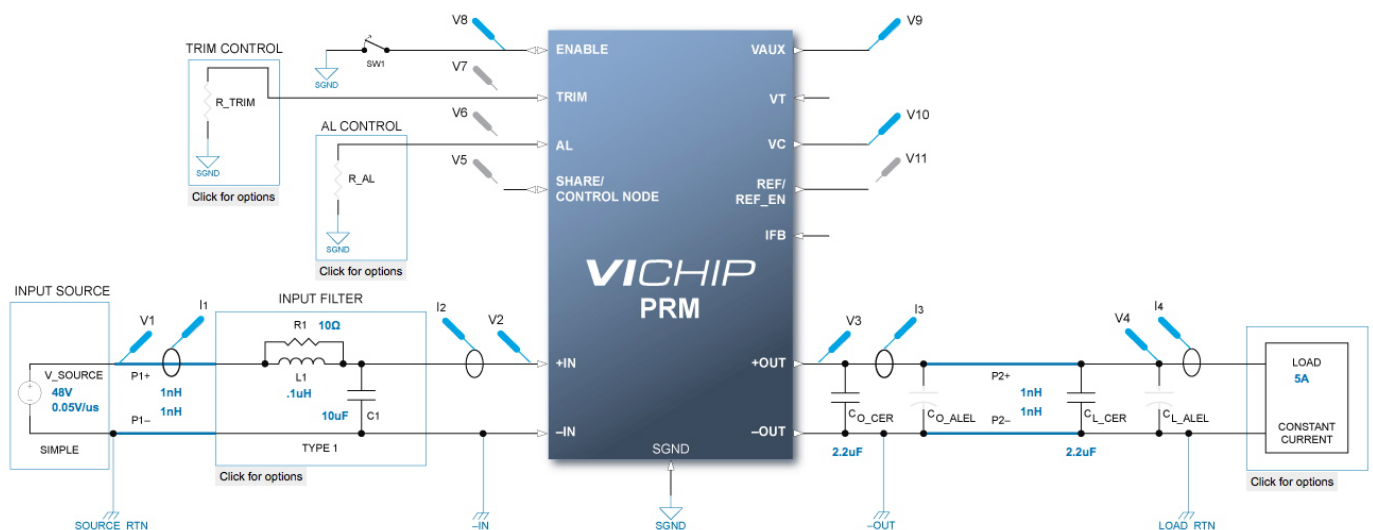|	
▶	Using Vicor's online simulator
⚒	Online simulator: VI Brick IBCs
⚒	Online simulator: BCMs
⚒	Online simulator: PRMs
⚒	Filter design tool
⚒	Design calculators

Graph Showing **Simulation Results**
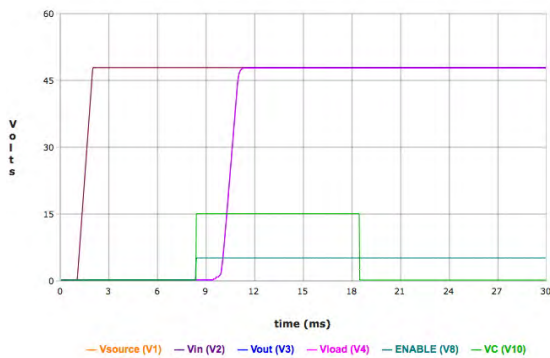
Calculation of Components for Parallel Damped Filter

Simulator Lets You **Define All Parameters**

PRM48BF480T500A00

Package Size	Full Chip
Input Voltage (V)	48
Output Voltage (V)	48.0
Output Power (W)	500
Operating Temperature (°C)	-40 to 125

Enabling Our Customers' Competitive Advantage

At Vicor, we enable customers to efficiently convert and manage power from the wall plug to point of load.

We master the entire power chain with the most comprehensive portfolio of high efficiency, high-density, power distribution architectures addressing a broad range performance-critical applications.

Vicor's holistic approach gives power system architects the flexibility to choose from modular, plug-and-play components ranging from bricks to semiconductor-centric solutions.

By integrating our world-class manufacturing and applications development, we can quickly customize our power components to meet your unique power system needs.

Focus Performance-Centric Markets / Applications

Communications
> 400 VDC Power
  Distribution
> Datacom
> Netcom
> Telecom
  Infrastructure

Computing
> Data Centers
> High Performance
  Computing
> Network Servers

Industrial
> ATE
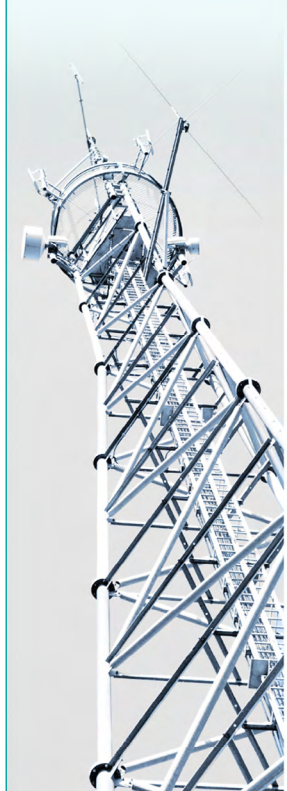> Lighting
> Process Control
> Transportation

Automotive
> Electric Vehicles
> Hybrid Vehicles

Defense/Aerospace
> Aircraft Test
  Equipment
> Ground Vehicles
> Radar
> Telemetry
> Unmanned
  Vehicles

VICOR

ACE Awards

BY EDN STAFF

It's hard to believe it's been a whole year, but here we are: Welcome to the EDN/EE Times Annual Creativity in Electronics (ACE) Awards, our yearly homage to those who have most inspired all of us in the engineering community through their engineering prowess, leadership, innovation, and, of course, creativity.

By the time you read this, the awards will have been given out with much ceremony at a special event during DESIGN West, in San Jose, California. The winners will have celebrated, wiped off the confetti, popped their balloons, and, by now, gone quietly back to doing what they do so well: creating the next generation of technological innovations, or inspiring the next generation of engineers. Please allow us one last shout-out to the people who keep us all up at night, wondering how we ourselves can do better.

On the following pages, you'll read about why Kathryn Kranen, president and CEO of Jasper Design Automation, received the Lifetime Achievement Award; why Steve Hageman is our second Jim Williams Memorial Contributor of the Year Award winner; why a certain team at Maxim was named Design Team of the Year; and why TI's Yogesh Ramadass is Innovator of the Year.

LIFETIME ACHIEVEMENT AWARD: KATHRYN KRANEN

Brian Bailey, Contributing Technical Editor

They say that the EDA industry gets no respect, but UBM Tech has just changed that by awarding an EDA veteran with the 2013 ACE Lifetime Achievement Award. The award is meant to honor the people and companies behind the technologies and products that are changing the world of electronics. That is a common theme when you look at past recipients, who include Gordon Moore, Wilf Corrigan, and Morris Chang. Kathryn Kranen has changed the industry not just once, but twice over. She has led two start-ups to success, and in each case she has transformed an emerging technology into a mainstream one. She first succeeded in doing that with Verisity Design Inc, an early verification automation company, and quickly grew it from being an interesting idea to the primary verification strategy in use by top semiconductor companies.

Kathryn Kranen has changed the EDA industry not once but twice.

Kranen has done that again at Jasper Design Automation by turning formal verification from a technology that required a PhD to understand into something available to the masses.

There are many adjectives that come to mind when thinking about Kranen, but perhaps the ones that most people would think of are focused, determined, and energetic. She has never been scared to be a lone voice. While most people in the industry would advise entrepreneurs to stay lean and build technology rather than a channel, Kranen told me in a recent interview that "to tackle big problems, and get big revenue, you have to spend to succeed." She conceded that if you aren't going to win big, you had better not raise too much money, but for Kranen, "there are those of us that passionately want to conquer

Award image: Trish Tunney

CELEBRATING THE ART OF ENGINEERING

EDN AND EE TIMES AGAIN HONOR THOSE BEHIND THE TECHNOLOGIES AND PRODUCTS THAT ARE CHANGING THE WORLD OF ELECTRONICS.

ACE AWARDS
EE Times
EDN

something harder." She will use techniques scorned by others. She understands both technology and business issues, and she ensures that the company and customer are both successful when entering into an agreement. She does not see it as a sale, but as a partnership.

You would think that would keep her busy, but Kranen has almost limitless energy and drive. She has been very active in the advancement of women in the industry and was awarded the Marie R Pistilli Women in EDA Achievement Award in 2005. She is chairman of the board of directors of the EDA Consortium (EDAC), an EDA vendor trade group

that promotes the health of the EDA industry.

While others in the industry like to complain about the state of the business, Kranen has always remained forthright in her belief that "every company needs to use its assets to compete the best it can. A company has to figure out how to differentiate and be relevant." This is something that she has managed to do consistently. Kranen's advice for entrepreneurs: "Start-ups must make sure that what they're doing is relevant, differentiated, and that they have a credible plan for success."

JIM WILLIAMS MEMORIAL CONTRIBUTOR OF THE YEAR: STEVE HAGEMAN

Suzanne Deffree, Executive Editor, Community

Good Karma. Pay it forward. Passing on the gift. Insert your favorite good-will description here, and it will describe this year's Jim Williams Memorial Contributor of the Year Award winner, Steve Hageman.

Hageman, as can be common, wandered into engineering as a child. "It all started about the fifth grade for some reason, like a lot of engineers my age," he says. "Something about the magic of pulling radio waves out of the air. I got the bug to build radios and started trying to find schematics and things to look at."

That search led him to the local library and its magazine subscription to Popular Electronics. "I used to devour those," he recalls. "Writing really came out of that as payback. I thought it was something you had to do to pay back all those fun hours you spent reading about other people's projects."

Armed with a BSEE and EECS from Santa Clara University, Hageman

went on to focus on analog/RF/embedded. His resume includes experience earned at companies including Agilent, CALEX, Hewlett-Packard, and Keithley Instruments. He started his own brand, Analog Home, in 2003, and describes it on his LinkedIn profile as "You provide the idea—I provide the Electronic Glue to make your product a reality."

As demonstrated in his popular EDN.com blog, The Practicing Instrumentation Engineer (www.edn.com/4374099) and the comments he posts across the Web site's various content using the screen name "LostInSpace2010," Hageman approaches his work with enthusiasm and an eagerness to share knowledge, much like the award's namesake, Jim Williams (www.edn.com/4374116).

Williams, an engineer's engineer and analog great who passed away in June 2011, contributed to many electronics publications, including EDN, willing to teach anyone who wanted

Steve Hageman is humbled and honored to receive an award named after the late Jim Williams.

to learn. In 2012, UBM Tech, EDN's parent company, renamed the annual ACE contributor of the year award after Williams to honor his legacy and his willingness to inspire.

Says a humble Hageman of winning the Jim Williams Memorial award: "It's a huge, huge honor. Jim did everything in analog. A lot of us had the same loves for the same things, like Tektronix oscilloscopes. The first time you got a Tektronix oscilloscope—the first time you managed to talk the boss into buying you a nice Tektronix oscilloscope—we all still remember. Getting a service manual or going through the old HP journals, I know Jim did those things, too. In fact, I still have all those journals and go through them periodically, finding interesting things. Just that love of circuits that Jim had, to a certain extent I have that, too, and I know there are other engineers I work with that have the same love of those things."

OTHER ACE AWARD WINNERS INCLUDE:

- **Company of the Year:**
  ARM
- **Executive of the Year:**
  Haruo Matsuno, President and CEO of Advantest Corp
- **Energy Technology Award:**
  STMicroelectronics for its FD-SOI technology

Declining to look at it as "work," Hageman seems to get as much out of the action of contributing and commenting as a member of the engineering community as those who read his work and interact with him online do.

"It's a hobby. I get enjoyment out of it. It also helps me to learn," he says. "I'm not one of those guys who can just see something and remember it forever. Thinking about it and writing it down forces you to think about it sequentially and get all the steps in. It also helps to ingrain it in my mind, so I learn from the process of writing, too."

Hageman, now an established engineer, still approaches engineering with the same curiosity he found as a kid in the library.

SOMETHING ABOUT THE MAGIC OF PULLING RADIO WAVES OUT OF THE AIR. I GOT THE BUG TO BUILD RADIOS.

"It's the same thing since fifth grade. I just get interested in something, like a little project. Whether it comes to fruition or not, I think about the design process and what you have to know and how to put it together. That brings you down an alley and then down several other alleys before you get to the end," he says. "And somewhere along the way, you've collected quite a bit of information. It's like training, constantly training. Certainly you have to keep knowing skills and throwing away skills."

As to why Hageman has not gotten comfortable, settling in with the extensive knowledge he's amassed in his career thus far, and instead continually seeks new ways to grow, share, and learn through various avenues, including making contributions to technical Web sites and communities, he sums it up nicely: "You get bored, otherwise."

EDN and UBM Tech congratulate Steve Hageman, 2013 Jim Williams Memorial Contributor of the Year Award winner.

Shown are the Hillsboro, OR, design team, one of three geographically separated design groups that together formed a 21-member team —scattered from Silicon Valley, to Hillsboro, to Bristol, England— that won Design Team of the Year for realizing the MAX2173 digital audio broadcast tuner.

DESIGN TEAM OF THE YEAR: MAXIM INTEGRATED'S MAX2173

Patrick Mannion, Brand Director

The Tao of Design should state officially somewhere that the smaller and easier to use an IC, the bigger and more complex the thought and energy are that went into its design. Such was the case with the MAX2173 direct-conversion digital audio broadcast (DAB) tuner, and the energy, skill, and design expertise of the 21-member design team that brought it to life.

Spread out between Hillsboro, OR; San Jose, CA; and Bristol, England, the MAX2173 design team overcame several tough challenges. Not only were they developing a cutting-edge RF product with demanding sensitivity and blocking performance requirements, but they also needed to do so while meeting demanding automotive-grade ESD and temperature standards and managing power consumption and die size—all while collaborating across multiple regions.

To deal with the geographic issue, each of the three design teams developed blocks in the overall design, but for any product to work, each team had to ensure that its block fit into the design seamlessly, without any mistakes, which could add costly delays requiring redesign and time-consuming tape-out cycles. This demanded constant communication between team members.

However, communication didn't end with the design team. The production test team needed to be aware of the production schedule. Inspired by this communication challenge, the team leader ensured excellent, open communication to keep everyone well informed of the specifics of each block and design schedule. The team pulled from their design know-how, available infrastructure, and proper forethought to align with the production test team efficiently. Along with strong design protocols, this communication among the team resulted in the production of high-quality product samples on the first pass.

The team delivered samples approximately one year after receiving the product definition. The product was ready for production approximately one year following the delivery of the first samples.

Of course, a relatively small die size had to be achieved in concert with the 6×6-mm TQFN package. As many designers are aware, suppliers of automotive electronics are under constant pressure to reduce size and power consumption. To overcome this challenge, the team creatively shrunk the baseband filter, a key component in the design, and combined that with excellent layout planning.

The resulting device is the first RF-to-bits DAB tuner on the market. It simplifies design and reduces design time, allows the DSP to support additional features, and reduces the cost and count of external components. The integrated ADCs reduce footprint, lower power consumption, and reduce cost. Digital filtering eliminates the need for filtering in the DSP while providing a programmable FIR, thereby saving MIPS in DSP and allowing support for other features or services. An integrated DCXO can digitally trim out crystal error, saving the cost of a TCXO or more expensive crystal. On-chip LDOs save space and reduce cost.

INNOVATOR OF THE YEAR: YOGESH RAMADASS

Rick Merritt, EE Times Editor at Large

Yogesh Ramadass was named Innovator of the Year at the 2013 ACE Awards ceremony for his pioneering work in energy-harvesting circuits. The Texas Instruments lead design engineer helped craft the TPS62736, an ultralow-power converter that manages microwatts generated from solar, thermoelectric, magnetic, and vibration energy.

The device is actually a second-generation design that evolved out of graduate work at MIT as part of a five-person team assisted by Anantha Chandrakasan, the head of electrical engineering and computer science there. The group developed a 0.3V energy-harvesting part that was presented in a 2008 paper at the International Solid-State Circuits Conference (ISSCC) (www.edn.com/4325471). It ultimately saw the light of day as a TI product, the bq25504.

The MIT work was funded in part by a grant from the US Defense Advanced Research Projects Agency. DARPA sees potential for energy-harvesting devices to power tiny, self-contained sensor networks that could be dispersed in a battlefield.

Others believe energy-harvesting circuits will drive

Yogesh Ramadass is helping pioneer the young but promising field of energy harvesting.

implantable medical devices, using the body's own heat or movement to provide power. In addition, researchers say the technology could be suitable for use in body area networks and RFID and other wireless terminals.

"Energy harvesting is still a relatively new field," Ramadass said in a recent article for TI's internal Web site. "It's exciting going from research to productization and creating a market," he added.

Ramadass is already at work on a next-generation energy-harvesting chip at TI. He also participates in developing high-power wired and wireless mobile-phone charger systems.

The TI engineer has co-authored dozens of technical papers, at least 10 of which have been cited dozens of times in related works. He was a co-recipient of the Jack Kilby best student paper award at ISSCC 2009 and the Beatrice Winner award for editorial excellence at ISSCC 2007. He serves on the technical program committee for ISSCC and also served as the chair of the analog, MEMS, mixed-signal, and imaging electronics committee for another technical conference.

ULTIMATE PRODUCTS

Rich Pell, Executive and Chief Technical Editor

The 2013 ACE Awards showcase the best in today's electronics industry, including the hottest new products and technologies that have made a difference in the electronics industry in the last year. Spanning a range of applications and technologies, this year's Ultimate Products reflect that more than ever.

Not surprisingly, some are from the always-hot communications sector, reflecting technologies such as 5G Wi-Fi, Bluetooth sensor iPhone app development, and high-performance networks and servers, as well as emerging communications. Others are focused on the ever-important power sector, and in particular automotive battery management in electric vehicles. Another addresses performance improvements and design simplification in the medical market. Rounding out the represented applications are areas as diverse as lightning sensing, custom LED lighting, and IP/system-centric design.

ANALOG ICs: AD9670/71 OCTAL ULTRASOUND AFE (ANALOG DEVICES)

The AD9670 was introduced as the industry's first octal (eight-channel) ultrasound receiver with on-chip digital I/Q demodulation and decimation filtering. Because of the

embedded demodulation and decimation feature, it is the first ultrasound receiver able to condition eight channels of data from RF to a baseband frequency, reducing the processing load on the system FPGA by at least 50% compared with other receivers.

By incorporating a 5-Gbit/sec JESD204B interface, the AD9671 reduces ultrasound system I/O data routing by as much as 80% compared with other data interface standards. The AD9670 and AD9671 also integrate a low-noise amplifier, variable-gain amplifier, anti-aliasing filter, and 14-bit ADC with a 125M-sample/sec sample rate and an SNR performance of 75 dB for enhanced ultrasound image quality. The extended anti-aliasing filter frequency range and a high ADC sample rate are also designed to help medical and industrial ultrasound equipment manufacturers meet the trend toward higher-frequency probes and superior image quality.

DEVELOPMENT KITS/EVALUATION BOARDS: BLUETOOTH LOW ENERGY SENSORTAG KIT (TEXAS INSTRUMENTS)

The goal of the SensorTag development kit is to make possible a Bluetooth low-energy device with the maximum number of sensors while achieving years of battery life on a single coin-cell battery. At the same time, it's designed to

shorten the design time for Bluetooth app development from months to hours.

With a free downloadable SensorTag app from the App Store and no required hardware or software expertise, the kit makes it easy for smartphone app developers to take advantage of the growing number of Bluetooth low-energy-enabled smartphones and tablets. It's offered as the first Bluetooth low-energy development kit focusing on wireless sensor applications and the only development kit targeting smartphone app developers.

LEDs & LIGHTING: LUXEON Z LEDs (PHILIPS LUMILEDS)

Designed as the smallest and most flexible high-power light source, LUXEON Z LEDs are offered as a step toward simplifying luminaire design and inspiring the imagination of the lighting designer while improving system luminance and miniaturizing light sources, enabling the next generation of uniform and efficient light sources. Their micro source size of 1.7×1.33 mm or 2.2 mm^2 is 80% smaller and delivers higher performance than standard LEDs.
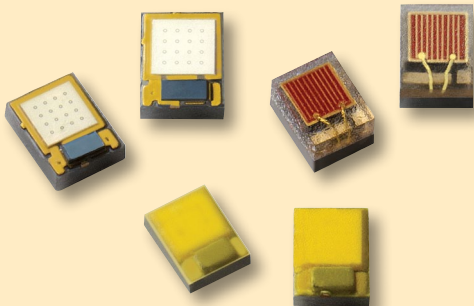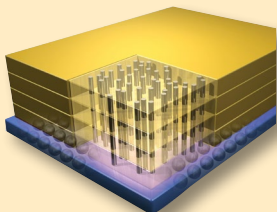
With LUXEON Z, designers can build their own custom 1×4, 2×2, 3×3, 4×4, and other arrays based on end luminaire design. The un-domed architecture of LUXEON Z is unique to LEDs in illumination and allows designers precise optical control, leading to more uniform and tighter beam patterns desired in directional and high-end applications. Configurations are virtually limitless, and with the ability to mount as many as 250 of the high-lumen LUXEON Z in one square inch, designers can reach new levels in lumen densities.

LOGIC/INTERFACE/MEMORY: HYBRID MEMORY CUBE (MICRON TECHNOLOGY)

The first 3-D IC to be successfully manufactured in volume with advanced through-silicon vias (TSVs), Micron's Hybrid Memory Cube uses a logic device as its base, with high-performance DRAM vertically stacked above it using TSV connections. Initial volume production of the Hybrid Memory Cube, with its combination of high performance, low power, next-generation features, and competitive cost, heralds 2013 as the turning point for 3-D ICs designed to enable high-performance networks and servers today and destined for markets ranging from industrial to consumer.

The HMC concept completely re-architects and redistributes normal DRAM functions while delivering:
- Scalable system architectures: Flexible topologies (expandability)
- Performance: Higher DRAM bandwidth
- Energy (power-efficient architectures): Lower DRAM energy per useful unit of work done
- Dependability (RAS): In-field repair capability

The result is bandwidth and efficiencies that are a leap beyond current device capabilities. HMC prototypes, for example, clock in with bandwidth of 128 Gbytes/sec compared with state-of-the-art module form factors that deliver 12.8 Gbytes/sec.

PASSIVES, INTERCONNECTS, AND ELECTROMECHANICAL: LPS1100 THICK-FILM RESISTOR (VISHAY INTERTECHNOLOGY)

The LPS1100 thick-film power resistor is offered as the industry's first resistor in the compact 57×60-mm package to offer a power rating of 1100W at a heat-sink temperature of +25°C. With its high power capabilities and high dielectric strength to 12 kV RMS, the LPS1100 is intended for power supply, inverter, converter, HEV-EV battery management, and snubber, chopper, precharge, discharge, and filtering resistor applications.

The LPS1100 thick-film resistor is non-inductive (less than 0.1 microhenry) and provides a resistance range from 1Ω to 1.3 kΩ. Designed for easy mounting to a heat sink, the device's compact footprint, low 25-mm profile, and low weight of 79 grams allow designers to reduce the size of their end products.

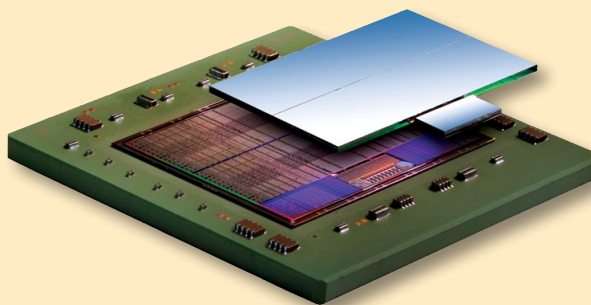## POWER: LTC6804 MULTICELL BATTERY MONITOR (LINEAR TECHNOLOGY)

Addressing automotive battery management, the LTC6804 high-voltage battery monitor for hybrid electric and electric vehicles and other high-voltage stacked-battery systems measures up to 12 series-connected battery cells with a total measurement error of less than 1.2 mV. The cell measurement range of 0V to 5V makes the LTC6804 suitable for most battery chemistries. All 12 cells can be measured in 290 μsec, and lower data acquisition rates can be selected for high noise reduction.

Multiple LTC6804 devices can be connected in series, permitting simultaneous cell monitoring of long, high-voltage battery strings. Each LTC6804 has an isoSPI interface for high-speed, RF-immune, local area communications. Using the LTC6804-1, multiple devices are connected in a daisy-chain with one host processor connection for all devices. Using the LTC6804-2, multiple devices are connected in parallel to the host processor, with each device individually addressed.

PROCESSORS (FPGAs, MCUs, MICROPROCESSORS): VIRTEX-7 H580T FPGA (XILINX)

Offered as the world's first 3-D heterogeneous all-programmable product, the Virtex-7 H580T FPGA features up to eight 28-Gbit/sec and 48 13.1-Gbit/sec transceivers, making it the only single-chip solution for addressing key N×100G line card applications and functions. The architecture is called heterogeneous because the GTZ 25-28G SerDes are on a separate and different die from the FPGA slices, allowing a mix of 25- to 28-Gbit/sec ("GTZ") SerDes (transceivers), fabric, BRAM, and 13.1G ("GTH") SerDes to meet the needs of the market in advanced traditional products.

timing, wire length, and routing congestion. Last-minute design changes and ECOs are addressed with incremental flows that allow for small changes to be quickly processed, making iterations faster after each change.

The heterogeneous implementation of the H580T device also allows independent technology choices for the core FPGA and 28-Gbit/sec transceiver die, which enables the right technology choices for the right function. This enables optimized power and performance and avoids big trade-offs, which often burden other aspects of a product. The inherent flexibility of the all-programmable technology, beyond hardware to software, digital to analog, and single to multiple die in 3-D ICs, is offered as addressing the communication market's ultimate need to reduce design costs while increasing performance.

SENSORS: AS3935 FRANKLIN LIGHTNING SENSOR (ams-TAOS USA)

A unique device, the AS3935 programmable lightning sensor IC detects the presence and approach of potentially hazardous lightning activity in the vicinity. It detects intra-cloud activity as well as cloud-to-ground flashes, often enabling risk to be evaluated for approaching storms. In addition, it identifies and rejects interference signals from common man-made sources, such as fluorescent lighting, microwave ovens, and switches.

Configurability allows the part to work both indoors and outdoors. Portable devices, such as GPS, watches, cell phones, and handhelds, can monitor the environment to warn of potential lightning strikes. Devices such as weather stations, clocks, and pool equipment can warn of approaching lightning strikes in the area, with relative confidence. Devices protecting equipment, such as UPS for telecom, medical equipment, televisions, and computers, can switch to battery-backed or generator power when strikes threaten the integrity of power supply and quality.

SOFTWARE: VIVADO DESIGN SUITE (XILINX)

The Vivado Design Suite is offered as the industry's first SoC-strength design environment consisting of a highly integrated IP and system-centric design platform for 28 nm, 20 nm, and future generations of all programmable devices. It is designed to help address design integration and implementation bottlenecks faced by FPGA users.

Vivado speeds the design of programmable logic and I/O as well as accelerates programmable systems integration and implementation into devices incorporating 3-D stacked silicon interconnect technology, ARM processing systems, analog mixed signal, and IP cores. To address implementation, Vivado includes a hierarchical design flow, logic synthesis with support for SystemVerilog, and a 4× faster, more deterministic place-and-route engine that uses analytics to minimize "cost" functions of multiple variables, including

TEST & MEASUREMENT SYSTEMS AND BOARDS: INFINIIUM 90000 Q-SERIES OSCILLOSCOPE (AGILENT TECHNOLOGIES)

The Infiniium 90000 Q-Series oscilloscopes, offering bandwidths from 20 to 63 GHz, were the first real-time oscilloscopes over 60 GHz to ship to customers. Their bandwidth and low noise/jitter have enabled measurements that were previously impossible on a real-time oscilloscope.

Scientists and engineers are using the 90000 Q-Series to look at high-speed designs, enabling advances in technologies such as 56-Gbyte/sec SerDes. In addition, the 90000 Q-Series also features 2 Gpts of data, allowing it to measure jitter on long patterns, a key component in emerging technologies.

WIRELESS/RF: BCM4335 5G Wi-Fi COMBO CHIP (BROADCOM)

The BCM4335 is offered as the industry's first complete 5G Wi-Fi combo chip for smartphones, tablets, ultrabooks, and other mobile devices. 5G Wi-Fi is a major evolutionary step from the existing 802.11a/b/g/n networks, and dramatically improves the wireless range in the home, allowing consumers to watch HD-quality video from more devices, in more places, simultaneously.

The BCM4335 integrates a complete, single-stream 5G Wi-Fi system —including MAC, PHY, and RF—with BT 4.0, FM radio, and software on a single silicon die. It is platform agnostic, and integration of the MAC, PHY, and RF allows it to be added to any smartphone or tablet regardless of application processor. Other features include wireless coexistence algorithms that mitigate radio interference, advanced "sleep modes" that extend battery life, and processing capabilities that off-load power-intensive tasks from the host processor.
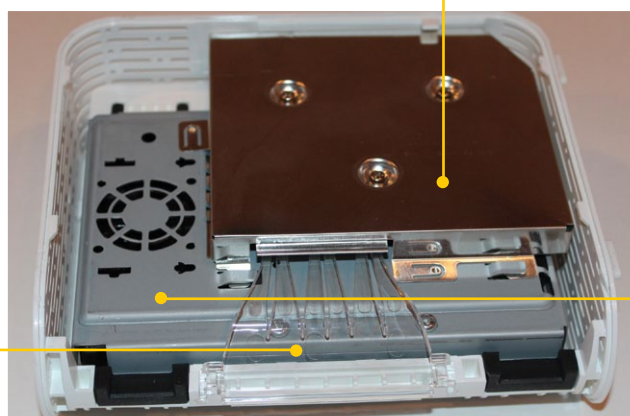
Disposable 1-Tbyte NAS drives:
How'd that happen?

Here's a tip: Don't start cleaning the area around your external network-attached storage (NAS) drive when it's backing up. Odds are that you're going to hit it. I did, and so a perfectly functioning 1-Tbyte drive, with my whole life stored on it, almost became a perfectly functioning doorstop.

The NAS drive in question is a 1-Tbyte Western Digital My Book World Edition, which I used for backing up multiple computers and for music streaming using a Sonos audio network via the shared router. While the device itself was dead, it was not a problem to recover the data from my other external hard drive and back it up to the shiny new 3-Tbyte drive.

I realized when holding the drive just how remarkable it was that a little over 20 years ago I was excited by a 40-Mbyte hard drive, and now here I was holding a 1-Tbyte drive that I just replaced with a 3-Tbyte drive for a scant $170. How did that happen? And why do we take it so much for granted? I had to go inside.

The main controller board enclosure houses the I/O, power, reset, and control electronics.

Taking the cover off exposed the plastic light pipe that was the source of that rather cool, Kitt-like (Any Knight Rider fans out there?) up-down light movement on the front of the drive. It channeled the light from a bank of six LEDs housed on the main control board. Oddly, I think it was the first time I'd uncovered a light pipe in situ.
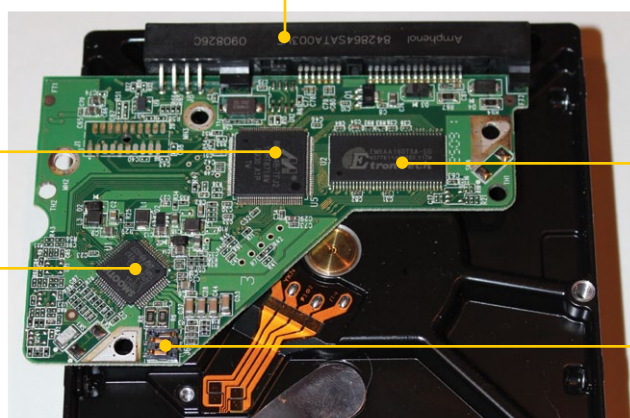
The control board itself was encased in metal shielding and attached to the hard drive via a right-angle edge connector. The entire drive was coupled to the main chassis using four rubber "shock absorbing" holders, which I wish had done a better job of, well, absorbing shock.

Amphenol 842864SATA003HF 90-degree connecter to main WD NAS control and interface board

Marvell 88i8846 system-control processor

Etron Tech EM6AA160TSA-5G, 256 Mbits of DDR SDRAM

STMicroelectronics SMOOTH L7251 3.1 motor control and driver IC

Four-pin interface to hard-drive platter motor; beats ribbon cable, but requires tight, well-defined placement

Three banks of plastic housings contain two LEDs each, with light guided to the front of the drive.

Battery backup

The LSI TruePHY ET1011C2-C Gigabit Ethernet transceiver debuted in 2008. It's built on 0.13-µm technology and is fully compliant with IEEE 802.3, 802.3u, and 802.3ab standards. Its main claim to fame is its use of an oversampling architecture to improve equalization.

Power-on button on rear, followed down the back by USB, Ethernet, reset, and power in

Three storage platters (These, and the read heads, have come a long way in the past 20 years. For more on modern storage techniques, including giant magnetoresistance all the way up to spintronics and quantum bits, take a look at this summary: http://bit.ly/Zg7yiW.)

Read-head armature in rest position (The armature is driven by the voice coil actuator on the left, housed between nickel-plated neodymium magnets, the most powerful permanent magnets available today.)

Coil and neodymium magnet housing (Coil is held between an upper and lower magnet with a four-wire interface to/from the SMOOTH L7251 to control read/write head position and acquire data.)
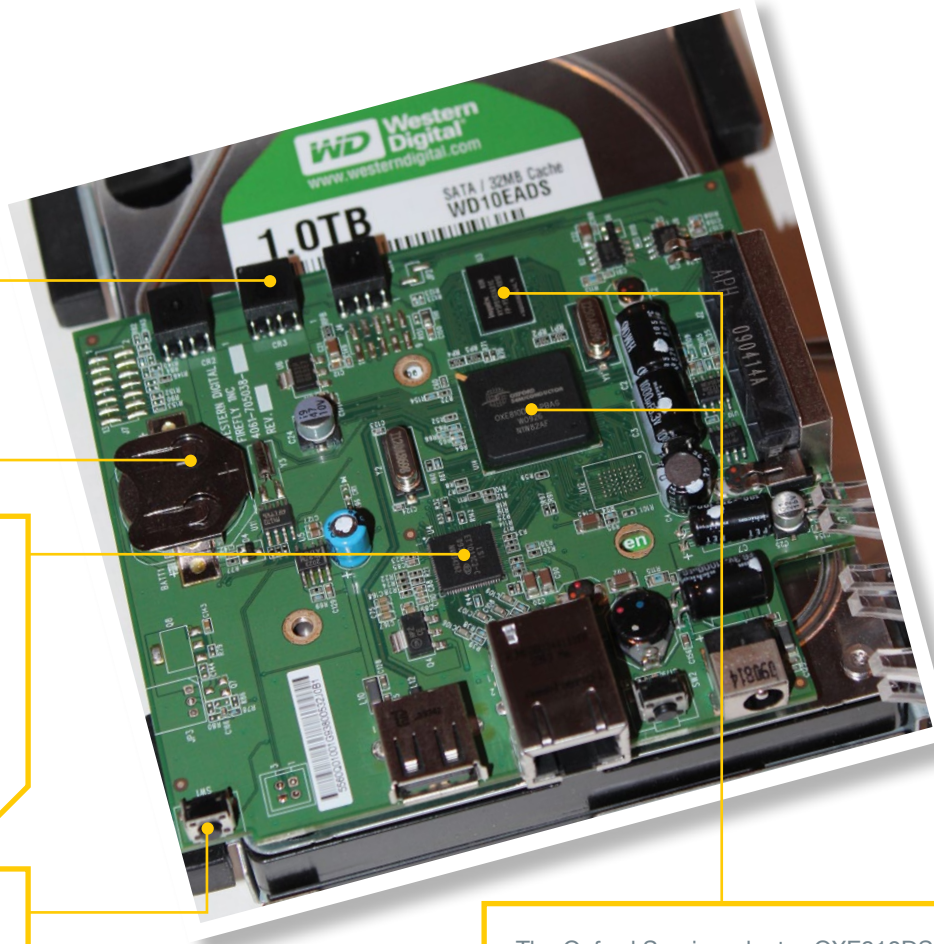
The Oxford Semiconductor OXE810DSE (now the PLX810, since PLX Tech acquired Oxford) is a Gigabit Ethernet to dual SATA controller. It is the main interface IC, with 802.11 support via Mini PCI. It has since been discontinued and replaced by the NAS 7821. Brian Dipert spent some time on the PLX chip in his teardown of an older WD NAS drive back in 2010 (www.edn.com/4312333). Also shown: 1 Gbyte of DDR2 memory (Hynix HY5PS1G1631C)
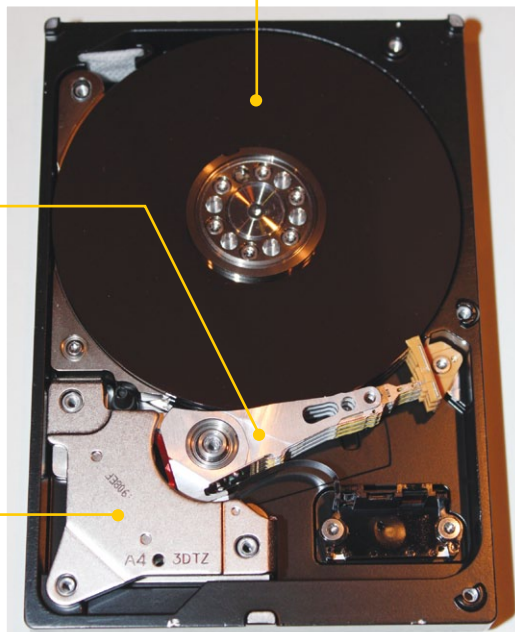
Over the years, fundamental research into electromagnets, quantum principles, materials, channel equalization, and motor-control and -positioning algorithms has been embodied within these drives. It's more than can even be touched on in a short teardown piece, yet we can take these drives so much for granted. As always, I'll be holding onto the parts, much like I do a good book. So much thought, research, and ingenuity have gone into realizing the product that throwing it out is actually hard to do, though I can only hoard so much until my wife gives me "that look."

designideas
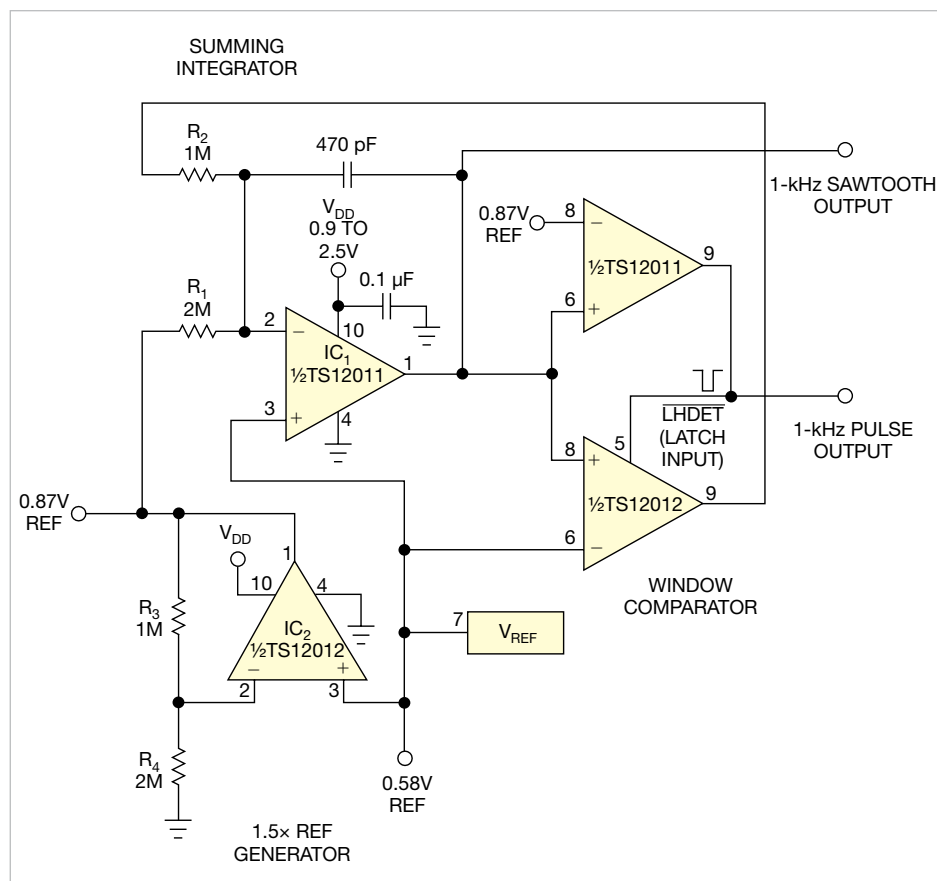
Micro-power sawtooth oscillator works on low supply voltages

Bruce D Moore, Consulting Analog Engineer

This sawtooth-oscillator circuit, drawing less than 3.2 µA and working at under 1V, is a useful building block that fits the bill for extremely low-power consumption and operation to low supply voltages. It could be used as the basis for a PWM control loop, a timer, or a VCO, or as a capacitance-to-frequency converter. It's a nifty circuit for two reasons: It uses an open-drain comparator output to make an accurate switched current source, and it uses a latch function to make a simple comparator into a window comparator, while needing no extra components.

The appeal of this circuit is found in the combination of the tiny size, the ridiculously low number of external components, a low supply current, and the ability to maintain a constant amplitude and frequency despite the variable battery voltage. Unlike the classic op-amp astable multivibrator, this design features comparator thresholds that are set by precision reference voltages rather than the output swing of the op amp in combination with resistor feedback.

A ratiometric fixed-frequency design of this type usually results in a variable-amplitude sawtooth waveform, which is undesirable in PWM control loops because it can affect the loop gain. As a side benefit, the up/down ramps can be independently controlled by scaling R_1 and R_2.

THE APPEAL OF THIS CIRCUIT INCLUDES ITS SMALL SIZE AND LOW EXTERNAL-COMPONENT COUNT.

Referring to Figure 1, there are only eight components in this circuit: two ICs, four resistors, a capacitor, and a power-supply-bypass capacitor. The key bits are two Touchstone Semiconductor analog building-block ICs in 4-mm^2 TDFN packages (the TS12011 and the TS12012), each containing an op amp, a comparator, and a reference. By leaning on their characteristics, the design can be kept terrifically tiny and simple.

Here's how the circuit works: A summing integrator feeding a window comparator generates the sawtooth wave. The integrator-summing node is held at V_{REF} by the feedback action of the amplifier. Thus, a fixed positive reference current set by R_1 is balanced by a larger-amplitude switched negative current set by R_2. The lower comparator block has an open-drain output; when its output is low, current is pulled from the summing node via R_2: $I_{R1} = (0.87 \times V_{REF} - 0.58 \times V_{REF})/R_1$ and

Figure 1 *This low-voltage sawtooth generator uses only eight components and draws extremely low power.*

I_{R2} (switched)=$0.58 \times V_{REF}/R_2$. If I_{R2} is set to $2 \times I_{R1}$, a symmetrical triangle wave results.

The frequency is set as follows:

$$f = \frac{1}{[1/I_{R1} + 1/I_{R2}] \times C \times V},$$

where V is the difference between $0.87 \times V_{REF}$ and $0.58 \times V_{REF}$. Here, f=850 Hz.

Figure 2 shows the waveforms at the sawtooth and pulse outputs.

The window comparator employs a built-in latch function of the TS12012 to provide hysteresis. The latch function has a clever feature: When LHDET is pulled low, the comparator inputs are still active and sensing the input state, until the inputs cross. The comparator in IC_2 gets set when the ramp crosses the lower threshold at $0.58 \times V_{REF}$, and reset when the ramp crosses $0.87 \times V_{REF}$. The reset pulse is momentary, but puts the latch in a state where the comparator inputs crossing cause it to set and latch again (which happens due to the switched reference current causing the integrator to ramp negative). The net result: No glue logic is needed.

The battery voltage ranges down to 0.9V with a miserly V_{DD}
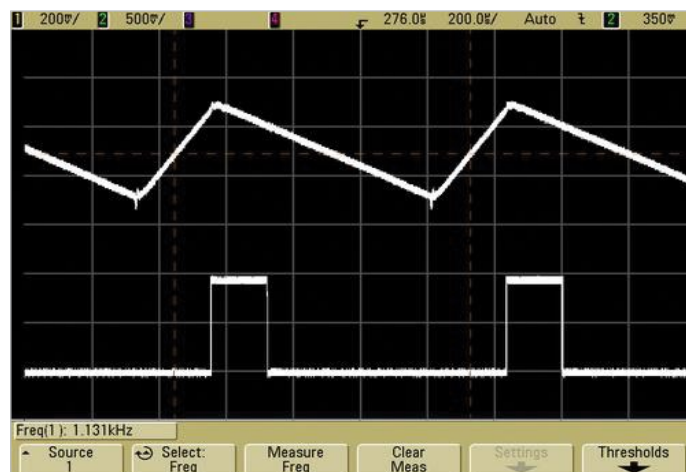
Figure 2 *The waveforms at the sawtooth and pulse outputs are shown. The pulse train is used to reset the latching comparator.*

current of 3.2 µA. Maximum operating frequency is limited by the op-amp slew rate and prop delays to about 3 kHz. Disconnecting R_1 and driving it with a voltage source greater than $0.58 \times V_{REF}$ gives you a VCO function.EDN

Connect a 4×3 matrix keyboard to a microcontroller using two I/O pins

Aruna Prabath Rubasinghe, University of Moratuwa, Moratuwa, Sri Lanka

Matrix keyboards are common as an input device in microcontroller-based projects. A conventional way of connecting a matrix keyboard to a microcontroller is to use multiple I/O pins of the MCU. The MCU then uses a scanning algorithm to identify which keys are pressed. A drawback of this method is that it requires a large number of the MCU's I/O pins to connect the keyboard. For example, to connect a 4×3 keyboard requires seven digital I/O pins. This becomes a problem when the project is based on a low-pin-count MCU or when the MCU being used does not have enough free I/O pins.

Two solutions for this issue are available: Use readily available I/O expanders, or assign a unique voltage to each key using a resistor network and then use an analog pin to read the voltage and determine which key is pressed. Each solution has its own disadvantages.

Since most of the time I/O expanders require a special communication protocol (I^2C or SPI, for example) to read and write data, the MCU should

have built-in communication modules, or the user has to implement the relevant communication-protocol software wisely, which adds significantly to the overhead of the MCU. On the other hand, assigning a unique voltage to each key using a resistor network becomes troublesome as the number of keys becomes high, which will lead to tight voltage margins. Then, as resistor values tend to change with temperature, the use of tight voltage margins can cause incorrect readings. Even switch bouncing can play a major role in producing incorrect voltages with this method. Another major drawback of this method is that it requires the presence in the MCU of an analog input pin.

The Design Idea described here addresses all of the above problems in an efficient manner and has several advantages: It requires only two I/O pins regardless of the number of switches connected; it does not require a special communication protocol; and it does not require an analog pin. The idea is based on two CD4017 Johnson counters, which are both common and

inexpensive.

Figure 1 shows the circuit for a 4×3 keyboard. R_1, R_4, R_5, and R_6 are used for current limiting; R_7, D_4, D_5, and D_6 form an OR gate.

The example described here shows how to implement this method to read a 4×3 matrix keyboard. One CD4017 is used to control the keyboard rows, while the other is used to control the columns.

The MCU generates a clock signal and feeds it to the counter IC controlling the columns. Initially, the 0th output of the column counter and row counter is at logic high, and the column counter increments as it receives clock pulses. At the fourth clock pulse, the column counter resets and simultaneously increments by one the counter controlling the rows. As the column controller resets, the row controller increments and the row controller resets with the fifth clock pulse from the column controller. As clock pulses generate, a count variable on the MCU should be incremented and should reset to one upon the fifth clock pulse to the row controller. The output of the

keyboard is OR'ed and connected to an external interrupt pin of the MCU.

An interrupt occurs only if a button pressed when both the row and the column of the respective button are at the logic-high level. If either row or column of the button is logic zero, an interrupt will not occur.

When an interrupt occurs, the MCU reads the count value at the moment; that value is equal to the button just pressed.

The clock count kept in the MCU increments as it generates clock pulses in intervals; this count is equal to the switch number on the keypad that could generate an interrupt if pressed. The flow chart in Figure 2 illustrates this scenario.

Note that even though this example shows a 4×3 keyboard, you can also read a 10×10 keyboard by using the remaining outputs of both 4017 counters. Furthermore, you can cascade additional 4017 ICs to expand the keyboard size as necessary. EDN

REFERENCE
1 Rubasinghe, Aruna, "Read 10 or more switches using only two I/O pins of a microcontroller," EDN, Feb 28, 2013, www.edn.com/4408027.
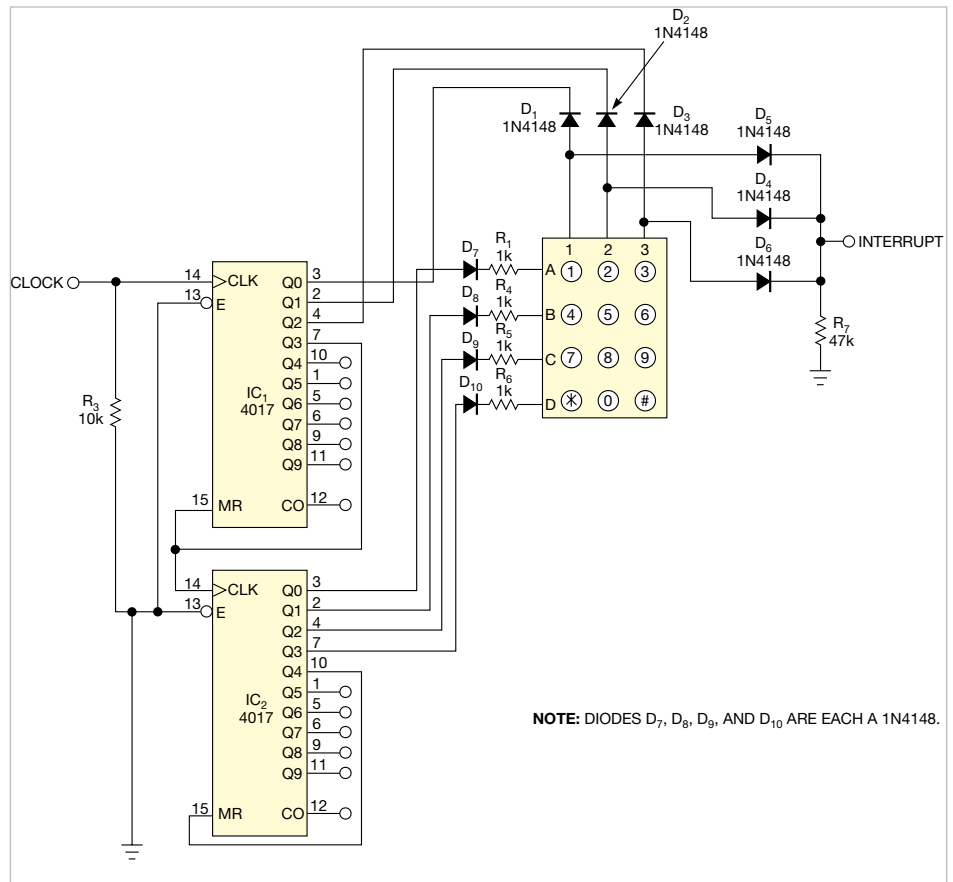
Figure 1 *This circuit for a 4×3 keyboard shows a more efficient architecture using two CD4017 Johnson counters with only two I/O pins.*
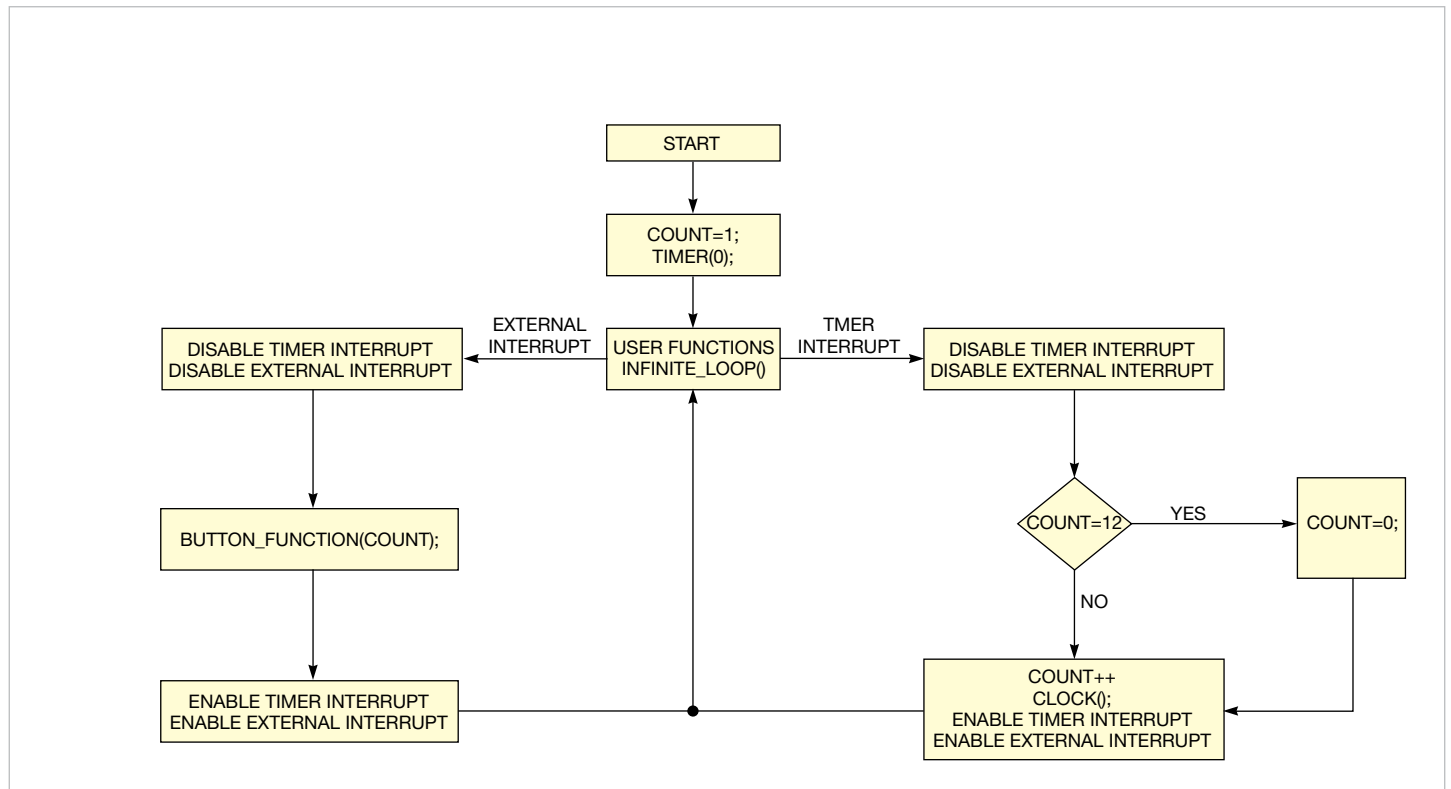
Figure 2 *The clock count kept in the MCU increments as it generates clock pulses in intervals; this count is equal to the switch number focused at the moment.*

designideas

Low-component-count zero-crossing detector is low power

C Castro-Miguens and M Pérez Suárez, University of Vigo, Spain, and JB Castro-Miguens, Cesinel, Madrid, Spain

There are many circuits published showing zero-crossing detectors for use with 50- and 60-Hz power lines. Though the circuit variations are plentiful, many have shortcomings. This Design Idea shows a circuit that uses only a few commonly available parts and provides good performance with low power consumption.

In the circuit shown in Figure 1, a waveform is produced at V_O with rising edges that are synchronized with the zero crossings of the line voltage, V_{AC}. The circuit can be easily modified so that it produces a falling-edge waveform that is synchronized with V_{AC}.

The circuit operates as follows. At the zero crossings of V_{AC}, the current through the capacitor and the LED of the HCPL-4701 optocoupler satisfies Equation 1 below. Equation 2 shows the standard conversion between radians per second and hertz; it also shows the derivation and explanation for $v_i(t)$. Equations 3 and 4 show the simplification used in Equation 1. Because the voltage across the LED is close to constant, differentiation of that value with respect to time results in a zero value.

$$i_c(t)=i_{LED}(t)=C\frac{d}{dt}[v_i(t)-v_{LED}]\approx C\frac{d}{dt}\times v_i(t)$$
$$=C\times\omega\times V_{AC-PK}\times\cos(\omega t)\rightarrow i_c(0)\approx C\times\omega\times V_{AC-PK}, \quad \textbf{(1)}$$

$$\text{where } \omega=2\times\pi\times f_{AC} \text{ and}$$
$$v_i(t)=|V_{AC}(t)|=|V_{AC-PK}\times\sin(\omega t)|. \quad \textbf{(2)}$$

$$C\frac{d}{dt}[v_i(t)-v_{LED}]$$
$$=C\frac{d}{dt}\times v_i(t)-C\frac{d}{dt}\times v_{LED}\approx C\frac{d}{dt}\times v_i(t), \quad \textbf{(3)}$$

$$\text{because } C\frac{d}{dt}\times v_{LED}\approx 0 \ (v_{LED}\approx\text{constant}). \quad \textbf{(4)}$$

The peak value of the current through the LED is a function of the capacitor, C, so you must choose a value for C under the constraint that at the initial time (t=0) and for a given minimum supply-voltage value, the intensity exceeds the triggering threshold value for the optocoupler. In the case of the HCPL-4701, it is $I_{F(ON)}=40\ \mu A$.

Diode D_1 not only allows for the capacitor to discharge but also prevents the application of a reverse voltage on the LED. The maximum reverse input voltage of the HCPL-4701 is 2.5V.

Resistor R_1 is included in order to discharge the energy stored in the capacitor in the latter portion of each cycle of $v_i(t)$ when $i_c(t)<0$ (Figure 1). Its maximum value is limited by the capacitor, by the peak value of the supply voltage ($V_{AC-PEAK}$), and by the maximum acceptable time delay of the current rising edges through the LED with respect to the corresponding ac-voltage zero crossing (Figure 2). Its minimum value is limited by the maximum allowable power dissipation in R_1 ($[V_{AC-RMS}]^2/$
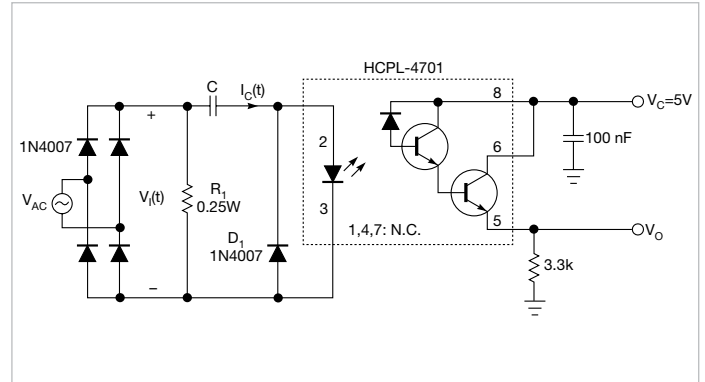
Figure 1 *The zero-crossing detector uses few components and consumes very little power. The V_O signal has a rising edge that is coincident with each zero crossing of the line voltage, V_{AC}.*

R_1). A practical compromise has to be reached.

Table 1 shows the time delay (t_{DELAY}) of the current rising edges through the LED and the power dissipation for three different values of R_1. Notice that the time delay of the rising edges of V_O with respect to the zero crossings of V_{AC} must include an additional delay for the optocoupler's propagation time delay. The HCPL-4701 has a typical propagation time delay of 70 μsec.

Based on the previous information, the following practical values for C and R_1 are obtained:
- For $V_{AC}=230V_{RMS}\pm20\%$ (Figure 3): C=0.5 nF/400V (MKT-HQ 370 polyester metallized, MKT series), R_1=560 kΩ/0.25W, t_{DELAY}=114 μsec (the time delay in the rising edges of V_O with respect to the zero crossings of V_{AC}), and P≈100 mW (average power from the ac line).
- For $V_{AC}=115V_{RMS}\pm20\%$ (Figure 4): C=1 nF/200V, R_1=220 kΩ/0.25W, t_{DELAY}=130 μsec (time delay in the rising edges of V_O with respect to the zero crossings of V_{AC}), and P≈65 mW (average power from the ac line).
- For operation from 80 to 280V_{RMS}: C=1 nF/400V and R_1=330 kΩ/0.25W.

Empirical results are shown for $V_{AC}=267V_{RMS}$, C_1=1 nF, and R_1=220 kΩ (Figure 5), and further results in Figures 6 and 7.
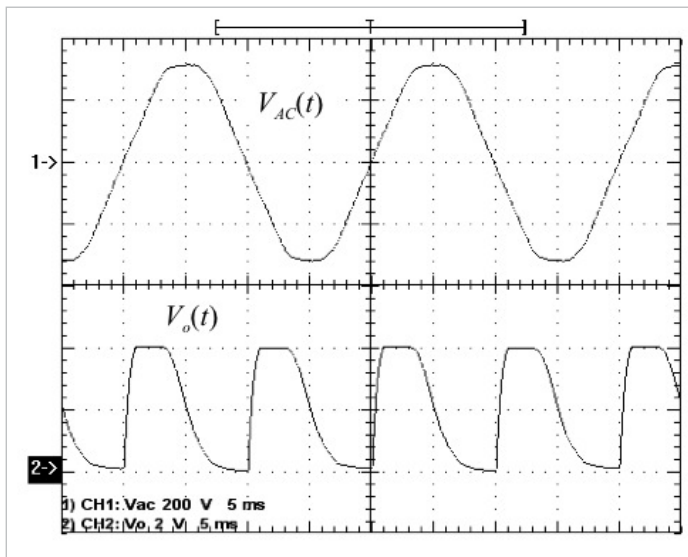
Note that as with any device connected directly to the mains, exercise extreme caution while bench testing the circuit. Follow proper guidelines when laying out a printed circuit board. EDN

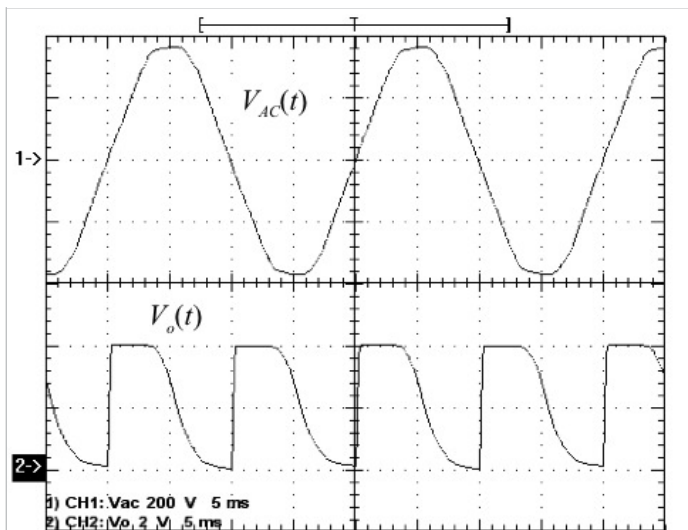**TABLE 1** I_{LED} TIME DELAY FOR DIFFERENT VALUES OF R_1

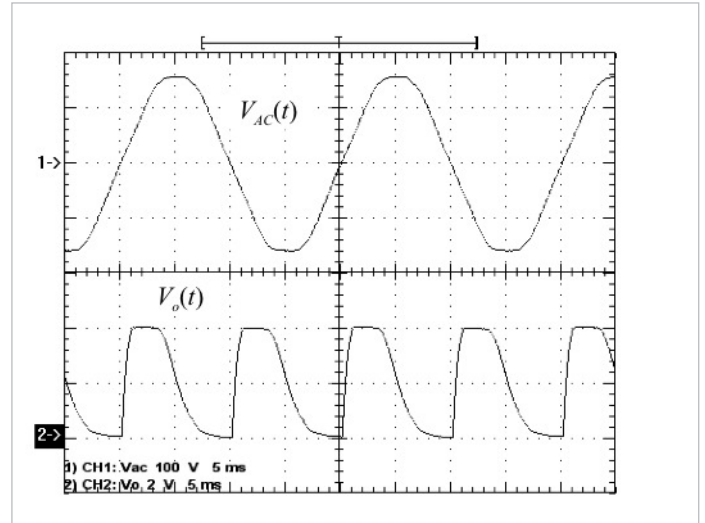| R_1	t_{DELAY} (μSEC)	V^2_{AC-RMS}/R_1 (mW)
470 kΩ	60	112.5
820 kΩ	100	64.5
4.7 MΩ	450	11.2
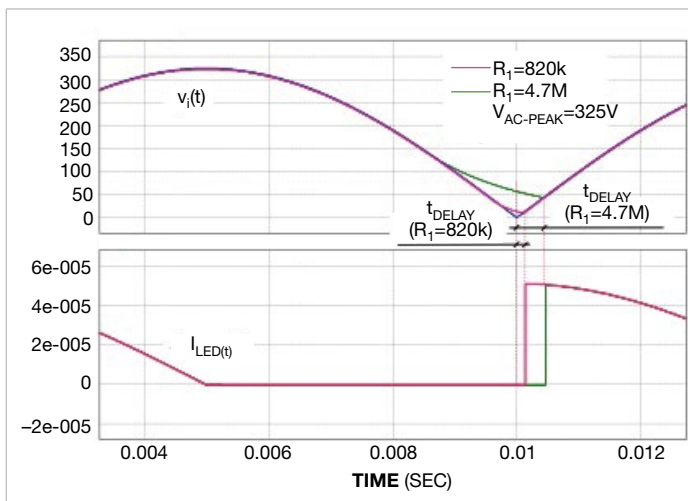
Figure 2 *The relationship between $v_i(t)$ and $I_{LED}(t)$ is a function of the value of R_1. The time delay between the zero crossing and the LED current is shown.*
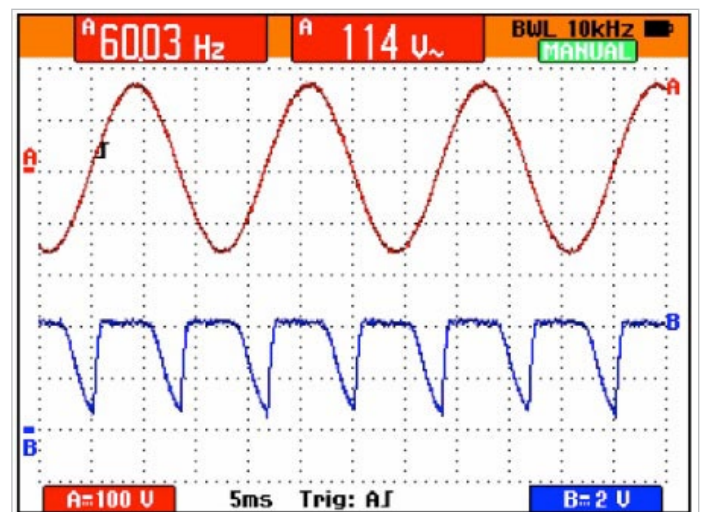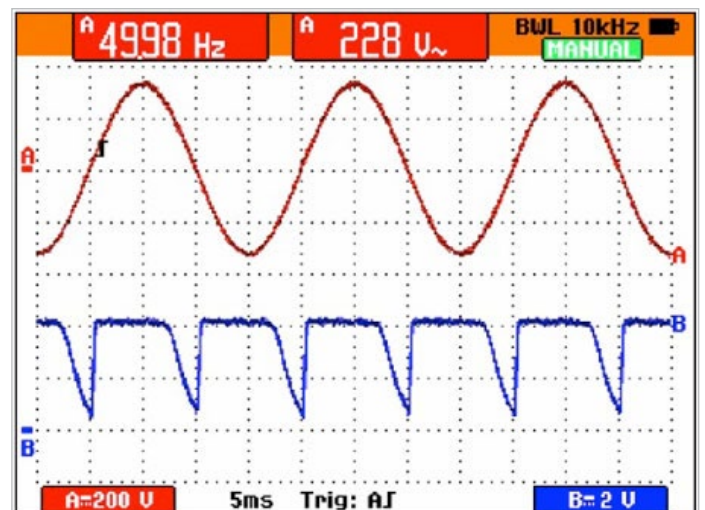

Figure 5 *Empirical results are shown for $V_{AC}=267V_{RMS}$, $C=1$ nF, and $R_1=220$ kΩ.*

Figure 3 *Empirical results are shown for $V_{AC}=230V_{RMS}$, $C=0.5$ nF, and $R_1=560$ kΩ.*

Figure 6 *Empirical results are shown for $VAC=114VRMS$, $C=1$ nF, and $R1=560$ kΩ.*

Figure 4 *Empirical results are shown for $V_{AC}=115V_{RMS}$, $C=1$ nF, and $R_1=220$ kΩ.*

Figure 7 *Empirical results are shown for $VAC=228VRMS$, $C=1$ nF, and $R1=560$ kΩ.*

productroundup

Multilayer chip beads attenuate EMC

TDK has developed a miniaturised multilayer chip bead series in case size 0603 (EIA 0201) that is nearly 80% smaller in volume and 65% in area than existing types with comparable performance, showing high impedance values over a wide frequency range. The MMZ0603-E series of multilayer chip beads combines compact dimensions of 0.6 x 0.3 x 0.3 mm with excellent electrical characteristics. The MMZ0603-E series is currently available in two high-impedance versions, one rated for 600Ω and the other for 1000Ω at 100 MHz. Both types offer even higher impedance values at 1 GHz of 1000Ω and 180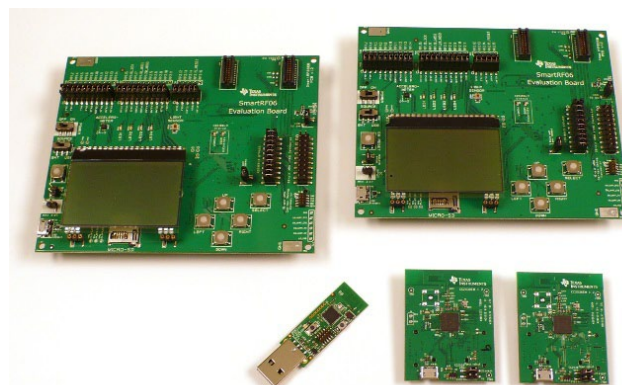0Ω, respectively. A single component can cover a very wide frequency range, ensuring highly efficient noise attenuation. The MMZ0603-E multilayer chip bead is suited for eliminating noise in compact mobile devices, especially in smartphones that must operate with multiple communication frequency bands.

TDK;
www.tdk.co.jp/tefe02/e9412_mmz.pdf

ZigBee single-chip hosts ARM Cortex-M3

Texas Instruments' CC2538 system-on-chip (SoC) is a ZigBee chip for applications in smart energy infrastructure, home and building automation, and intelligent lighting systems. Positioned as the most integrated ZigBee solution available, the CC2538 has an ARM Cortex-M3 MCU, memory and hardware accelerators, including a security engine, on one piece of silicon. It supports ZigBee PRO, ZigBee Smart Energy and ZigBee Home Automation and lighting standards. The SoC also supports IP standards-based development using IEEE 802.15.4 and 6LoWPAN IPv6 networks for maximum flexibility. With scalable memory options from 128K to 512K of flash it will sustain a mesh network with hundreds of end nodes via integrated 8K to 32K RAM options that are pin-for-pin compatible for maximum flexibility. It enables secure, fast bring-up of a system while using less energy through AES-128/256, SHA2 integrat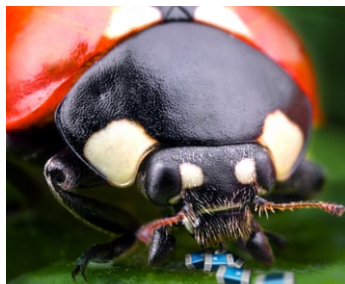ed hardware encryption engine, optional ECC-128/256, and RSA hardware acceleration engine for secure key exchange. The chip uses 1.3 uA in sleep mode; it operates up to 125C and supports fast digital management—no interfaces are required externally or between system-on-chip components.

TI, www.ti.com/cc2538-pr-eu

39 nH in 01005 package size

Murata says it is offering the largest inductor value available within a standard ultra-miniature 01005 (EIA) package size measuring 0.4 x 0.2 x 0.2 mm. With an inductance value of 39 nH, the LQP02TN39 comprises the highest value in a series of 59 items with 0.2 nH being the lowest value available. Tolerance from the nominal inductance value is within ± 0.1 nH for inductors up to 4.2 nH and within ± 3% for all values above. In addition to the addition of the 39 nH value to the series three other values have been added; 22 nH, 27 nH and 33 nH. Murata intends to continue developing these components and says it will will further widen the available range of inductance values, improve Q characteristics and reduce package sizes in the future.

Murata, www.murata.eu

Dual-channel bi-directional optocoupler

Avago Technologies has introduced a high-speed dual-channel bi-directional optocoupler with ultra low profile for industrial communication networks. The ACSL-7210 is a bi-directional 25 MBd digital optocoupler optimised for bi-directional industrial communication networks using high speed protocols such as the Profibus fieldbus, and SPI. The device achieves 3,750 VRMS signal isolation in a low profile SO-8 package while supporting high speed full-duplex data communications with data rates up to 25 Mbd. It supports full duplex communications, data rates down to DC, has a profile of under 2 mm, and has CMOS-level inputs and outputs. Maximum pulse width distortion is 10 nsec and maximum propagation delay is 40 nsec; minimum common-mode rejection is 20kV/μsec at 1 kV VCM. It is IEC/EN/DIN EN 60747-5-5-compliant with VIORM = 567 VPEAK and reinforced insulation.
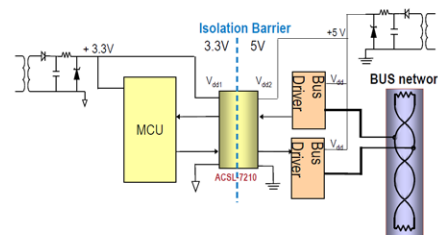
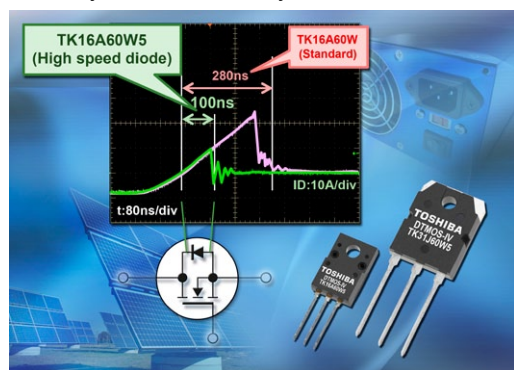**Avago, www.avagotech.com**

Micro-module regulator delivers 20A

Linear Technology's LTM4637 is a 20A DC/DC step-down µModule (micromodule) regulator with onboard precision differential remote sense amplifier. This enables automatic correction of voltage errors caused by droop across PCB traces, which is valuable for powering loads such as FPGAs requiring high currents at low voltages. Total output DC voltage accuracy is guaranteed at ±1.5% from -40°C to 125°C. The LTM4637 includes the inductor, MOSFETs, DC/DC controller and compensation circuitry. It is housed in a low height (profile) 4.32mm LGA package with a 15mm x 15mm footprint. With a VIN range of 4.5V to 20V, the device's operating efficiency is optimised for 5V and 12V input systems (88%, at 12 VIN and 1.8 VOUT at 20A). The output voltage can be set with one resistor, from 0.6V to 5.5V. Four devices in parallel can deliver 80A of load current. The LTM4637 features protection functions for overcurrent and overvoltage conditions. The internal temperature of the device can be monitored via an internal temperature sensing diode. The LTM4637 is rated for operation from -40°C to 125°C; its price is $22.10 (1000).
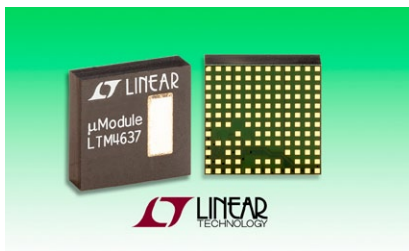
**Linear Technology,
www.linear.com/product/LTM4637**

600V super junction MOSFETs

Toshiba Electronics Europe (TEE) has introduced 4th generation, low-on-resistance DTMOS IV devices with reduced recovery times. The family of 600V MOSFETs with integrated high-speed intrinsic diodes, TK16A60W5, TK31J60W5 and TK39J60W5, achieve significant improvements in power efficiency by combining the RDS(ON)*A (ON-resistance area) characteristics with fast reverse recovery times. In addition, the use of a single epitaxial process ensures only small increases in ON resistance and recovery times at high temperatures. The TK16A60W5 is supplied in a TO-220SIS package. Maximum current rating (ID) is 15.8A and RDS(ON) is 0.23Ω. The diode shows a typical reverse recovery time (trr) of 100 nsec. In comparison, the standard version shows a trr of 280 nsec. Both the TK31J60W5 and TK39J60W5 are supplied in a TO-3P(N) package and have maximum currents of 30.8A and 38.8A respectively. Maximum respective RDS(ON) ratings (VGS = 10V) are 0.099Ω and 0.074Ω . Typical trr diode characteristics are 135 nsec and 150 nsec. Variants in TO-247 packaging are scheduled to be available by autumn 2013.

Toshiba, www.toshiba-components.com

PIN power diodes with 'soft' switching

Power Integrations' 200V Qspeed silicon diodes exceed the performance of Schottky and trench Schottky devices, offering 'soft' switching characteristics that are beneficial for high-efficiency, high-frequency power supply secondary rectifiers and audio amplifiers. The LQA200 series of 200V diodes is based on merged-PIN technology that offers 'soft' switching and low reverse recovery charge (Qrr). This balance of features enables high-frequency operation and permits the use of small, inexpensive magnetic components while maximising operational efficiency. Available from 10 A to 40 A in common-cathode configuration, these 'soft' 200 V diodes reduce peak reverse voltage, increasing voltage margin and enhancing operational reliability and ruggedness. The need for snubber capacitors is also reduced or even eliminated, which further improves efficiency and lowers cost. Designers can make a trade-off between board area/component count and circuit efficiency. When compared with equivalent Schottky products, the Qspeed diodes reduce Qrr by up to 80%, and have a 45% lower junction capacitance. LQA200 diodes are available in DPAK, D2PAK and TO-220 packages, and cost from $0.40 to $1.20 (10,000).
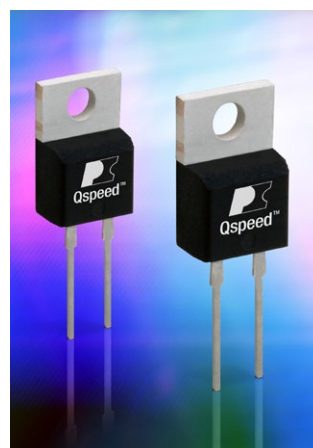
Power Integrations, www.powerint.com/en/products/qspeed-family/q-series

150W AC-DC medical power supply

XP Power has announced the GCS150 series of IT and medically-approved 150W single output AC-DC power supplies that meet the 80 Plus Silver energy efficiency specifications. With active power factor correction (PFC), the series has a typical efficiency of 93% and a no-load input power consumption of less than 0.5W. The GCS150 is available with a +12, +15, +24, +28 or +48 VDC single output voltage, an additional 12V fan output is also available. Using convection cooling alone the GCS150 can deliver up to 110W. When using 7 CFM of forced air flow, or by specifying an optional fan model, the full output power of 150W is available. Multiple mechanical formats give the design engineer choice when incorporating into the end-application. Operating temperature range of – 40 to + 70 degrees C will suit most environments and there is no derating until +50C. The GCS150 series complies with the IT equipment safety specifications of UL/EN/IEC 60950-1 and the current 3rd edition medical safety standards of EN 60601-1, ANSI/AAMI ES60601-1 and CSA22.22 No 60601-1. The units provide 2 x MOPP and risk management files are available.

XP Power, www.xppower.com

productroundup

High precision foil resistors

Riedon, specialist resistor manufacturer, has added two series of resistors that use Bulk Metal Foil technology. The UHPL series of through-hole moulded resistors provides high precision with a tolerance of ±0.005%, a TCR of ±2ppm and a load life stability of ±0.005%. The ultra-high precision, surface mount UHPC series achieves a TCR of ±0.05ppm with a power coefficient of 5ppm at rated power and a load life stability of ±0.005%. The UHPL series resistors are built to handle unconventional environmental conditions with minimal drift over more than 10,000 hours while offering tight tolerance, fast response time, low current noise and low thermal EMF. The UHPC series builds on the same Bulk Metal technology to provide a significant reduction in the resistive element's sensitivity to ambient temperature variations (TCR) and to self-heating when power is applied (Power Coefficient of Resistance, or PCR). This all helps achieve the load life stability, low noise and tight tolerances. The UHPC resistor has a full wrap-around termination that assures secure contact during the manufacturing process, as well as providing stability during multiple thermal cycles.

Riedon Inc, www.riedon.com

Automotive Hall-effect sensor ICs

Two factory one-time programmable linear Hall-effect sensor ICs which eliminate the need for customers to optimise or program the devices for their finished sensor assemblies are now available from Allegro MicroSystems Europe. The A1318 and A1319 each provide a low-noise temperature-stable output, and are targeted at high-bandwidth displacement- and angular-position-sensing applications involving a 3.3-V supply rail. Although the device architecture supports magnetic input sensitivity ranges of 1.32 to 2.64 mV/G and 2.64 to 5.94 mV/G, respectively, the products initially being released to market are factory programmed to specific magnetic input sensitivity levels. The first device types released are the A1318LLHLX-1-T (1.35 mV/G sensitivity), the A1318LLHLX-2-T (2.5 mV/G sensitivity) and the A1319LLHLX-5-T (5.0 mV/G sensitivity). The A1318 and A1319 are ratiometric Hall-effect sensor ICs which provide a voltage output that is proportional to the applied magnetic field. Temperature coefficients for both sensitivity and the quiescent voltage output are programmed over temperature at Allegro to maximise accuracy and minimise distribution tolerances. The A1318 and A1319 provide low output noise (13 mV p-p at 5.0 mV/G sensitivity for the A1319) and low EMI susceptibility at various frequencies. They also support a fast refresh rate of 20 kHz for high bandwidth applications.

Allegro, www.allegromicro.com

High-isolation RF switch for wireless infrastructure

Peregrine Semiconductor's high-isolation SPDT RF switch for the wireless infrastructure market, the UltraCMOS-based PE42420, has high isolation of 64 dB at 4 GHz—an approximately 20% increase over competing devices. The switch features HaRP technology enhancements to deliver high linearity, with an IIP3 of 65 dBm. By providing high linearity and isolation in a single, small package, the PE42420 switch simplifies Digital Pre-Distortion (DPD) loop design. This high-performance switch enables increased network capacity and higher data rates in infrastructure applications such as Base Station Transceiver Systems (BTSs), Remote Radio Heads (RRHs), and wireless backhaul; as well as Industrial, Scientific and Medical (ISM) band devices that operate in the 2.4 GHz and 5.8 GHz fre-quencies. The 0.1 to 6 GHz PE42420 switch supports 1.8V control logic, enabling the use of lower-voltage, and lower-power MCUs. ESD tolerance is 2kV HBM on all pins. The PE42420 switch is available in a 20-pin 4 mm x 4 mm LGA package and is priced starting at $1.25 each.


Peregrine, www.psemi.com
A video is at; http://youtu.be/Wpl1_TjVnM8

600V half-bridge gate drive IC

Infineon has introduced a "Compact" member of its Eice-DRIVER family; the 2EDL EiceDRIVER, for applications with a blocking voltage of 600V. Equipped with a very fast bootstrap diode and resistor, the components enable high efficiency in a very compact construction. The new family of driver ICs, designed for use with power semiconductors such as in the newest CoolMOS generation, exhibit improved switching behaviour. Depending on current strength and packaging, the price per component ranges from €0.31 to €0.61 (10,000). The family also includes the EiceDRIVER Safe, which is designed exclusively to meet high demands for security and reliability in the industrial market. The seven devices in the 2EDL EiceDriver Compact class are designed for use with IGBTs as well as with MOSFETs. They are available in DSO-8 and DSO-14 packages. The output current for the new devices is set to 0.5 or 2.3A. In the DSO-14 assembly also have extended creepage. For a range of indus-trial applications, the device is sampling now and an evaluation board (pictured) can be ordered.
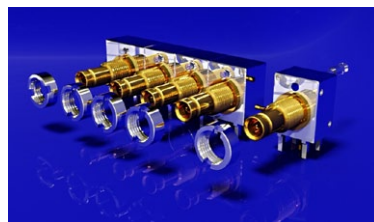
Infineon, www.infineon.com/eicedriver
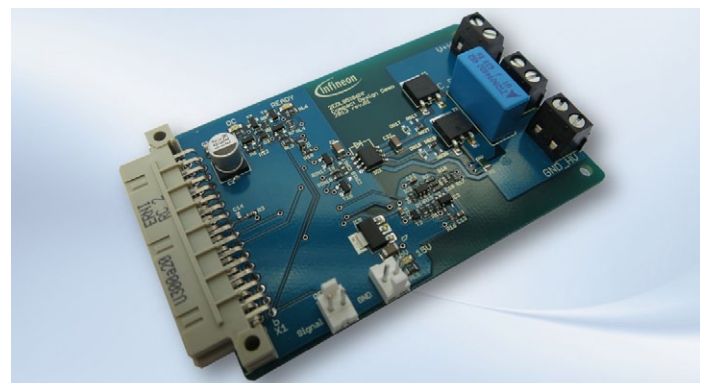
Multi-connector range for CoaXPress

Cambridge Connectors's CXP-Multi-Connector is a precision 6-GHz 1.0/2.3 Stackable Multiport Connector system that meets the requirements of the newly JIIA ratified CoaXPress (CXP) specification for use in High Speed Image and Data Transmission. It meets the needs of the machine vision industry, providing a small form-factor stackable multi-port connector system which can operate in high speed, high definition video applications and provides polarised inter-connection capabilities. The system comprises two connector body widths (13 and 9 mm) secured together with precision press-fit links providing an array of connector ports with precise pitch separations of 9 and 11 mm. A multiway connector is formed with 'n' down-connection ports plus one high speed up-connection port. Standard configurations are anticipated to provide 2 ports, 4+1 ports and 6+1 ports but the flexibility of the system means that a wide variety are available pre-configured by Cambridge Connectors. Each port can incorporate a light pipe to display identification or status data; straight and right angle versions are available. The secure latching mechanism, compatible with standard 1.0/2.3 connectors, provides high connection integrity with a simple push/pull operation.

Cambridge Connectors, www.cambridgeconnectors.com

PICs get more analogue integration

8-bit MCUs from Microchip feature on-chip 12-bit ADC, Op Amps, high-performance 16-bit PWMs and high-speed comparators; advanced analogue and digital integration is combined with low power consumption, enabling self-sustaining smart control loops with minimal CPU intervention: use them in LED and other lighting applications, battery management, digital power supplies, motor control and general-purpose applications. This expansion of the 8-bit PIC16F178X enhanced Mid-Range core microcontroller (MCU) family increases Flash memory densities; adds intelligent analogue and digital peripherals, such as on-chip 12-bit ADCs, 16-bit PWMs, 8-bit and 5-bit DACs, operational amplifiers, and high-speed comparators with 50 nsec response time, in addition to EUSART (including LIN), I2^C and SPI interface peripherals. The PIC16F178X are the first PIC MCUs to implement the new Programmable Switch Mode Controller (PSMC), which is an advanced 16-bit PWM with 64 MHz operation and high-performance capabilities. The MCUs also feature eXtreme Low Power (XLP) technology for active and sleep currents of 32 µA/MHz and 50 nA. The MCUs have a 32 MHz internal oscillator, 2 - 16K Words (3.5 - 28K Bytes) of Flash, 256 - 2K Bytes of RAM and 256 Bytes of data EEPROM.

Microchip; www.microchip.com/get/T2VS

Safety chip capacitors in higher values

Syfer Technology has announced additions to its UL and TÜV approved range of SMD 250Vac safety capacitors. The upper capacitance value has been expand Syfer's B16 (TÜV/UL approved) and B17 (TÜV approved) safety certified capacitor ranges. Values in the 2220 package size are now available up to 22nF for the B16 X2 rating, and to 5.6nF for the B17 Y2/X1 rating. If the ProtectiCap option is specified, the upper value for B16 devices increases to 33nF. The ranges are approved for direct connection across AC mains voltages up to 250Vac, providing transient and surge protection in networked and mains-based electronic equipment. Syfer's FlexiCap termination is an option available for all sizes in this range up to and including the 2220 format devices. Syfer offers MLCCs with flexible terminations with certification to IEC, EN and UL safety standards. Syfer sees a trend to replace film capacitors with surface mount MLCCs. For engineers designing equipment to meet IEC 60950, these parts have approvals to IEC 60384-14:2005, UL60384-14:2010 as well as UL 60950-1.

Syfer, www.syfer.com

Flexible digital temperature sensor

Measurement Specialties' TSYS02 family of compact digital temperature sensors integrates into a variety of industrial control, HVAC/R and heating/cooling systems, combining low power and high accuracy in an ultra-small TDFN8 package. The series' performance-cost ratio makes these sensors suitable for automotive and medical applications, and the SMT-compatible package enables the sensors to be used in high volume applications for on-circuit temperature control. Designed with ease-of-use and flexibility in mind, these fully-calibrated sensors come in three different data output options: I2^C for integration into digital interface bus systems; PWM for simple control units; and $\Sigma\Delta$ modulation for integration into analogue circuitries. 16-bit temperature sensing resolution combined with the low power and highly accurate characteristics make these sensors cost-effective replacements for thermistors, NTCs (negative temperature coefficients) and RTDs (resistance temperature detectors). Available in a TDFN8 package, the TSYS02 measures 2.5 x 2.5 mm, while drawing a maximum of 12.5 µA. Operating temperature range is -40°C to +125°C. Every TSYS02 is factory-calibrated to provide a high accuracy of ±0.2°C. Custom calibration is also available to meet specific application needs. Pricing is $1.85 (10,000).
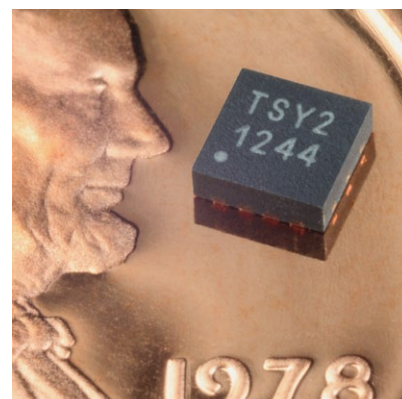
Measurement Specialties, www.meas-spec.com

Debugging with a LASER

Counting the printers, media players, power-tool aiming devices, and laser pointers used to tease the cat, I have more than a dozen lasers in my house, and many more around my office. I certainly didn't foresee that happening at the time of my first encounter with laser technology 50 years ago. My first full-time job was as an electronics technician for a large military-electronics contractor. And among my first assignments was testing a remarkable new thing called a laser. The laser was so new that it was spelled in all caps like an acronym, sometimes even with periods between letters. An office joke was that "L.A.S.E.R." stood for Latest Angle to Secure Expensive Resources.

Another technician and I were put in a lab with a laser and left to test it day after day. The laser we were testing was quite something for its time—a 5W pulsed ruby laser with a flash-tube exciter. The ruby rod and a straight flash tube ran down the two foci of an elliptically bored-out aluminum cylinder, which itself was wrapped in cooling tubes. The laser, about the size of a 2-lb coffee can, looked like something straight out of a Buck Rogers movie.

Our job was to record data from about 10,000 laser test firings. Heat dissipation, then as now, was the limiting factor on laser power, and measurements from a dozen thermocouples were what we logged, by hand.

The testing took place during a very hot July. The air-conditioning at our lab couldn't keep up with the load, and open windows, fans, and T-shirts became the defenses against the weather. The open windows and heat seemed to bring out the flies. Nobody ever figured out the exact source of the flies, but they were everywhere. By early afternoon each day, dozens of large flies found their way to our side of the window screens.

In conditions made worse by the heat and the real bugs, the boredom got to us: Fire the laser, read the instruments, write down the data, wait for the flash-tube capacitors to recharge, swat the flies.

There was little break from the tedium, and our idle minds quickly turned to finding out what the laser could do. The output of the 5W laser was normally dumped onto a steel plate—safe but dull. We sought more exotic targets. We were disappointed that we could not make our laser drill a hole in a razor blade, the standard "wow" demonstration of laser power in the early days of the technology. The best we could do was create a pretty, blue-ish dot on a Gillette single-edge blade. But our laser could poke a clean hole through stacked sheets of paper. Twenty-seven sheets was our record.

OUR IDLE MINDS TURNED TO FINDING OUT WHAT THE LASER COULD DO.

What I don't recall is which of us came up with the idea of the laser fly swatter. The laser turned out to be remarkably good at eliminating the pesky flies. Our technique was quite refined: We shut one of the big, double-hung windows, trapping the flies between the glass and the screen to restrict their movement. We aimed the laser at a fly, unconcerned in the days before OSHA about exactly where the laser beam traveled on its way out of the lab. Flash! Crack! One less fly.

About a week after the end of lab testing, however, we had to answer some tough questions from our boss. Did we have any idea, he asked, what might have caused the dozens of small holes that now peppered the window screens in that lab?

With experience I have become much more safety conscious, and I'm now careful to consider a full range of consequences—both intended and unintended—when testing new systems.**EDN**

Richard Davis is a telecommunications engineer working in mobile-phone services, including E911 and location services.